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Topic 3.5.1: Vadose Zone Models

Recommendation 150: Decide how to represent intact and subsided conditions for the proposed new conceptual closure cap design for the purpose of calculating infiltration. Produce new intact and subsided infiltration cases based on new conceptual design.

Topic 1.2: LFRG Issues Assigned to Next PA Revision

Recommendation 95: Produce a separate data package for the ELLWF closure cap and infiltration estimates generated by HELP modeling.

Impact of Different Vegetative Cover Scenarios on Infiltration Rates for the E-Area PA Intact Case

Scope

This memorandum addresses the effects of vegetative cover type (bamboo versus Bahia grass) and the timing of pine tree intrusion on intact infiltration rate for the proposed E-Area Low-Level Waste Facility (LLWF) closure cap system. It builds upon earlier reports whose purpose is to lay the foundation for the infiltration data package that will be assembled during the next revision of the E-Area LLWF Performance Assessment (PA):

- Dyer (2017a) establishes the conceptual modeling framework for the E-Area PA HELP infiltration model simulations.
- Dyer (2017b) confirms closure of the water mass balance for scenarios involving cap subsidence resulting from the disposal of non-crushable waste.
- Dyer and Flach (2017) describe a probabilistic model for estimating subsided-area infiltration rates for vadose-zone PORFLOW simulations.
- Shipmon and Dyer (2017) summarize a sensitivity analysis of closure cap material property and design parameters that will impact infiltration rates predicted by the HELP model.
- Dyer (2018) outlines a method for generating uncertainty distributions for intact- and subsided-area infiltration rates for the GoldSim probabilistic system model.

Conclusions

The impact of geomembrane layer defects and pine tree intrusion on infiltration rate was evaluated using HELP Version 4.0 (Dixon, 2017) for five closure-cap scenarios: (1) F-Area Tank Farm (FTF) Bahia grass (Phifer et al., 2007); (2) E-Area Bahia grass using the 2008 E-Area PA timeline for pine tree intrusion (Phifer et al., 2007); (3) E-Area Bahia grass using a revised timeline for pine tree intrusion given by Skibo (2017); (4) E-Area unmanaged bamboo cover (Skibo, 2017); (5) E-Area managed bamboo cover (Skibo, 2017). Conclusions are:

- HELP model simulations for the five closure-cap scenarios above reinforce that the FTF Bahia grass case with 2% slope and 585-foot slope length is a reasonable upper bound for E-Area LLWF infiltration rates.
- The main difference between the FTF Bahia grass and the E-Area LLWF cases is a shift in the E-Area intact infiltration rate profiles by up to 100 years (Figure 1 and Figure 2) due to a corresponding shift in the defect profiles for the geomembrane layer (Figure 3 and Figure 4). The shift arises because the E-Area final closure cap will not be installed until the end of the 100-year institutional control period, whereas the FTF closure cap will be installed at the start of institutional control. The impact of the 100-year offset on intact infiltration rates is most significant during the first 600 to 700 years after the start of institutional control.
- The difference in intact infiltration rates between the E-Area bamboo and Bahia grass cases appears during a narrow window from 160 to 300 years (shaded region in Figure 5), after the start of institutional control when pine tree intrusion occurs. The benefit of a bamboo versus Bahia grass vegetative cover is small compared to infiltration changes occurring over thousands of years due to cap degradation. However, this difference is potentially of significance for disposal units with no or minimal non-crushable waste, for which the intact cap scenario controls disposal limits. Radionuclides potentially most affected will be ones whose mass flux at the water table peaks during this period.
- An assumed 35-year extended maintenance period beyond the end of institutional control to remove pine tree seedlings (Skibo Bamboo Managed case) does not appear to offer significant reductions in intact infiltration rate over an extended period.

Note: Infiltration rates and timelines in this memorandum are preliminary and should not be used for final design and modeling purposes.

Discussion

Table 1 compares the number of geomembrane layer defects assumed in the HELP v4.0 model simulations for the five closure-cap scenarios. In the HELP model, the number of defects is defined as the number of 1 square centimeter holes. The assumptions and calculation bases used to arrive at the number of defects and the pine tree intrusion rate for the FTF Bahia grass case are described in detail by Phifer et al. (2007) in Appendix I (see lower table on pg. 329 for the number of defects assumed in the FTF case versus time). The same FTF assumptions for the rate of pine tree intrusion and the rate of increase in the number of geomembrane defects are also used in the Phifer/Nelson E-Area Bahia grass scenario; however, the actual number of defects for each model simulation time step was adjusted to account for the 100-year shift in the disposal unit timeline due to the delayed installation date for the final closure cap. The Skibo E-Area Bahia grass and bamboo scenarios also use Phifer et al. (2007) as a basis for the rate of increase in geomembrane defects, but Skibo (2017) as the basis for the different pine tree intrusion timelines. Similarly, the number of geomembrane defects for each model simulation time step was adjusted to account for the different Skibo E-Area grass and bamboo timelines. The time-adjusted defect numbers were linearly interpolated using the FTF defect numbers and interpolation equation reported by Phifer et al. (2007) in the table on page 325 of Appendix I. For the E-Area cases, the interpolated time (Yr_x) used in the linear interpolation equation was "relative year minus 100" to account for the later cap installation date. For example, the number of defects at relative year 180 for the E-Area cases is based on the FTF defect number at relative year 80. The initial number of "installation defects" assumed at time zero for the FTF and time 100 years for the E-Area cases is four (4) as shown in Table 1.

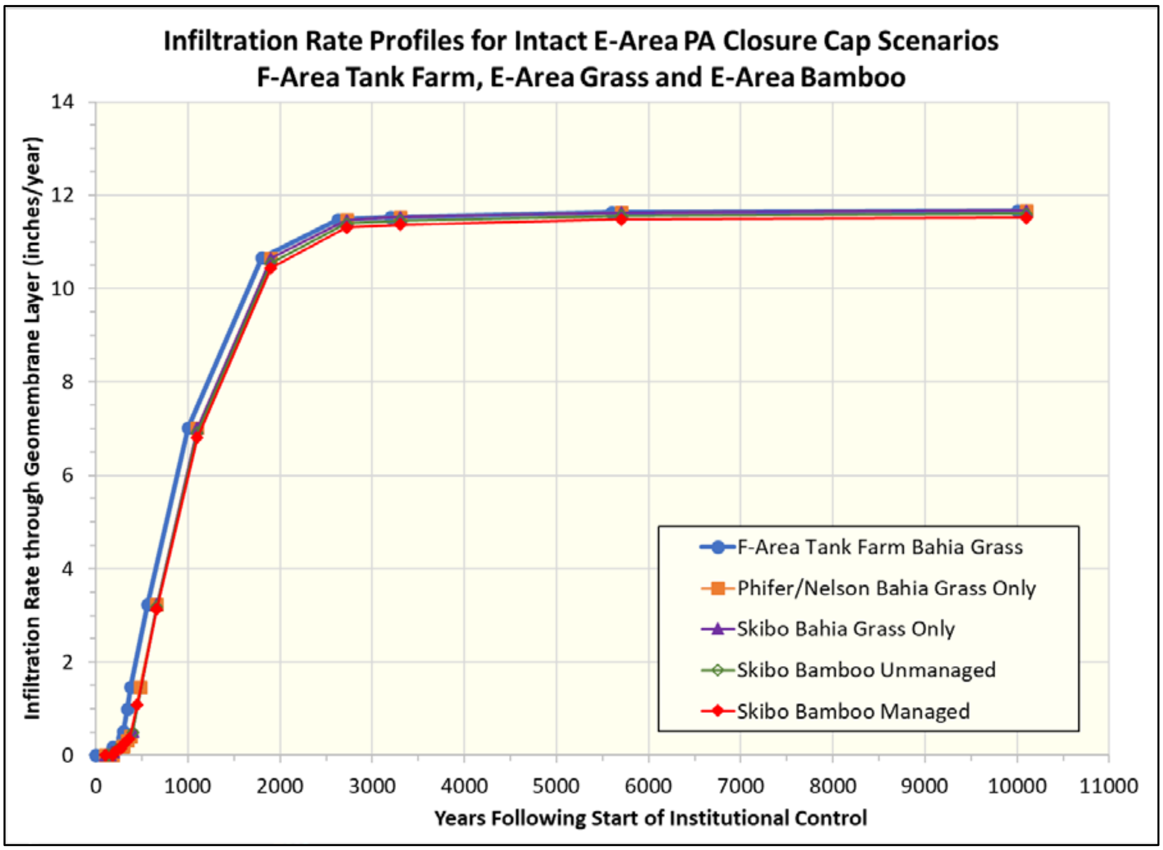

Figure 1. Comparison of Infiltration Rate Profiles for FTF Bahia Grass and E-Area Bahia Grass and Bamboo Scenarios (linear-linear scale, 0 to 10,000 years)

Table 2 provides a summary of intact infiltration rates predicted by the HELP model as a function of time for the five closure-cap scenarios. Note that each scenario has its own unique timeline because of differences in the assumed timing for pine tree intrusion. The managed bamboo case assumes an extended maintenance period of 35 years beyond the end of institutional control to remove pine tree seedlings, along with periodic surface treatments and replanting as needed to promote a dense stand of bamboo growth and leaf litter production. The data in Table 2 are plotted in Figure 1 (linear-linear scale), Figure 2 (log-log scale), and Figure 5 (log-log scale).

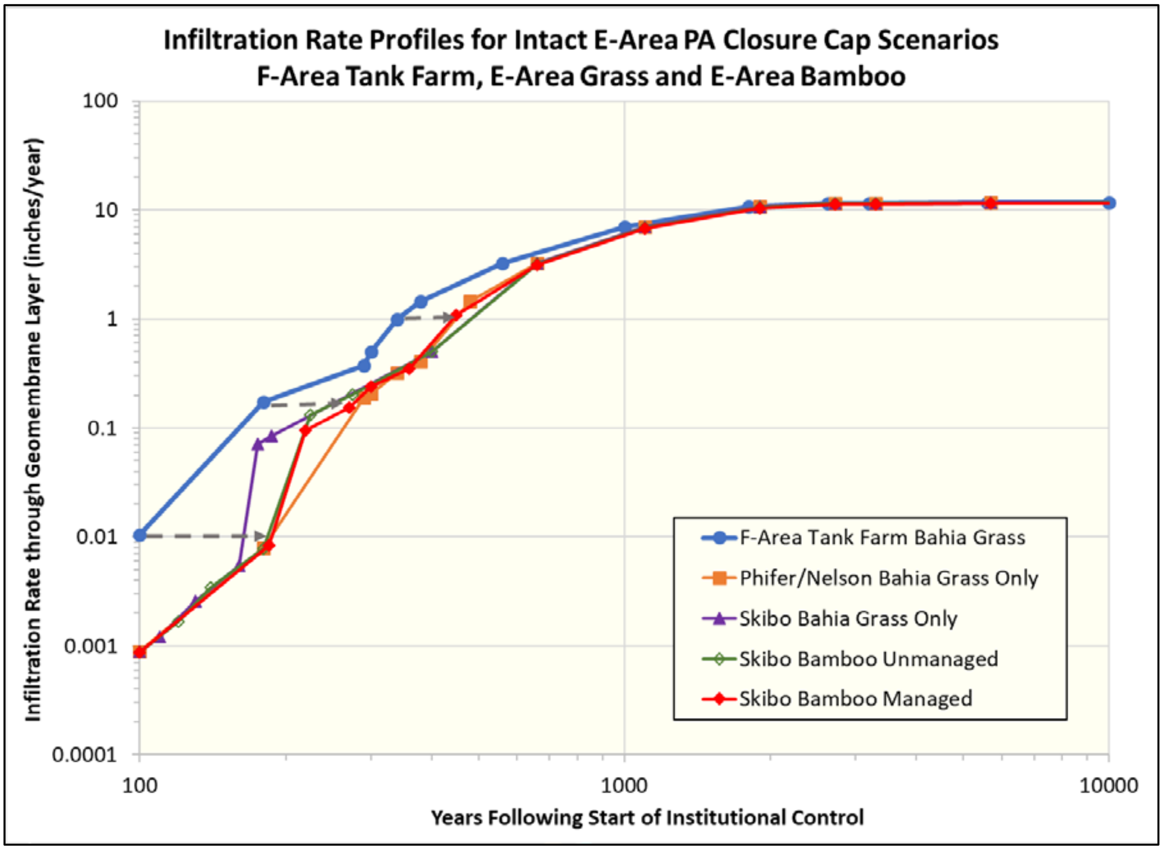

Figure 2. Comparison of Infiltration Rate Profiles for FTF Bahia Grass and E-Area Bahia Grass and Bamboo Scenarios (log-log scale, 100 to 10,000 years)

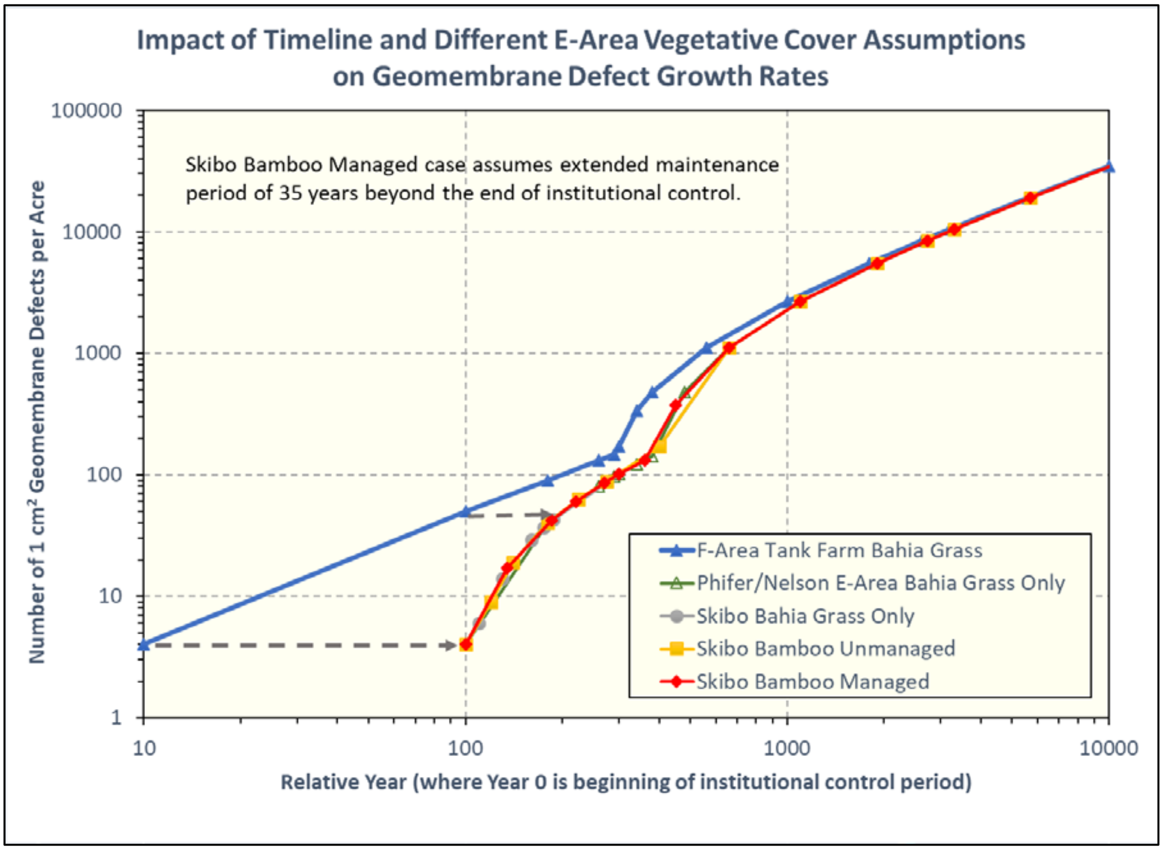

Figure 3. Comparison of Geomembrane Defect Growth Rates for FTF Bahia Grass and E-Area Bahia Grass and Bamboo Scenarios (10 to 10,000 years)

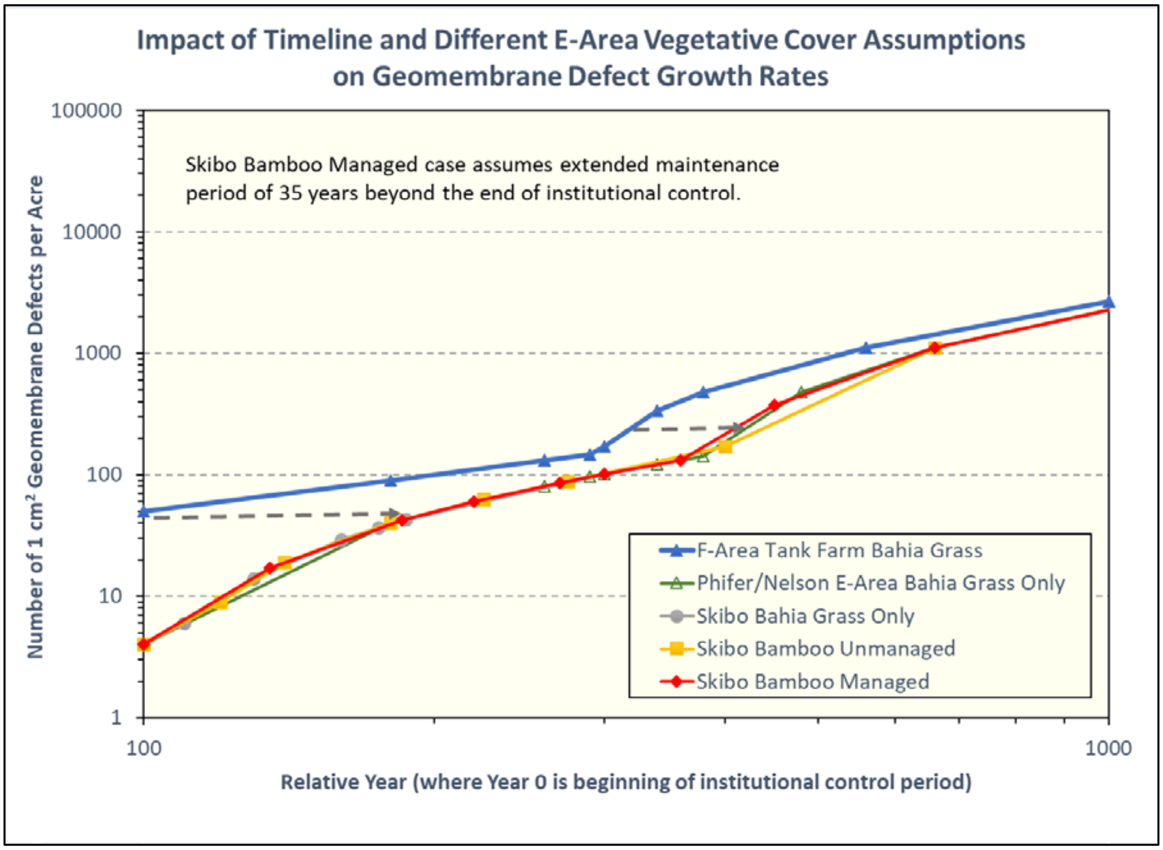

Figure 4. Comparison of Geomembrane Defect Growth Rates for FTF Bahia Grass and E-Area Bahia Grass and Bamboo Scenarios (100 to 1,000 years)

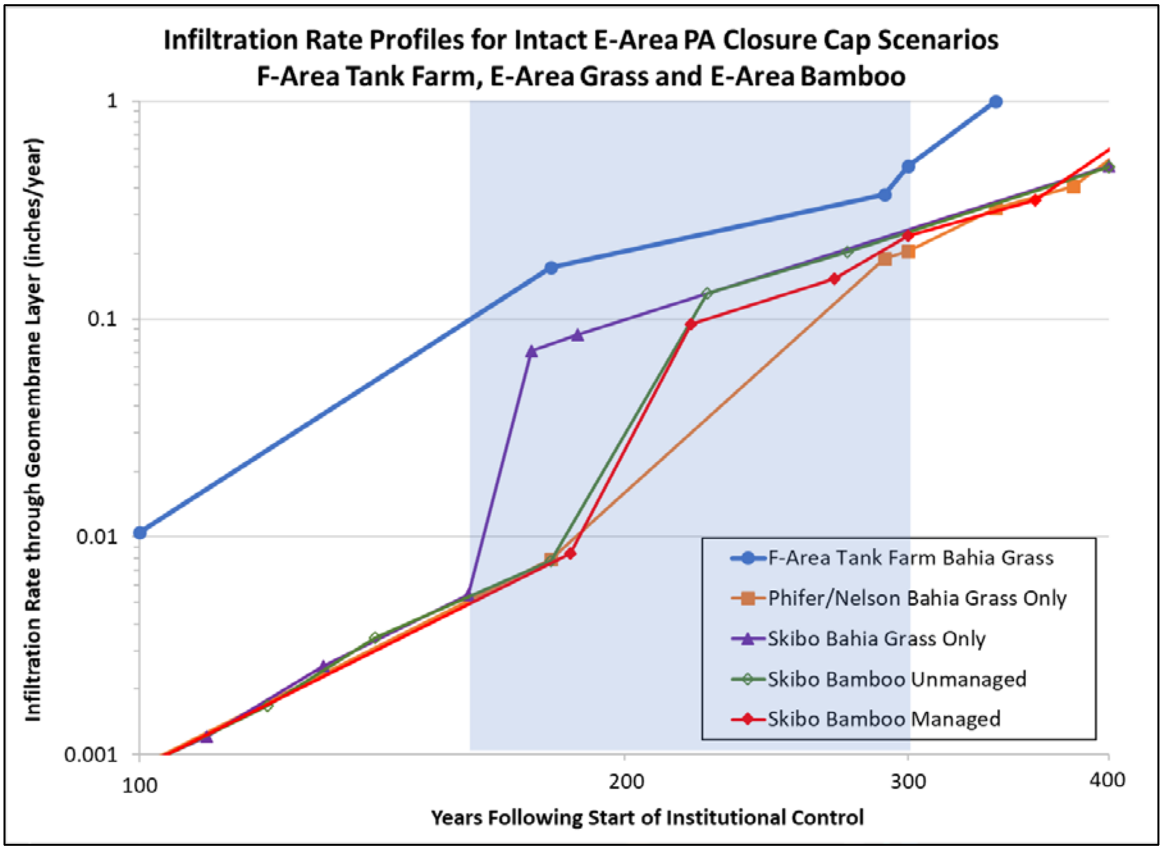

Figure 5. Comparison of Infiltration Rate Profiles for FTF Bahia Grass and E-Area Bahia Grass and Bamboo Scenarios (log-log scale, 100 to 400 years)

Table 1. Defect Assumptions for use in HELP Model Simulations for Slit and Engineered Trenches – Next Revision of the E-Area LLWF Performance Assessment

	Number of 1 cm^2 holes in geomembrane layer									
Facility Event	Relative Year (yr)	F-Area Tank Farm (# defects)	Relative Year (yr)	E-Area Phifer/Nelson Grass Only (# defects)	Relative Year (yr)	E-Area Skibo Grass Only (# defects)	Relative Year (yr)	E-Area Skibo Bamboo Unmanaged (#defects)	Relative Year (yr)	E-Area Skibo Bamboo Managed (# defects)
Start of Institutional Control	0	4	0		0		0		0	
Interim Cap Installed	NA		0		0		0		0	
Establish 600-foot Bahiagrass Buffer	0		0		0		0		0	
Final Cap Installed	0		100	4	100	4	100	4	100	4
Bamboo Planted as Final Vegetative Cover	NA		NA		NA		100		100	
End of Active Cap Maintenance	100	50	100		100		100		135	17
	180	90	180	40						
Initial Pine Tree Encroachment	260	131	260	80	110	6	120	9	185	42
Tap Roots Reach Geomembrane	290	146	290	96	160		180		270	85
Pine Trees Cover 1/3 Cap	300	170	300	101	130	14	140	19	220	60
Pine Trees Cover 2/3 Cap	340	334	340	121	160	29	180	40	300	101
Pine Trees Cover 100% Cap	380	479	380	141	175	37	225	63	360	131
Mature Pine Tree Stand with 100-year Turnover	380		380		187	43	275	88	450	373
			480	479	400	170	400	170		
	560	1115	660	1115	660	1115	660	1115	660	1115
	1000	2669	1100	2669	1100	2669	1100	2669	1100	2669
	1800	5496	1900	5496	1900	5496	1900	5496	1900	5496
Silting In of Lateral Drainage Layer Complete	2623	8403	2723	8403	2723	8403	2723	8403	2723	8403
	3200	10442	3300	10442	3300	10442	3300	10442	3300	10442
	5600	18921	5700	18921	5700	18921	5700	18921	5700	18921
	10000	34466	10100	34466	10100	34466	10100	34466	10100	34466

Pine tree roots reach geomembrane or pine trees cover 1/3 cap, whichever comes later.

The number of defects for the F-Area Tank Farm case are given by Phifer et al. (2007) in WSRC-STI-2007-00184, Rev. 2, Appendix I, pg. 329, lower table.

The number of defects for the four E-Area cases are also derived from the F-Area Tank Farm case, but are adjusted to account for the four different E-Area grass and bamboo timelines shown in the table above. The time-adjusted defect numbers are calculated via linear interpolation of values reported by Phifer et al. (2007) in WSRC-STI-2007-00184, Rev. 2, Appendix I, tables on pp. 325 and 329.

Table 2. Comparison of Infiltration Rates through the Geomembrane/GCL Barrier Layers for the E-Area LLWF Bahia Grass and Bamboo Cases to the F-Area Tank Farm Bahia Grass Case (HELP v4.0 simulations; 2% slope, 585-foot slope length; see Table 1 for timelines)

Year	F-Area Tank Farm (inches/year)	Year	E-Area Phifer/Nelson Grass (inches/year)	Year	E-Area Skibo Grass (inches/year)	Year	E-Area Skibo Bamboo Unmanaged (inches/year)	Year	E-Area Skibo Bamboo Managed (inches/year)
1	0.00088	100	0.00088	100	0.00088	100	0.00087	100	0.00087
100	0.01045	180	0.00791	110	0.00121	120	0.00168	185	0.0084
180	0.17259	290	0.18881	130	0.00255	140	0.00344	220	0.09443
290	0.37093	300	0.20409	160	0.00544	180	0.0078	270	0.15301
300	0.50343	340	0.32167	175	0.07115	225	0.13123	300	0.24035
340	0.99578	380	0.40513	187	0.0843	275	0.20242	360	0.3501
380	1.45639	480	1.45728	400	0.50397	400	0.49672	450	1.08818
560	3.23001	660	3.23003	660	3.23196	660	3.18764	660	3.13879
1000	7.01547	1100	7.01494	1100	7.01469	1100	6.9157	1100	6.80388
1800	10.65504	1900	10.64993	1900	10.6486	1900	10.54856	1900	10.4406
2623	11.47275	2723	11.47205	2723	11.46762	2723	11.39286	2723	11.30814
3200	11.53166	3300	11.532	3300	11.53005	3300	11.45317	3300	11.37254
5600	11.63172	5700	11.63143	5700	11.6295	5700	11.55771	5700	11.47873
10000	11.6707	10100	11.6734	10100	11.67263	10100	11.60356	10100	11.52038

References

Dixon, K. L. (2017) HELP 4.0 Documentation Updates for Software and Data. SRNL-STI-2017-00104. Savannah River National Laboratory, Aiken, SC.

Dyer, J. A. (2017a) Conceptual Modeling Framework for E-Area PA HELP Infiltration Model Simulations. SRNL-STI-2017-00678. Savannah River National Laboratory, Aiken, SC.

Dyer, J. A. (2017b) E-Area Low-Level Waste Facility Vadose Zone Model: Confirmation of Water Mass Balance for Subsidence Scenarios. SRNL-STI-2017-00728. Savannah River National Laboratory, Aiken, SC.

Dyer, J. A. (2018) Method for Including Uncertainty in Infiltration Rates in the E-Area PA System Model. SRNL-STI-2018-00121. Savannah River National Laboratory, Aiken, SC.

Dyer, J. A., and Flach, G. P. (2017) E-Area LLWF Vadose Zone Model: Probabilistic Model for Estimating Subsided-Area Infiltration Rates. SRNL-STI-2017-00729. Savannah River National Laboratory, Aiken, SC.

Phifer, M. A., Jones, W. E., Nelson, E. A., Denham, M. E., Lewis M. R., and Shine, E. P. (2007) FTF Closure Cap Concept and Infiltration Estimates. WSRC-STI-2007-00184, Rev 2. Savannah River National Laboratory, Aiken, SC.

Shipmon, J. C., and Dyer, J. A. (2017) Analysis of Factors that Influence Infiltration Rates using the HELP Model. SRNL-STI-2017-00506. Savannah River National Laboratory, Aiken, SC.

Skibo, A. Z. (2017) SRNL Bamboo (*Phyllostachys* Species) Planting Site Assessment; Savannah River Site. SRNL-STI-2017-00638, Rev 1. Savannah River National Laboratory, Aiken, SC.

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