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U.S. Nuclear Regulatory Commission
ATTN: Mr. Michael J. Fuller
Division of Waste Management and Environmental Protection
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Washington, DC 20555

Subject: Transmittal of Final Copy of Model/Code and Documentation for a Biosphere Model in GoldSim [Intermediate Milestone (IM) 06004.01.006.220]

Dear Mr. Fuller:

The purpose of this letter is to transmit the subject deliverable. The final copy of the model/code and documentation was prepared to document activities under Task 6 (Develop a Biosphere Model Using GoldSim, Subtask C). This version of the model/code and documentation includes addressing comments requested by the U.S. Nuclear Regulatory Commission (NRC) that were received on June 29, 2007. Though not required, an information-only copy of the responses have been included for your convenience. For clarity, we have repeated each comment and have provided our responses in italics.

We appreciate the careful evaluation of the documentation and software by the NRC staff. Their comments have led to some additional improvements in the software and documentation. Included in the NRC comments were suggestions for additional improvements in the model which were beyond the original scope as specified in the statement of work. We welcome the opportunity to discuss these items with you.

Also, as we have discussed with Ms. Turner Gray and Christepher McKenney, once we have finalized the software, we plan to begin the process to copyright BDOSE. Please note that this would not change NRC access to this or subsequent versions of the software.

If you have any questions regarding this report, please contact Ali Simpkins at (210) 522–6260 or me at (210) 522–2139. Your cooperation in this matter is appreciated.

Sincerely,

David R. Turner
Assistant Director
Non-Repository Programs

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BDose Comments
June 29, 2007
Reviewers: Cynthia Barr, Dave Esh,
Karen Pinkston, and Anita Gray

Specific BDose Model Comments:

1. A good job was done in implementing changes based on previous comments.

Resolution: Comment accepted.

2 It is obvious that a lot of effort was put into improving the product. The addition of instructions on the front page, the addition of warning flags, the descriptions within the model file, and the use of clone elements are all good practices.

Resolution: Comment accepted.

3. The model file is nicely organized and easy to browse.

Resolution: Comment accepted.

4. Up front in the model file there should be a list of assumptions (or package) that the user is directed to consult to ensure there aren't gross inconsistencies between the biosphere model and the other parts of the PA to which BDose is attached (e.g., infiltration rates, climatic parameters, erosion rates).

Resolution: Comment noted. No change is made at this time. This change will be considered with future revisions.

5. In \BDOSE\Biosphere\Crop_Module\Generic_crop_parameters,
the writeup to the left of the Irrigationwater_INT switch refers to this switch by the wrong name.

Resolution: Comment accepted. Text changed to correctly identify the control switch by its proper name.

6. It is unclear why the excavation volume check was not also used for the driller scenario. Also, the addition of a check to ensure that the volume of material that is being spread over the intruder spread area is not too much for that area would be useful.

Resolution: Comment accepted. Drilling and excavation calculations have been changed to incorporate excavated material dilution. Warnings have been added to ensure the drilling volume or total excavated volumes are larger than the source volumes.

7. The warning at the bottom of the installation instructions does not fully capture the

problems that occur when the existing model has a species list that is a subset of the species list in the BDOSE model. A value of zero is used for any species that is present in BDOSE but not the parent model in all vectors that use the species list. This includes vectors like the Kd vectors, etc. Goldsim does not give a warning that this is occurring, so unless a user knows about this problem and checks every single vector in the model to make sure that they are accurate, they will get incorrect results.

Resolution: Comment accepted. The warning has been augmented to describe the nature and potential for this type of error.

8. Instructions for the case when the groundwater model has more species than the BDOSE model were not added although it was indicated that these instructions were going to be added in the response to previously submitted comment #3 of the April 2007 comments.

Resolution: Comment noted. The incorporation of BDOSE into an existing model with RNs not included in BDOSE is beyond the scope of this basic instruction set, This type of model manipulation would require a significant modification/extension of the BDOSE data sets (i.e., Kds, uptake coefficients, transfer coefficients, dose coefficients). This is the reason BDOSE has a large (49) list of RNs based on multiple possible analysis sites.

9. The warning under installation instruction #2 has a grammatical issue (i.e., ..."are synchronized in order prior to"...).

Resolution: Comment accepted. The grammatical issue has been addressed.

10. Some of the acute exposure inputs are based on the assumption that the worker who drills and the worker who excavates both spend 160 hours working. This assumption may not be accurate because an excavation could take a lot more time to do than drilling a well.

Resolution: Comment noted. It is intended that site and worker specific data will be used in lieu of these default values.

11. An intruder spread area of 100 m^2 is potentially too small of an area to spread all of the material that could be exhumed in the excavation scenario. A larger intruder spread area should be used for this scenario.

Resolution: Comment noted. It is intended that site and receptor specific data will be used in lieu of these default values.

12. It is inconsistent to use an irrigation rate associated with Idaho and a precipitation rate that is based on the average precipitation in the US because Idaho is much more arid than much of the rest of the country.

Resolution: Comment noted. It is intended that site specific data will be used in lieu of these default values. The default precipitation value is a midpoint value for the US and Idaho irrigation rate is used as a representative value for a state with irrigation farming of crops like

potatoes that are grown in many resident farmer-type gardens/farms.

13. A number of the parameters for various consumption rates need to be truncated. Inclusion of uncertainty is good, but some of the values seem to be extremes. For example:
    a. INT_water_consumption_rate can be sampled at drinking water intake values of > 6000 L/yr.
    b. The intruder consumption rate for fruit can be more than 2 kg/day.
    c. The intruder consumption rate for fish can be more than 2 kg/day.

Resolution: Comment noted. Water consumption rate values have been set to fixed default values of 730.5 L/yr. The truncation of other consumption rate distributions has been left to the end user to truncate or supplement with site and receptor specific data.

14. Total intake rates may need to be constrained by some sort of overall caloric intake measure or quantity. If the consumption rates aren't properly correlated or constrained, you can get very extreme results.

Resolution: Comment noted. The validity of this comment is acknowledged, and it is proposed that this issue be addressed in possible future development.

15. It isn't clear how exposure times for the intruders are implemented for some pathways. For example:

    a. The air exposure time for the chronic intruder is ~ 1000 hr (per year) but inhalation dose is based on 8400 m^3/yr without apparently scaling for the amount of breathing done in the exposure time.
    b. The ground surface shine time is set/sampled differently than the air exposure time, it is not clear what conditions this is meant to represent.
    c. The volume of air and amount of soil ingested by the excavation intruder should be much larger than for the driller intruder based on the longer times required to implement those tasks, however they are the same in the model file.

Resolution: Comment noted. It is intended that site and receptor specific data will be used in lieu of these default values.

16. The Excavate_SHINE_DOSE_GRND and related excavation pathways use driller parameters instead of excavation parameters.

Resolution: Comment accepted. Calculations for the excavation pathway doses have been changed to use the excavation parameters.

17. The stream and pond dilution factor calculations are somewhat crude conceptually and could be improved. However, they are probably sufficient for staff use.

Resolution: Comment noted. Future revisions to the code could possibly improve on the

conceptual model.

18. The areal soil concentrations do not include the mixing of non-waste from the drill core with the waste directly in the calculation. Instead, the concentration is defined based on an assumed 1 cm layer depth for the cuttings for drilling and 15 cm for excavation and the soil_spread_area. The dilution factors should probably be calculated based on scenario parameters (such as a user-defined drill depth) or a warning should be placed in the model instructions/file that the user should check whether the assumptions built into the calculation are consistent with the scenario.

Resolution: Comment accepted. Drilling and excavation calculations have been changed to incorporate excavated material dilution. Warnings have been added to ensure the drilling volume or total excavated volumes are larger than the source volumes.

19. It is not clear why the soil_spread_depth parameter is used downstream in the calculations for both the drilling and excavation scenarios (in container \BDOSE\Biosphere\Soil_module\Soil_parameters) considering the information discussed in the comment above.

Resolution: Comment accepted. The parameter soil_spread_depth has been removed from the evaluation of the excavated materials. The volumetric and areal concentration of waste in the spread materials is now primarily established by the spread area (for the chronic intruder). For the chronic intruder environment logic has been introduced to evaluate potential secondary dilution of excavated materials by plowing.

20. It is unclear why the volume of waste excavated by the acute intruder driller is larger than and different from the volume of waste exhumed by the chronic intruder driller. The chronic intruder should be exposed to the same amount of waste but with it mixed in a 15 cm layer, instead of assumed to be spread in a 1 cm layer for the acute driller.

Resolution: Comment noted. The use of an individual excavation volume for the acute excavation scenario was to provide flexibility to the excavation scenario and to maintain a consistency between the drilling and excavation scenarios.

21. See previously submitted comments (April 2007) to correct misspellings which were found throughout the model. Some of the misspellings were not addressed.

Resolution: Comment accepted. Text and titles within BDOSE were reexamined and corrected for spelling errors and mislabeling.

Documentation Comments - "Description of Methodology for Biosphere Dose Model - BDose"

1. The description of the model is much improved, and the level of detail is sufficient.

Resolution: Comment noted.

2. Page 4, Section 2.1, Only internal dose coefficients from EPA FGR 11 are cited in the text on page 4, while Table 1 indicates (and the code provides) an option to use ICRP 72 dose conversion factors are also available.

Resolution: Comment accepted. Reference to ICRP 72 added.

3. Page 4, Section 2.1, The text in the last paragraph of this section implies that the BDose code calculates groundwater concentration at future times of interest. The RT module can perform this function, while the BDose model is intended to be linked to a larger GoldSim model that includes contaminant transport. Please clarify this in the text.

Resolution: Comment accepted. Text changed.

4. Figure 2-1 implies that animals consume groundwater directly from the aquifer. It is not clear why the animals would not consume livestock water drawn from a well in addition to surface water. This scenario might be appropriate for deer getting water from groundwater seeps but may not be appropriate for livestock in a residential farmer scenario.

Resolution: Comment accepted. Figure modified.

5. While the footnote to Figure 2-1 is helpful, the footnote appears to be more appropriate next to the text in the "groundwater" and "soil" boxes. Also it is misleading to show that the soil could be contaminated by both irrigation water and can be a separate, independent input by the user in the intruder scenarios, as these scenarios are independent. I think it would be easier to include two separate figures for groundwater dependent versus intruder scenarios, as originally suggested by NRC comment.

Resolution: Comment accepted. Two figures have been created.

6. Figure 2-1 is missing "external dose" in one of the boxes.

Resolution: Comment accepted. Figure fixed.

7. On page 5, Figure 2-1, the pathway describing the ingestion of contaminated soil should be included.

Resolution: Comment accepted. Figure changed to add ingestion of soil.

8. Page 5, Section 2.2.1, The RT module simulates transport, as well as decay and ingrowth, that allows consideration of time-dependent groundwater concentrations. It is implied that BDose is calculating these concentrations and that only decay and in-growth are considered by the RT module. Please clarify the text.

Resolution: Comment accepted. Text changed.

9. Page 5, Section 2.2.1, It is not clear from the documentation that time-varying build-up of contamination in the soil is not considered for some models (as well as recycling of contamination in subsequent irrigation years). In essence, for every time step of the simulation, an independent dose is calculated based on the groundwater concentration for that time step that is either provided by user input or from linkage to a larger groundwater model. It would be helpful to list the various soil models and provide a brief description in the documentation. It would also be helpful to clarify that some of the soil models produce constant results for constant groundwater concentrations, while others consider time-varying build-up of concentrations and dose.

Resolution: Comment accepted. Documentation modified. Early in the project it was decided that recycling of contamination would not be considered.

10. Page 6, Section 2.2.1, equation 2-2, The documentation should describe the differences in various soil leaching conceptual models. On reviewing results from the different soil models, there generally doesn't seem to be that much difference in results between the models. Although the code documents the models, information on the differences between models and when these models may produce significantly different results is lacking in the documentation (e.g. differences in equilibrium times and dose for more mobile versus less mobile species and between shorter-lived and longer-lived species.) Any additional information that could be provided in the documentation regarding the differences between these models would be helpful. An evaluation of various soil leaching models could be the subject of future work.

Resolution: Comment noted. Soil model documentation within the model is sufficient.

11. Page 6, Section 2.2.1, It is not clear why the soil depth (indicated to typically be the root zone) is used in the equations on this page. It would seem more appropriate to use the contaminated zone thickness. Additionally, dependent on the assumptions regarding soil contamination depths versus root zone depths, the doses could be over or under-estimated. This model assumption or limitation is not discussed in the model limitations section. Consideration of the root depth versus contaminated zone or cover thickness could be considered in future work.

Resolution: Comment noted. Clarification added. This is consistent with GENII which the model is based on.

12. Page 7, Section 2.2.3, Allowing the user to input groundwater concentrations as the surface water concentration is not intuitive. Suggest changing the name to "user input surface water concentration" and providing this capability in the code, in lieu of using the groundwater concentration as the surface water concentration (user may want to keep other groundwater-dependent pathways separate).

Resolution: Comment noted. No change is made at this time. This change will be considered

with future revisions.

13. Page 7, Section 2.2.3.2, The pond concentrations assume no build-up of contamination and also assume the thickness of the contributing aquifer is the same as the depth of the pond (i.e., assume seepage rates (outputs) equivalent to inputs and same dimension of the pond and aquifer in the vertical direction). Please clarify this in the text. Suggest considering more sophisticated pond model in future work.

Resolution: Comment noted. Text added. Pond module improvements will be considered in future revisions.

14. Page 12, Section 2.3.1, The text indicates that the excavation volume is a user input. However, this input is not included in the equations. It is my understanding that the code doesn't consider dilution of the waste with clean excavation or well cutting materials and that the undiluted contamination is brought to the surface and spread over either a 1 cm layer for the well intruder scenario or mixed with 15 cm layer of soil if a farmer scenario is considered. Please clarify the text.

Resolution: Comment noted. Model and documentation modified to add dilution.

15. Page 12 and 13, Section 2.3.2, It is not clear that the assumptions regarding the depth of contamination (1 cm) are the most appropriate for radionuclides dominated by external dose. Consider alternative models under future work.

Resolution: Comment noted. Will consider for future work.

16. On page 14, it states that "certain pathways can be turned off by entering zero for the usage rates or exposure times or modifying the pathways under Receptor Definitions with the Controls Section." This information should be clearly documented in the model in the form of instructions for the user.

Resolution: Comment noted. There is a text box that explains this within the 'Receptor Definitions' container.

17. Page 15, Section 2.5, Consider expanding the model limitations and assumptions. Several additional assumptions and limitations are listed in these comments that should be included in this section.

Resolution: Comment noted. Several changes made throughout the document as suggested previously.

Comments on Default Input Parameters - Appendix of Documentation - Table 1:

1. Table 1 of the Appendix is a very good summary of the input parameters. Consider providing addition tables for those parameters that are specified by radionuclide, (e.g.,

soil_RN_KD, Transfer Coefficients).

Resolution: Comment accepted. Tables 2 - 5 added to the appendix for internal and external dose coefficients, soil_RN_KD, and transfer coefficients.

2. It would be helpful if the parameters that were given a default value of 1 and need to be edited by the user in order for them to obtain sensible results (e.g., Source_Excavation_Volume) were labeled in Table 1 so that the user could quickly identify which parameter values they need to make sure to change.

Resolution: Comment accepted. Parameters of this nature are noted in the Remarks column of Table 1 to denote the need for site and conceptual model specific information.

3. Some of the information for some of the parameter values, such as the units and in the remarks, is on the previous page because there are page breaks in the middle of parameter groups. Table 1 could be made more clear by either repeating this information on the new page or noting that the parameter group is continued from the previous page.

Resolution: Comment noted. Units carried in each page for clarity.

4. Table 1 should describe the relationship of the listed parameter values to the corresponding distributions. For example, for a parameter that uses a triangular distribution, it would be good to say that the values listed correspond to the minimum, most likely, and maximum values rather than just listing the three numbers.

Resolution: Comment noted. The user is assumed to have a basic knowledge of biosphere dose modeling which would include knowledge of standard distribution parameters. However, each of these are listed within the BDOSE model so the user could find them there if desired.

5. The units listed for the milk consumption parameters are labeled as being in kilograms, when in the model the units are in liters.

Resolution: Comment accepted. Text corrected.

6. The game carbon fraction is in Table 1 twice.

Resolution: Comment accepted. Text deleted.

7. Page 2, Change "Source Term" to "Source"-source term is a release rate not a concentration.

Resolution: Comment accepted. Text deleted.

8. Page 2, Please reconcile the text and table with respect to the DCF options provided in BDose (also includes ICRP 72 internal dosimetry). Consider including infinite source DCFs for external exposure in future revisions.

Resolution: Comment accepted. Text modified to reflect ICRP 72 option as well.

9. Page 2, The groundwater concentrations can also be calculated by GoldSim (when linking to larger model), as well as provided by user input.

Resolution: Comment accepted. Text corrected.

10. Page 2, Please reconcile differences in the diameter of the well (6 inches versus 22 inches on page 4 "well_diameter_acute").

Resolution: Comment accepted. Text edited to denote the difference in the residential water well and farming irrigation well.

11. Suggest including a separate table that lists parameter values that are correlated and those parameter values that are expected to be site-specific, so the user doesn't have to read the comments for every parameter value to determine which ones need to be changed or linked.

Resolution: Comment noted. Will consider for future work.

12. Page 4, Please reconcile the text, equations, and "source_excavation_volume_acute" to clarify whether a larger volume of soil can be excavated that essentially dilutes the contaminant concentration in soil in the excavation scenario.

Resolution: Comment accepted.

13. Page 5, "soil_RN_KD", It is not clear why the sand Kds are used as the default. These Kds are generally the lowest values and would allow more leaching to occur. However, this may not be significant considering the soil model selected.

Resolution: Comment accepted. Text edited to clarify and Table 4 added to provide context and choices of Kds for the analyst.

14. Page 5, "Vol_water_in_soil", It is not clear why lower field capacity values are used in lieu of moisture contents. Nonetheless, the value seems reasonable.

Resolution: Comment noted. This model parameter is intended to represent the moisture retaining capacity of the soil. This value is defined in the reference listed (Baes and Sharp, 1983) as volumetric water content at field capacity based on 154 pasture and cropland soils. Field capacity is referenced in this study since it is the amount of water remaining in soil after saturation and drainage time, vice moisture content as the amount of water in saturated soil, which would be slightly greater.

15. Page 5, Should considering providing links for correlated or cloned parameter values (e.g., "irrigation rate" is tied to "crop irrigation rates" and should therefore be linked).

Resolution: Comment noted. Will consider for future work. These specific parameters were not linked to provide the analyst flexibility in modeling various irrigation rates based on the scenario in question.

16. Page 5, Should consider adding warnings in code and creating separate table listing those parameter values that are correlated or dependent on one another (e.g., "precipitation rate" should not be lower than "evaporation rate").

Resolution: Comment noted. Will consider for future work. These specific parameters were not linked to provide the analyst flexibility in modeling various rates based on site-specific data and the scenario in question.

17. Page 6, Should consider adding warning or note in code and indicating in separate table in documentation regarding the linkage between the fraction of contaminated food and the consumption rates. Should consider adding a link to US EPA Exposure Factors Handbook in code. Should consider that the area of the contaminated zone is tied to the contaminated zone consumption rates (i.e., smaller areas may not be able to support certain pathways such as animal consumption). Future work should consider adjusting the dose from ingestion or consumption rates considering the size of the contaminated zone, similar to what is done in RESRAD.

Resolution: Comment noted. Will consider for future work. See NRC comments below.

General Comments/Suggestions for Future Work:

The BDose code is a very good effort to construct a biosphere model that will be of use to staff in evaluating waste determination submitted by DOE under the NDAA. Suggested enhancements to the module are listed to improve either usability or to minimize staff effort in modifying the parameters/models in order to fully optimize its use in the future.

- The biosphere model was linked to an existing GoldSim model that used biosphere dose conversion factors (BDCFs) from LaPlante (1997) applicable to Yucca Mountain for the groundwater pathway. A comparison of dose outputs from the existing GoldSim model versus dose outputs from the BDose model reveals significant (e.g., order of magnitude) differences for several key radionuclides (e.g., Cs, several isotopes of Pu) in some cases. For example, Cs-137 doses are an order of magnitude higher in the BDose code. This example illustrates the importance of parameter selection for certain key inputs into the biosphere model that may be radionuclide dependent or site-specific. These order of magnitude differences suggest that the biosphere module may represent a significant amount of uncertainty with respect to the overall modeling evaluations indicating the risk-significance of this and future work on the biosphere module. Additionally, the documentation indicates that the input parameters used in the BDose code generally represent national averages, suggesting that a considerable amount of work may still be necessary for NRC staff to research and input site-specific parameter values. Future CNWRA work could include a robust

uncertainty and sensitivity analysis to identify the most important parameter values for various key radionuclides, as well as important site-specific parameter values that need to be changed by the user. Based on the results of the sensitivity and uncertainty analysis, additional work in researching and defining appropriate site-specific input parameter values at NDAA sites could be performed.

- A suggestion was made to revise the well intruder scenario to allow a cuttings pile or pond to be created. The scenario evaluated in BDose results in a very thin layer of contamination being spread out over a larger contaminated area, thereby underestimating the potential external radiation doses to a well intruder collocated next to a cuttings pile or pond. Future enhancements to the code should consider this alternative scenario.

- Several suggestions for future work are discussed in the comments above (e.g., evaluation of need for existing or inclusion of additional soil leaching models, adjusting internal dose by contaminated area size, adjusting plant ingestion considering contaminated zone versus root zone thickness, considering alternative external radiation exposure sources-thicker or infinite source).

All comments noted and we welcome the opportunity to discuss these suggestions.