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Model Comparisons

Clive DU PA Model v1.4

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1.0 Introduction

The Clive DU PA Model has undergone several revisions in the development and review process. Three major versions have been released: v1.0, v1.2, and v1.4. This document highlights major changes made in these models and compares results.

2.0 Model Updates

There are three main versions of the Clive DU PA Model: Clive DU PA Model v1.0 (v1.0), Clive DU PA Model v1.2 (v1.2), and Clive DU PA Model v1.4 (v1.4). Several major updates occurred in each new version.

The differences in results between v1.0 and v1.2 are primarily from evaluating the DU waste disposed below grade instead of above grade. However, the DU waste was still dispersed in the deep time model as a consequence of intermediate lake return. Other changes include differences in cover design from a riprap cover to an evapo-transpirative cover, a change in approach to erosion calculations using a landscape evolution model (SIBERIA), and a few other model changes, such as changes in the tortuosity exponent distributions.

In addition to various minor changes, model v1.4 includes several notable updates, including:

- Substantial revision to the deep time model that no longer disperses below grade waste based upon return of an intermediate lake, accounting for eolian deposition until a lake returns (based on recently collected field data), and addressing lake dispersal area and diffusion into the lake based on lake dynamics.
- Updated embankment geometry per the latest design drawings (see Appendix 3, *Embankment Modeling for the Clive DU PA* white paper)
- Updated infiltration modeling based on changes to hydraulic properties in the cover system, resulting in lower net infiltration (see Appendix 5, *Unsaturated Zone Modeling for the Clive DU PA* white paper)

3.0 Results Comparison

Results from the Clive DU PA Model v1.4 are compared to results from the Clive DU PA Models v1.2 and 1.0 below. For comparison purposes, the Clive DU PA Model v1.0 was updated (at the time of v1.2 release) into GoldSim version 10.5 service pack 4 (sp4) and was rerun for 10,000 realizations with the waste configured as it is in the current model: all the waste buried below grade. Gullies were allowed to form in all models and were included in receptor scenarios. The Clive DU PA Model v1.4 was updated into GoldSim version 11.1.2.

3.1 Groundwater Concentration and Rancher Dose

Peak groundwater concentrations of ^{99}Tc are shown for model comparison purposes in Table 1, along with rancher dose and total population dose.

Table 1. Comparison or groundwater concentrations and receptor dose results for PA model iterations.

	Mean			Median			95th Percentile		
	v1.0	v1.2	v1.4	v1.0	v1.2	v1.4	v1.0	v1.2	v1.4
Peak ^{99}Tc groundwater concentration within 500 yr (GWPL = 3790 pCi/L) (pCi/L)	3.4E4	7.4E2	2.6E1	2.0E3	2.0E1	4.3E-2	1.8E5	4.5E3	1.5E2
Peak rancher dose within 10,000 yr (mrem/yr)	3.9E-3	1.6E-2	6.2E-2	2.9E-3	1.4E-2	5.1E-2	9.4E-3	3.7E-2	1.5E-1
Total population dose within 10,000 yr (rem)	3.5E-1	1.6E0	1.2E1	2.8E3	1.4E0	1.1E1	8.7E3	3.3E0	2.6E1

The ^{99}Tc groundwater summary addresses the peak concentrations for the 500-yr period, for which the peak occurs at 500 yr. Hence, these are summary statistics are 500 yr. Similarly the rancher does and population dose summaries represents the doses at 10,000 yrs.

Concentrations of ^{99}Tc in v1.2 and v1.4 are much lower than those in v1.0, primarily because of the reduction in the infiltration rate with the new ET cover and potentially the narrowing of the tortuosity coefficient distributions. In v1.0 and v1.2, ^{99}Tc concentrations exceed the groundwater protection limits (GWPLs) in the 95th percentile, and the mean for v1.0 also exceeds the GWPL for ^{99}Tc. Note that the median did not exceed the GWPL in any model. In the current version of the model, v1.4, the mean, median, and 95th percentile values are much lower than the GWPLs for all radionuclides of concern, including ^{99}Tc as shown in Table 1. Reductions in groundwater concentrations are tied to lower infiltration rates which resulted from less conservatism in unsaturated zone modeling (see the *Unsaturated Zone Modeling for the Clive PA* white paper, Appendix 5). This is despite the waste being placed below grade (i.e., closer to groundwater) in the v1.2 and v1.4 models. The infiltration rate is much lower, which mitigates the effect of lower waste placement.

Doses to the ranch worker receptor are also compared for Clive DU PA Model v1.0, v1.2, and v1.4 in Table 1. Doses for Models v1.2 and v1.4 are slightly higher than for v1.0, indicating that model revisions for infiltration and tortuosity resulted in increased rates of radon migration to the ground surface. Total population doses (used as the basis for ALARA cost calculations in the Final Report) also increased due to increased radon flux at the surface. However, the doses from all three model iterations are much less than the performance objectives, and the total ALARA population doses are very small.

Specifically in the infiltration model, the single value saturated hydraulic conductivities of the radon barriers were replaced by statistical distributions developed from the range of hydraulic conductivities recommended by Benson et al. (2011). In addition, distributions were developed for van Genuchten hydraulic parameters alpha and n for both the surface and evaporative zone layers of the ET cover. Thus, net infiltration was modeled using a wide range of hydraulic input parameters. As a result, on average, volumetric water contents in the radon barriers are generally drier in Model v1.2 and v1.4 than in Model v1.0. So there is more air-filled porosity available for the radon to diffuse through. Looking at the sensitivity analyses for v1.2 and v1.4, the most sensitive parameter to dose endpoints is the radon escape/production ratio. This suggests that radon is the primary driver for dose. These sensitivity analyses results indicate that the characteristics of the radon barriers have an influence on radon flux.

3.2 Deep Time

Deep time lake and sediment concentrations for the three model releases are summarized in Table 2 and Table 3. Note that the results for v1.4 are based on a specific model timestep of 90,000 years, because that timestep coincides with a greater chance of a deep lake being present at the site. This is considered a more representative value for the lake and sediment concentrations, because it is corresponds to a time at which a large lake is most likely to occur according to 10,000 realizations of the model. It avoids the occasional high values that drive the concentrations reported for Model V1.0 and Model v1.2. Nevertheless, the sediment concentrations are much smaller in Model v1.4, and the lake water concentrations are smaller. Lake and sediment concentrations decreased considerably in each successive new model version.

Table 2. Deep time peak lake and sediment U-238 concentrations within 100,000 years for v1.0 and v1.2.

	Mean		Median		95th Percentile	
	v1.0	v1.2	v1.0	v1.2	v1.0	v1.2
Peak lake water uranium-238 concentration within 100,000 yr (pCi/L)	5.2E-1	1.2E-1	2.0E-3	6.6E-4	2.5E1	7.9E-1
Peak sediment uranium-238 concentration within 100,000 yr (pCi/g)	1.5E3	7.7E2	1.2E3	5.2E2	3.5E3	2.6E3

Table 3. Deep time lake and sediment U-238 concentrations at model year 90,000 for v1.4.

	25th Percentile	Median	Mean	95th Percentile
U-238 lake concentration (pCi/L)	1.4E-7	2.1E-5	1.8E-2	1.1E-1
U-238 sediment concentration (pCi/g)	1.7E-4	1.8E-3	2.0E-2	9.5E-2

In Model v1.2 the DU waste was still dispersed upon intermediate lake return. The primary difference between Model v1.0 and v1.2 was related to changes in the way different versions of GoldSim handled time steps. Since the peak concentrations across time are the reported results, time steps impact when the peaks occur, and affect mixing (averaging) in a time period. The differences are somewhat artificial in this sense.

The lake water and sediment concentrations are orders of magnitude lower in v1.4 of the model. This is largely because the DU waste is not dispersed upon return of an intermediate lake, the dispersal area is increased based on site-specific data, diffusion takes into account both arid and moist periods, and eolian deposition is included in the modeling process. The sediment concentrations in the deep time model are much less than background concentrations of U^{238} in the area (average about 2 pCi/g). (Note that sediment concentrations for Ra^{226} are more similar to background because of ingrowth – see Page 9 of the Main Report.) This model allows diffusion of the waste into the lake, rather than covering the waste, although some covering the waste is likely during inter-glacial periods. Also, note that the current inter-glacial is expected to last for many tens of not several hundreds of thousands of year because of the concentration of carbon-dioxide in the atmosphere. The longer the inter-glacial period, the more covering of the waste is likely from eolian deposition, rather than diffusion-based mixing that is assumed under more moist conditions.

Note also that radon flux at the time of the first lake recession was calculated in the Deep Time Supplemental Analysis model and in v1.4. For reference, deep time rancher doses were calculated based on the radon flux results. These results are presented in the Main Report but are not presented here because previous model versions did not make these calculations.