UNC Draft Responses to USNRC Group 2 RAI Clarification Comments
March 2, 2020

A.] Additional Data

The only additional data needed is the following (no new modeling runs necessary),

- Additional tables similar to the tables in Appendix A from Appendix Y (i.e., the consolidation report) that would include the monthly UNSAT-H modeling results for the years 2043 through 2062 (i.e., 20 years of long-term shrub growth) for the planned repository profiles at B2, B8, B10, and B11.
    - The information would include the year, month, monthly PET, monthly precipitation, monthly transpiration, monthly evaporation, monthly runoff, and monthly water storage.

Response: *Refer to submitted Excel Spreadsheet for daily values for years 2043 through 2062 for Profile B8. The long-term simulation that included the maturation of vegetation and concluded with years 2043 to 2062 with shrubs was only performed for Profile B8 in Appendix Y.*

B.] Clarifying questions:

Technical questions (labeled as Q) pertaining to the Group 2 RAI Responses - 1st submittal dated October 14, 2019

- **Page 5: RAI 3.8-2 Response on transpiration**

RAI stated that, "although Appendix G, Attachment G.7, Fig. 14 (page 45) and in Appendix Y, Fig. 12 (page 23) are representing the same set of values, the figures are different."

Q Which one is correct?

Response: *Appendix G, Attachment G.7, Fig. 14 is correct. This is the figure that summarizes data from year 1949 that was used in the modeling as a typical year. Figure 12 is a generic typical year used to illustrate that there is significantly more PET than precipitation. The verbiage prior to Figure 12 states that it was not used in any analysis. Figure 12 in Appendix Y will be replaced with Figure 14 from Att. G.7 to eliminate confusion.*

Page 46 in Appendix G, Attachment G.7 states that,
Winter "is a period in the modeling when PET is low and transpiration of moisture through vegetation is minimized or completely ceased."
However, the PET for the wettest year never dips below 4 in/month.

From the response:
"More specifically, PET depends on the daily maximum and minimum temperatures and site latitude."

Q Does this mean that the year 1906 was a unusually wet year?

Response: *Yes, 1906 was the wettest year on record for the region with annual precipitation of 23.8 in. This was more than double the average annual precipitation of 11 in.*

From the response:
"Below the minimum value, sometimes known as the wilting point, transpiration is unable to remove any water."

Q What is the minimum value?

Response: *Refer to page 53, Section 6.6 of Attachment G.7 where these values are defined. For reclaimed vegetation the wilting point was set at 40,000 cm and for grassland and shrubs it was 70,000 cm. The reference for these values is Fayer and Walters 1995.*

From the response:
"When all nodes with roots reach this level of suction head, transpiration is reduced to zero."

Q How many nodes are there representing roots and which is the deepest?

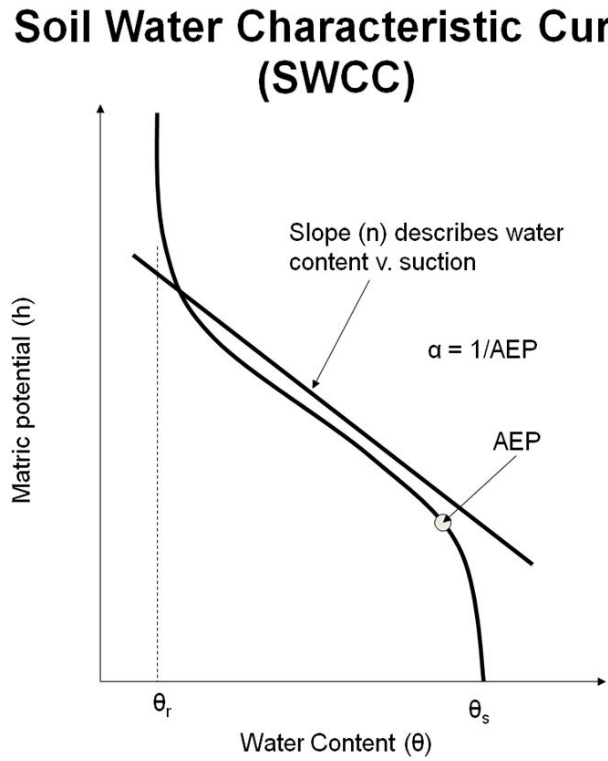
Response: *For simulations without vegetation the answer is zero. For simulations containing vegetation, the number of nodes within the root zone depends on the modeled profile. Refer to the supplied UNSAT H input files. The number of nodes is dependent on the profile – profiles varied for the existing profile with existing cover versus the profile with mine spoils and the proposed ET Cover. Also, sensitivity of the surface rock/soil admixture was evaluated varying this admixture depth from 1ft-2in to 2ft-3in. That said, the roots were allowed to penetrate to a depth of 147 cm for simulations utilizing reclaimed vegetation; 142 cm for profiles with grass; and 155 cm for profiles with shrubs. Refer to Table 10, page 51 of Att. G.7 for this information.*

- **Page 6: RAI 3.8-2 Response on evaporation**

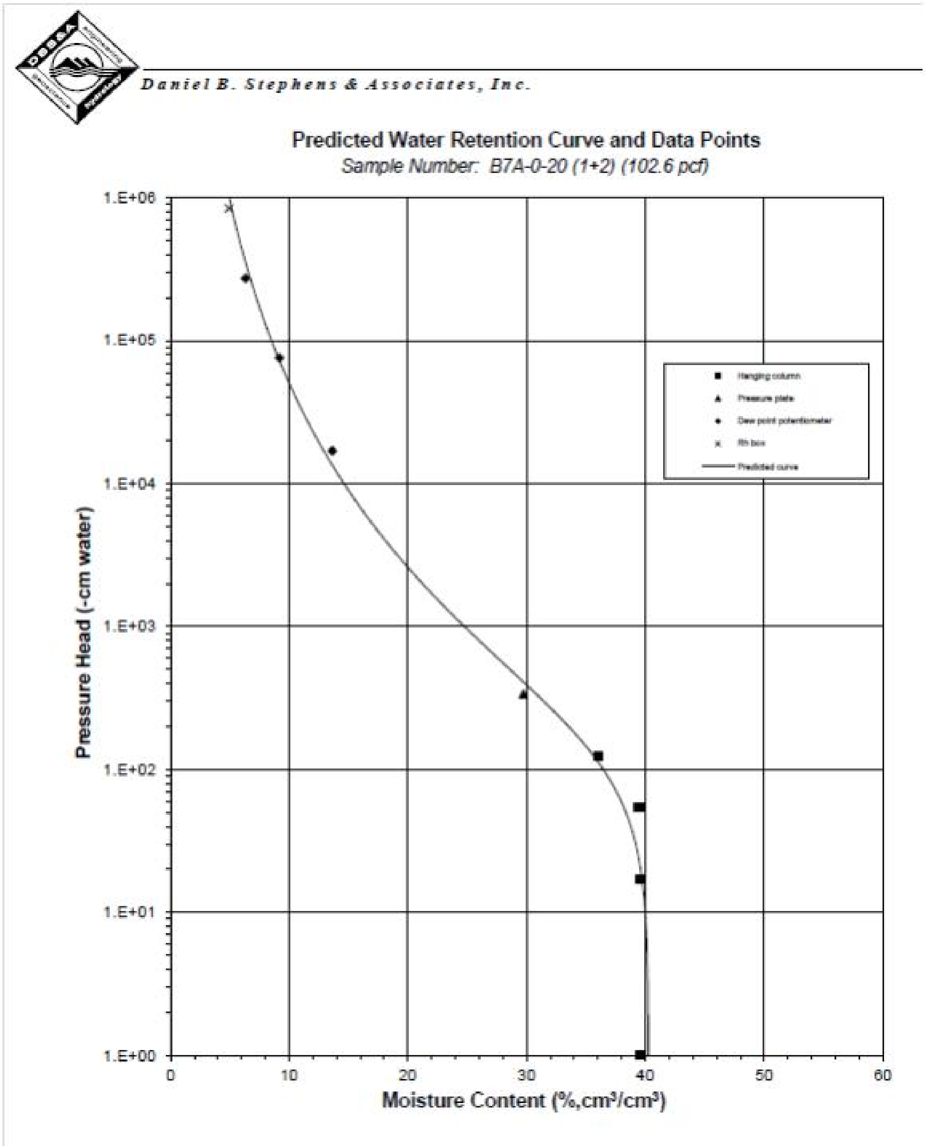
From the response:
"If the soil surface dries to a value at or above a user-defined matric potential limit, the time step is solved again using a Dirichlet condition at the surface."

Q What is, or explain, the user-defined matric potential limit?

Response: *A requirement of the UNSAT H software is defining the maximum head value (soil suction) soil can dry to. This value was defined as 1E06 cm for these simulations. If you recall the shape of a typical fine-grained soil moisture characteristic curve, as the soil moisture content approaches the residual moisture content, soil suction moves vertically up. This limits how high this vertical movement can go.*



Example of a moisture characteristic curve from potential cover soil tested. It can be seen from the following graph that an assumption of 1e06 cm is conservative since the residual moisture content has not quite been reached at this head value.



From the response:
"In this situation, the surface potential is held constant at the matric potential limit, and evaporation is set equal to the flux from below."

Q Why does it need to be held constant?

Response: *It is held constant because the soil wants to continue to move toward steady state conditions. At the surface, if there has been no precipitation for awhile, the upper boundary condition on that surface node is potential evapotranspiration (PET) which is trying to pull moisture from that surface node. But the node is not allowed to dry past the suction head of 1E6 cm so it will stay at that head value until moisture reaches the node and allows the head to drop due to precipitation/infiltration or moisture moving up from below.*

Q Does all evaporation occur at the surface, i.e., only at the surface?

Response: *Yes. Evaporation only occurs at the surface node.*

Q If not, what is the deepest node that evaporates?

Response: *NA*

Q In the future repository profiles, will moisture move up as a liquid or as a vapor?

Response: *In these simulations, moisture is moving in liquid form. The soil moisture in liquid form from nodes defining vertical points in the soil profile move from lower energy gradients toward nodes with higher energy gradients. The energy gradients are a function of the node elevation and the moisture/head value of each node.*

- **Page 10: RAI 3.8-5 Response on i.**

From the response:
"…multiple simulations were performed to provide a full suite of sensitivity analyses that evaluated the envelope of possibilities for soil, vegetation, and climate."

Q Where are the sensitivity cases involving climate (besides the standard 18 average-years/2 wettest-years cycle)?

Response: *In Att. G.7, Section 7, Table 16, page 57 – this table summarizes the series of simulations that was performed varying the surface admixture depth, soil texture, vegetation, and climate. These were the initial simulations performed to qualify adequate soil borrow sources given the myriad of other variables. The climate evaluated typical conditions to the most extreme (wettest year on record while forcing all precipitation to infiltrate) to beyond extreme where this wettest year on record was applied in consecutive years. The worst case results are shown in Figure 18, page 66. These results show the worst case combination of input parameters that require the thickest cover to minimize flux. These worst case input parameters were then used in a long-term simulation summarized in Att. G.7, Section 8, Figure 19, page 68 whereby the profile was modeled without vegetation for 3 years, then stepped through the vegetation maturation process with each stage taking twenty years (10 years of typical climate conditions followed by the wettest year on record applied in two consecutive years and finally eight more typical climate years). Thus the beyond extreme condition was applied every twenty years. The results summarized in Figure 20 show that flux is minimized at a relatively shallow depth – much less than the recommended cover thickness.*

Q What major insights were obtained from the sensitivity analyses documented in App. G, Att. G.7, App. A-C?

Response: *The most sensitive variable is the amount of water applied to the cover profile. The more precipitation applied to the profile, the deeper the infiltration. Soil texture has an impact, but the simulations presented in the report were limited only to acceptable borrow soil. There were some very sandy soils that were evaluated as borrow that were deemed unacceptable. Because the ratio of PET:precip is so high for this area of the country, the other variables such as vegetation type and admixture depth had minimal impact.*

Q From App. G, Att. G.7, App. C, Table 104, page 195, why does the thickness of the admixture (i.e., soil & rock) make so little difference?

Response: *See reply above and directly below. Given the other variables, the depth of admixture was relatively insensitive.*

Q What parameters or boundary conditions are used in UNSAT-H to represent the rocks (33% by volume) in the uppermost soil?

Response: *The storage capacity of the admixture layer is reduced by 33%. Specifically, the van Genuchten parameters for the soil residual and saturated moisture content are reduced (App. G, Att. G.7, Equation 14, page 54). At the same time, the saturated hydraulic conductivity of this layer is reduced by the formula shown App. G, Att. G.7, Equation 13, page 53. Consequently, even though the storage capacity of the layer is reduced, the rate moisture moves through it is slowed by the presence of the rock.*

Q How do the rocks affect the energy balance?

Response: *See reply above.*

Q Do the rocks take more energy to heat up compared to the soil?

Response: *Heat is not part of these simulations. Heat cannot be included if plants are used and is generally not used for cover water balance analyses.*

Q Do the rocks slow down the upward movement of moisture (i.e., create a more tortuous path)?

Response: *Yes. The saturated hydraulic conductivity is reduced in the admixture layer as described above.*

- **Page 10: RAI 3.8-5 Response on ii.**

Q Which of the validation studies listed in the response would be most similar to the conceptual model of ET at the future repository in Church Rock? Specifically, studies that documented field study measurements validating previous UNSAT-H modeling or simulation results showing soil evaporation rates on the order of 10's of centimeters per year.

Response: *Dwyer 2003 is the best since it is a long-term demonstration in Albuquerque with similar soils and climate as Church Rock. Scanlon et al 2002, 2005 also evaluated this data. The evaporation predicted in these references is of similar magnitude to that estimated at Church Rock.*

- **Page 10: RAI 3.8-5 Response on iii.**

Q Is there an upward gradient that results in evaporation of moisture from below <u>during the winter</u>?

Response: *There is an upward gradient if the conditions dictate it. That is moisture moves from lower (less negative) energy gradients toward soil with higher energy (more negative)*

gradients. If precipitation occurs, the surface gradient will be down until conditions allow it to reverse. Transpiration is zero during the winter, so all ET during the winter is via surface evaporation. The evaporation is slowed during the winter because PET is less during this period compared to the summer (warmer weather).

Q If yes, how is that possible (e.g., with snow on the ground)?

Response: *Snow coverage cannot be specifically modeled. The simulations conservatively assume all precipitation infiltrates into the profile and does not sit on the surface. In reality, a significant amount of snow coverage sublimates and never infiltrates. Snow coverage for practical considerations at the Church Rock site is short lived and is generally in conjunction with frozen ground whereby moisture movement temporarily ceases.*

Q If no, what months have no upward gradient?

Response: *The gradient direction is dependent on precipitation. Precipitation occurs more so in the summer than the winter but occurs in both. Gradient is downward after precipitation occurs as the profile attempts to move toward steady state and back up when drying. That is, upward gradients occur when the soil suction of the upper soil node is higher than the node below. The gradients change direction based on the weather and subsequent soil conditions. Net flux was the concern in these simulations and corresponding depth of cover to minimize flux.*

- **Page 13: RAI 3.8-7 Response on a)**

Q Could more detail be provided to explain the following question: *Why does the Ks value for the recompacted radon barrier after the construction of the repository (3.6x10-5 cm/s in Tab. 11) have the same Ks value of the existing radon barrier (3.6x10-5 cm/s in Tab. 9)*? The RAI response given was not clear to the NRC staff. "They have the same value because they are the same soil. UNC assumed that the radon barrier was compacted when it was initially installed. The soil is intended to be left in place and recompacted to about the same compaction effort to produce similar hydraulic conductivity values."

Response: *The radon barrier soil is alluvial soil excavated from a borrow source near the site. The soil was excavated and compacted to form the radon barrier. Rock was then placed on top of this layer to form the final existing cover system. The plan moving forward is to salvage the rock on top of the radon barrier to be used in the final ET Cover. The radon barrier soil is to be left in place. The final condition of the radon barrier prior to placement of mine spoils on it will be to have a uniform density with a maximum water content. It is presumed that the final density will be about the same as the existing density of the soil. The specified minimum compaction for the radon barrier after removal of the rock is 95% of Maximum dry density per ASTM D698 while limiting moisture content to dry of the optimum. Thus the same soil with the same density should produce the same saturated hydraulic conductivity.*

Q In addition, won't the weight of the mine spoils and new cover decrease the hydraulic conductivity value of the radon barrier?

Response: *Refer to previous reply. Yes, it will likely increase the density slightly and thus decrease the saturated hydraulic conductivity slightly. The changes will be relatively small. However, in the analysis the decrease in the saturated hydraulic conductivity was conservatively*

ignored. A lower saturated hydraulic conductivity would slow the movement of moisture. Furthermore, based on experience, the decrease from a small increase in density in an already compacted sample will not significantly change the saturated hydraulic conductivity.

- **Page 13-14: RAI 3.8-7 Response on c)**

Table A1

Year	Precip		PET	Transp		Evap		Runoff		Drain
1	29.743		211.744	8.42		11.98		0		1.14910E-06
2	29.743		211.744	10.049		11.809		0		1.15220E-06
10	29.743		211.744	13.373		11.938		0		1.15220E-06
11	60.35		215.456	5.136		34.1		0.634		1.14910E-06
12	60.35		215.456	3.998		45.512		5.371		1.14910E-06
13	29.743		211.744	6.067		21.059		0		1.14910E-06
14	29.743		211.744	6.169		18.683		0		1.15220E-06

From the response:
Increased E and reduced T “is presumed to be due to the shallower profile and reduced storage capacity of the upper portion of the profile above the fine-grained soils that slow downward water movement.”
[Looking at Fig. 8, page 19 in App. Y, the above mentioned fine-grained soils are 12 ft down.]

“The infiltrated water is held closer to the surface and more readily available for evaporation.”

Q What layer is the infiltrated water in?

Response: *The infiltrated water has saturated the fill to the top of the fine tailings. The low Ksat of the fine tailings slows any drainage through it and thus the infiltrated water has backed up in the profile to the base of the existing cover.*

Q Although evaporation increases, why does the transpiration drop from 13 cm in the average year to 5 cm in the wet year?

Response: *The head (defined as 30 cm, Section 6.6, page 50) corresponding to the water content above which plants do not transpire because of anaerobic conditions occurs at a shallower depth and slowly increase as the saturated conditions retreat in subsequent years. That is, in year 10 the full plant root depth is allowed to transpire because the soil in the full root depth has a head greater than this value. In Year 11 and more so in 12, the backed up water saturated much of the root zone and thus limited the lower portions of the roots from transpiring water. Refer to table below revealing the saturated/positive head values in years 2014 and 2015*

(Note: positive head values are really negative while negative head values are really positive. The values highlighted in yellow show positive pressure with saturated conditions.)

Initial Conditions		**2003**	**2008**	**2012**	**2013**	**2014**	**2015**
NODE	DEPTH	HEAD	HEAD	HEAD	HEAD	HEAD	HEAD
1	0.0	2.92E+01	1.00E+05	1.00E+05	1.57E+03	1.00E+05	1.00E+05
2	0.1	2.92E+01	6.59E+04	7.70E+04	1.29E+03	2.87E+01	2.78E+01
3	0.3	2.92E+01	1.54E+02	6.73E+04	1.17E+02	2.85E+01	2.76E+01

4	0.6	2.92E+01	9.21E+01	3.94E+04	9.38E+01	2.81E+01	2.72E+01
5	1.0	2.92E+01	7.75E+01	1.53E+02	7.95E+01	2.75E+01	2.66E+01
6	1.6	2.92E+01	7.17E+01	1.08E+02	7.32E+01	2.67E+01	2.59E+01
7	2.5	2.92E+01	7.61E+01	9.21E+01	7.69E+01	2.56E+01	2.48E+01
8	3.6	2.92E+01	8.13E+01	8.33E+01	8.13E+01	2.42E+01	2.35E+01
9	5.0	2.92E+01	8.00E+01	7.75E+01	8.00E+01	2.26E+01	2.19E+01
10	7.0	2.92E+01	7.56E+01	7.32E+01	7.54E+01	2.04E+01	1.97E+01
11	10.0	2.92E+01	6.68E+01	7.16E+01	6.65E+01	1.72E+01	1.65E+01
12	12.0	2.92E+01	5.80E+01	7.31E+01	5.75E+01	1.52E+01	1.45E+01
13	13.5	2.92E+01	4.89E+01	7.58E+01	4.84E+01	1.37E+01	1.30E+01
14	14.0	2.92E+01	4.43E+01	7.71E+01	4.37E+01	1.32E+01	1.25E+01
15	15.0	2.92E+01	4.15E+01	8.08E+01	4.09E+01	1.22E+01	1.15E+01
16	16.0	6.27E+03	3.99E+01	8.05E+01	3.92E+01	1.12E+01	1.05E+01
17	17.0	6.27E+03	4.04E+01	7.95E+01	3.96E+01	1.02E+01	9.49E+00
18	19.0	6.27E+03	4.23E+01	7.77E+01	4.06E+01	8.24E+00	7.52E+00
19	22.0	6.27E+03	4.77E+01	7.51E+01	4.32E+01	5.29E+00	4.56E+00
20	27.0	6.27E+03	5.87E+01	7.06E+01	4.67E+01	3.62E-01	-3.92E-01
21	32.0	6.27E+03	8.16E+01	6.62E+01	5.04E+01	-4.60E+00	-5.37E+00
22	37.0	6.27E+03	1.42E+02	6.18E+01	5.38E+01	-9.57E+00	-1.03E+01
23	42.0	6.27E+03	1.96E+06	5.74E+01	5.59E+01	-1.45E+01	-1.53E+01
24	47.0	6.27E+03	2.69E+09	5.29E+01	5.60E+01	-1.95E+01	-2.03E+01
25	52.0	6.27E+03	2.69E+09	4.83E+01	5.57E+01	-2.45E+01	-2.53E+01
26	55.0	6.27E+03	6.67E+08	4.55E+01	5.56E+01	-2.75E+01	-2.83E+01
27	57.0	6.27E+03	7.09E+05	4.37E+01	5.54E+01	-2.95E+01	-3.03E+01
28	59.0	6.27E+03	7.06E+05	4.18E+01	5.48E+01	-3.14E+01	-3.23E+01
29	60.0	6.27E+03	6.96E+05	4.09E+01	5.37E+01	-3.24E+01	-3.32E+01
30	61.0	6.27E+03	6.77E+05	3.99E+01	5.38E+01	-3.34E+01	-3.42E+01
31	62.0	2.69E+09	6.45E+05	3.92E+01	5.77E+01	-3.44E+01	-3.52E+01
32	63.0	2.69E+09	5.89E+05	3.93E+01	7.14E+01	-3.54E+01	-3.62E+01
33	65.0	2.69E+09	5.00E+05	3.95E+01	1.19E+02	-3.74E+01	-3.82E+01
34	68.0	2.69E+09	3.71E+05	3.99E+01	1.31E+04	-4.04E+01	-4.12E+01
35	73.0	2.69E+09	1.96E+05	4.06E+01	1.32E+05	-4.53E+01	-4.62E+01
36	80.0	2.69E+09	6.61E+04	4.17E+01	4.18E+04	-5.23E+01	-5.31E+01
37	90.0	2.69E+09	1.93E+04	4.33E+01	1.60E+04	-6.22E+01	-6.31E+01
38	100.0	2.69E+09	1.20E+04	4.50E+01	1.17E+04	-7.21E+01	-7.30E+01
39	110.0	2.69E+09	8.81E+03	4.68E+01	9.38E+03	-8.20E+01	-8.29E+01
40	120.0	2.69E+09	5.50E+03	4.87E+01	6.40E+03	-9.19E+01	-9.29E+01
41	130.0	2.69E+09	3.41E+03	5.08E+01	4.02E+03	-1.02E+02	-1.03E+02
42	140.0	2.69E+09	2.78E+03	5.28E+01	3.07E+03	-1.12E+02	-1.13E+02
43	150.0	2.69E+09	2.82E+03	5.46E+01	2.97E+03	-1.22E+02	-1.23E+02
44	160.0	2.69E+09	3.00E+03	5.62E+01	3.07E+03	-1.32E+02	-1.33E+02
45	170.0	2.69E+09	3.10E+03	5.74E+01	3.14E+03	-1.42E+02	-1.43E+02
46	180.0	2.69E+09	3.22E+03	5.82E+01	3.22E+03	-1.51E+02	-1.53E+02

47	187.0	2.69E+09	4.25E+03	5.87E+01	3.88E+03	-1.58E+02	-1.59E+02
48	192.0	2.69E+09	7.86E+03	5.90E+01	6.38E+03	-1.63E+02	-1.64E+02
49	195.0	2.69E+09	1.12E+04	5.92E+01	1.02E+04	-1.66E+02	-1.67E+02
50	197.0	2.69E+09	1.17E+04	5.93E+01	1.16E+04	-1.68E+02	-1.69E+02
51	198.0	2.69E+09	1.17E+04	5.94E+01	1.17E+04	-1.69E+02	-1.70E+02
52	199.0	6.99E+05	1.17E+04	5.94E+01	1.17E+04	-1.70E+02	-1.71E+02
53	201.0	6.99E+05	1.17E+04	5.96E+01	1.17E+04	-1.72E+02	-1.73E+02
54	204.0	6.99E+05	1.17E+04	5.98E+01	1.17E+04	-1.75E+02	-1.76E+02
55	209.0	6.99E+05	1.17E+04	6.03E+01	1.17E+04	-1.80E+02	-1.81E+02
56	217.0	6.99E+05	1.17E+04	6.15E+01	1.17E+04	-1.88E+02	-1.89E+02
57	227.0	6.99E+05	1.17E+04	6.41E+01	1.17E+04	-1.98E+02	-1.99E+02
58	237.0	6.99E+05	1.17E+04	6.87E+01	1.17E+04	-2.08E+02	-2.09E+02
59	247.0	6.99E+05	1.17E+04	7.70E+01	1.17E+04	-2.18E+02	-2.19E+02
60	257.0	6.99E+05	1.17E+04	9.23E+01	1.17E+04	-2.28E+02	-2.29E+02
61	267.0	6.99E+05	7.72E+04	1.24E+02	1.54E+03	-2.38E+02	-2.39E+02
62	277.0	6.99E+05	3.88E+04	2.08E+02	3.51E+02	-2.48E+02	-2.49E+02
63	287.0	6.99E+05	1.08E+02	9.44E+02	1.05E+02	-2.58E+02	-2.59E+02
64	297.0	6.99E+05	8.34E+01	2.39E+05	8.56E+01	-2.67E+02	-2.69E+02
65	307.0	6.99E+05	7.33E+01	3.50E+05	7.50E+01	-2.77E+02	-2.79E+02
66	317.0	6.99E+05	7.32E+01	3.37E+05	7.44E+01	-2.87E+02	-2.89E+02
67	327.0	6.99E+05	7.75E+01	2.86E+05	7.81E+01	-2.97E+02	-2.99E+02
68	337.0	6.99E+05	8.10E+01	2.20E+05	8.09E+01	-3.07E+02	-3.08E+02
69	347.0	6.99E+05	7.82E+01	1.44E+05	7.81E+01	-3.17E+02	-3.18E+02
70	354.0	6.99E+05	7.12E+01	8.68E+04	7.09E+01	-3.24E+02	-3.25E+02
71	359.0	6.99E+05	6.24E+01	4.49E+04	6.20E+01	-3.29E+02	-3.30E+02
72	362.0	6.99E+05	5.35E+01	2.46E+04	5.30E+01	-3.32E+02	-3.33E+02
73	364.0	6.99E+05	4.62E+01	1.64E+04	4.56E+01	-3.34E+02	-3.35E+02
74	365.0	6.99E+05	4.25E+01	1.37E+04	4.19E+01	-3.35E+02	-3.36E+02
75	366.0	6.99E+05	4.06E+01	1.17E+04	4.00E+01	-3.36E+02	-3.37E+02
76	367.0	2.64E+03	4.00E+01	1.03E+04	3.93E+01	-3.37E+02	-3.38E+02
77	368.0	2.64E+03	4.11E+01	9.30E+03	3.99E+01	-3.30E+02	-3.33E+02
78	370.0	2.64E+03	4.42E+01	7.75E+03	4.16E+01	-3.17E+02	-3.24E+02
79	373.0	2.64E+03	5.24E+01	6.26E+03	4.49E+01	-2.98E+02	-3.10E+02
80	378.0	2.64E+03	6.79E+01	4.88E+03	4.85E+01	-2.65E+02	-2.87E+02
81	385.0	2.64E+03	1.04E+02	3.91E+03	5.22E+01	-2.20E+02	-2.54E+02
82	394.0	2.64E+03	2.27E+02	3.32E+03	5.51E+01	-1.62E+02	-2.12E+02
83	405.0	2.64E+03	2.69E+09	3.01E+03	5.61E+01	-9.01E+01	-1.60E+02
84	416.0	2.64E+03	2.69E+09	2.92E+03	5.59E+01	3.77E-02	-1.09E+02
85	425.0	2.64E+03	2.69E+09	2.94E+03	5.56E+01	8.03E+02	-6.68E+01
86	431.0	2.64E+03	7.10E+05	2.99E+03	5.55E+01	2.72E+03	-3.88E+01
87	436.0	2.64E+03	7.08E+05	3.05E+03	5.52E+01	3.07E+03	-1.54E+01
88	439.0	2.64E+03	7.02E+05	3.10E+03	5.43E+01	3.12E+03	-1.35E+00
89	441.0	2.64E+03	6.88E+05	3.13E+03	5.35E+01	3.15E+03	2.09E+01

90	442.0	2.64E+03	6.63E+05	3.14E+03	5.51E+01	3.16E+03	5.14E+01
91	443.0	1.17E+04	6.20E+05	3.21E+03	6.27E+01	3.22E+03	5.91E+01
92	444.0	1.17E+04	5.49E+05	3.42E+03	8.73E+01	3.41E+03	6.02E+01
93	446.0	1.17E+04	4.41E+05	3.92E+03	2.04E+02	3.85E+03	6.25E+01
94	449.0	1.17E+04	2.90E+05	4.84E+03	1.69E+05	4.65E+03	6.66E+01
95	454.0	1.17E+04	1.23E+05	6.59E+03	8.07E+04	6.21E+03	7.62E+01
96	461.0	1.17E+04	3.40E+04	8.68E+03	2.35E+04	8.21E+03	9.81E+01
97	470.0	1.17E+04	1.49E+04	1.04E+04	1.36E+04	9.97E+03	4.78E+03
98	480.0	1.17E+04	1.01E+04	1.13E+04	1.04E+04	1.10E+04	1.09E+04
99	495.0	1.17E+04	7.03E+03	1.17E+04	7.88E+03	1.16E+04	1.16E+04
100	515.0	1.17E+04	4.22E+03	1.17E+04	5.01E+03	1.17E+04	1.17E+04
101	540.0	1.17E+04	2.97E+03	1.17E+04	3.40E+03	1.17E+04	1.17E+04
102	570.0	1.17E+04	2.76E+03	1.17E+04	2.96E+03	1.17E+04	1.17E+04
103	610.0	1.17E+04	2.91E+03	1.17E+04	3.02E+03	1.17E+04	1.17E+04
104	660.0	1.17E+04	3.06E+03	1.17E+04	3.11E+03	1.17E+04	1.17E+04
105	710.0	1.17E+04	3.12E+03	1.17E+04	3.15E+03	1.17E+04	1.17E+04
106	763.0	1.17E+04	3.51E+03	1.17E+04	3.41E+03	1.17E+04	1.17E+04
107	813.0	1.17E+04	5.61E+03	1.17E+04	4.74E+03	1.17E+04	1.17E+04
108	863.0	1.17E+04	9.98E+03	1.17E+04	8.43E+03	1.17E+04	1.17E+04
109	903.0	1.17E+04	1.16E+04	1.17E+04	1.12E+04	1.17E+04	1.17E+04
110	933.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
111	958.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
112	978.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
113	993.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
114	1003.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
115	1010.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
116	1015.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
117	1018.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
118	1020.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04
119	1021.0	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04	1.17E+04

- **Page 15: RAI 3.8-7 Response on figure provided with e)**

Q Where is the upward gradient to the surface after 2023? The figure shows drier conditions a foot below the surface and wetter conditions at the surface.

Response: *Not sure what you are asking. The chart shows suction values at designated depths (middle or base) of the applicable soil layer. The red is the base of the mine spoils, the green is the middle of the radon barrier/liner (the soil that is to be left in place from the existing cover), and the blue is the middle of the ET Cover. The ET Cover mid-point is 2-ft below the surface.*

Q Isn't the surface (i.e., soil & rock admixture) too wet, i.e., above the wilting point, to have soil water evaporate?

Response: *The surface can't be too wet to evaporate. The wetter the surface the more evaporation. The wilting point is related to transpiration, not evaporation.*

Q Why is the soil suction at the surface held constant?

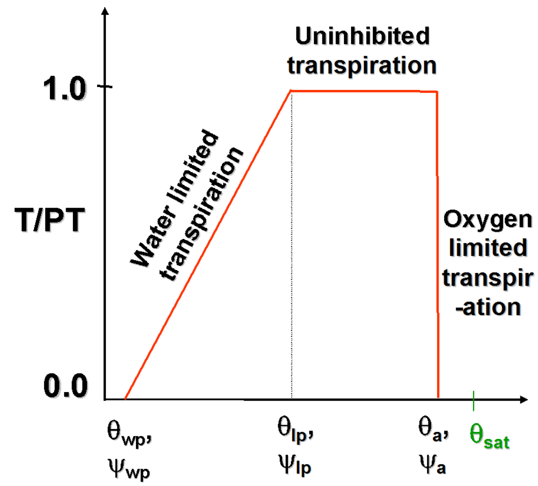
Response: *It is not held constant. It varies depending on whether there is precipitation and thus infiltration and subsequent drying. It is not allowed to get drier or have a higher soil suction value than 1E06 cm as described in reply to* ***Page 6: RAI 3.8-2 Response on evaporation above.***

From the response (bottom of page 7):
"If the surface soils dry to near residual moisture content during dry periods, the soil suction is large (orders of magnitude greater than gravity) and draws up moisture from underlying soil. This effect is amplified near the surface and has less effect as the profile depth increases."

Q Isn't most of the cover below 1 ft (i.e., the borrow soil) too dry for plants to grow? Wilting point is around 1500 kPa or 15,000 -cm while the borrow soil is even drier values around 40,000 -cm.

Response: *The wilting point is defined as described above and in Att. G.7, Refer to page 53, Section 6.6 where these values are defined. For reclaimed vegetation 40,000 cm, grassland and shrubs 70,000 cm. Reference is Fayer and Walter 1995. The 15,000 cm is generally assumed to be wilting point for typical agriculture plants. If the soil is drier (suction is higher) than these defined suction values, transpiration will not occur. The following figure is offered to help understand how the defined values affect transpiration.*

Plant Limiting Function



θ_{wp} , ψ_{wp} = wilting point, transpiration ceases.

θ_{lp}, ψ_{lp} = water content below which (or suction above which) transpiration is limited by water availability (limiting point)

θ_a , ψ_a = water content above which (or suction below which) transpiration ceases due to lack of oxygen (anaerobiosis point)

Q If the fine-grained tailings were saturated for decades, why do they suddenly become drier in the three years after the model starts running (i.e., 2000 to 2003)?

Response: *It is not sudden. The graph shows only the year end values at the end of the three years. Keep in mind that the graph showing soil suction is in logarithmic scale and that the suction values for the tailings are still very wet (near saturation) and mostly still in anaerobic conditions.*

- **Page 16: RAI 3.8-7 Response on f) ii.**

Could the response be explained in more detail?

Q Specifically, why is there no change in the transpiration rate between the average precipitation years (Years 1-10) and the above average precipitation years (Years 11 – 12)?

Q Similar to Profile B2, why does the evaporation rate does react to the increase of available water, but the transpiration does not?

Response: *Answer to both of these questions. Refer to Profile B2 Table A1 (Existing) to A2 (After), Profile B8 Table A3 (Existing) to A4 (After), Profile B10 Table A5 (Existing) to A6 (After), Profile B11 Table A7 (Existing) to A8 (After): in each existing condition there is minimal change*

between years 1 to 10 and 11 and 12 while there is a significant change in evaporation from years 1 to 10 to years 11 and 12. The existing condition has a 2-ft cover profile that consists of a rock surface layer with some fine-grained sand. This cover is allowing for significant infiltration of precipitation. Conversely, drying is reduced due to the reverse capillary barrier effect of the coarse over fine-grained soil. Thus, this infiltrated water travels down through the profile into the underlying materials above the bottom fine-grained tailings. The fine-grained tailings have a very low saturated hydraulic conductivity that allows minimal drainage though it. Consequently, the large amount of water that infiltrated in years 11 and 12 is held within the soil layers above the fine grained tailings, reaching saturation. In fact the water level above the fine-grained tailings rises toward the surface and occupies much of the soil layer containing roots. This saturated or near saturated condition eliminates the ability of the plants to transpire where the roots are within soil having suction less than the anaerobic defined value of 30 cm. Refer to reply above for: ***Page 13-14: RAI 3.8-7 Response on c).***

The 'After' profile contains an ET Cover that is twice as thick as the existing cover and is fully conductive. Thus, infiltrated water is more easily removed via ET. There is no saturated or near saturated condition with the ET Cover that limits the ability of plants to transpire infiltrated moisture.