ADVANCED TURBO FRMAC

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OUTLINE

- Advanced Inputs and Calculations – Public Protection
- Advanced Do It Yourself Calculations – Public Protection
- Advanced Inputs and Calculations – Ingestion
- Advanced Do It Yourself Calculations – Ingestion
- Final Exercise

Time permitting:

*Revising the Source Term

*Pitfalls in Dose Assessment

ADVANCED PUBLIC PROTECTION INPUTS AND CALCULATIONS

OTHER INPUTS FOR DRL CALCULATIONS

Additional, detailed inputs for the DRL Calculation

Populated with default values, and do not **need** to be altered to run a calculation

A thorough understanding of the inputs is recommended before the user changes values from the defaults

OTHER INPUTS – BREATHING RATES

- Default Assumptions
  - Early Phase – Adult Male Light Exercise Breathing Rate
  - All other Phases – Adult Male Activity Averaged Breathing Rate
- Changing the Breathing Rate
  - Questions may arise about specific populations or protective actions where a higher breathing rate may better fit the scenario

Breathing Rates Help

Select Gender: Male ICRP Guidance: ICRP 60

Inputs

Activity Time: ✓ Indicates a valid summation of 24 hours

Activity	3 Month Old	1 Year Old	5 Year Old	10 Year Old	15 Year Old	Adult
Sleeping	17.0	14.0	12.0	10.0	10.0	8.5
Sitting	N/A	3.33	4.0	4.67	5.5	5.5
Light Exercise	7.0	6.67	8.0	9.33	7.5	9.75
Heavy Exercise	N/A	N/A	N/A	N/A	1.0	0.25
	✓ 24.0 hrs	✓ 24.0 hrs	✓ 24.0 hrs	✓ 24.0 hrs	✓ 24.0 hrs	✓ 24.0 hrs

Activity Time Units: hr

[0.0, 24.0]

Breathing Rates:

Activity	3 Month Old	1 Year Old	5 Year Old	10 Year Old	15 Year Old	Adult
Sleeping	9.00E-2	0.15	0.24	0.31	0.42	0.45
Sitting	N/A	0.22	0.32	0.38	0.48	0.54
Light Exercise	0.19	0.35	0.57	1.12	1.38	1.5
Heavy Exercise	N/A	N/A	N/A	N/A	2.92	3.0

Breathing Rate Units: m^3 / hr

[0.0, 36.0]

Results

Activity-Averaged Breathing Rates: ☑ Auto Calculate

3 Month Old	1 Year Old	5 Year Old	10 Year Old	15 Year Old	Adult
0.12	0.22	0.36	0.64	0.84	0.92

Activity-Averaged Breathing Rate Units: m^3 / hr

[0.0, 36.0]

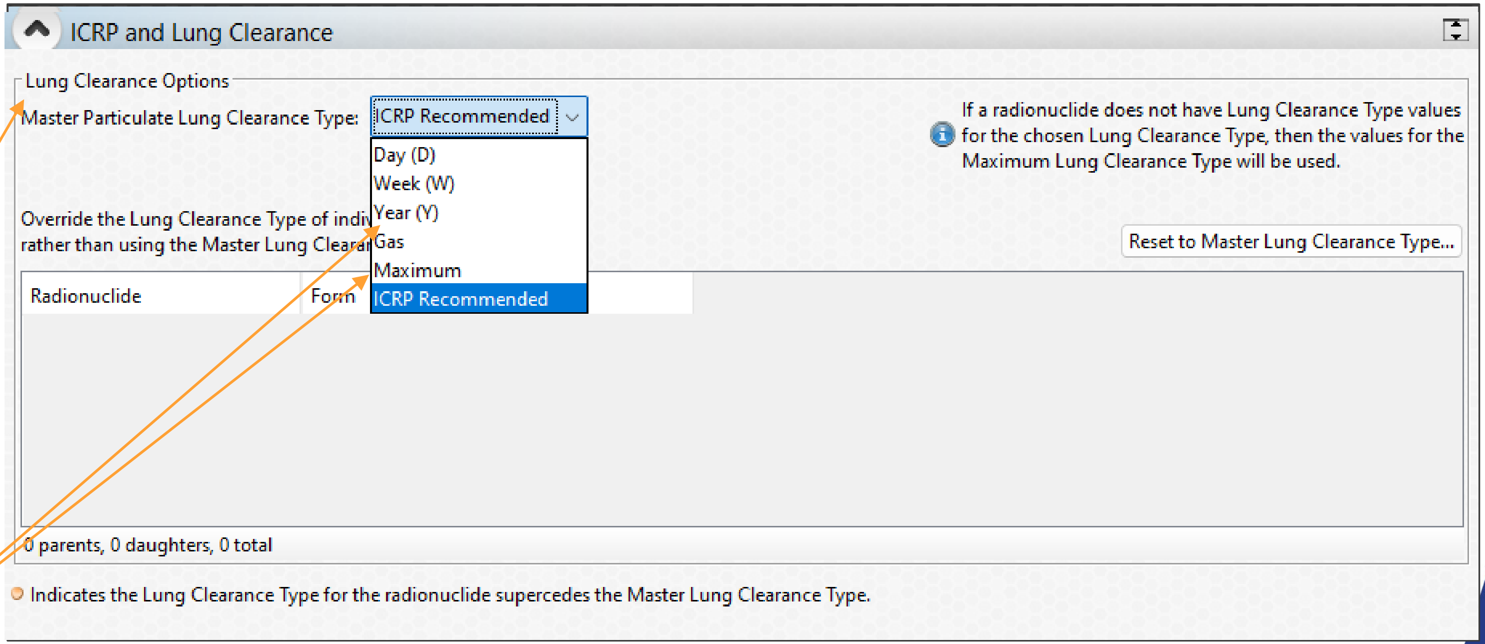
OTHER INPUTS – ICRP AND LUNG CLEARANCE

Default to ICRP Recommended Clearance Type – Differs from NRC assumption

Each radionuclide can be changed independently

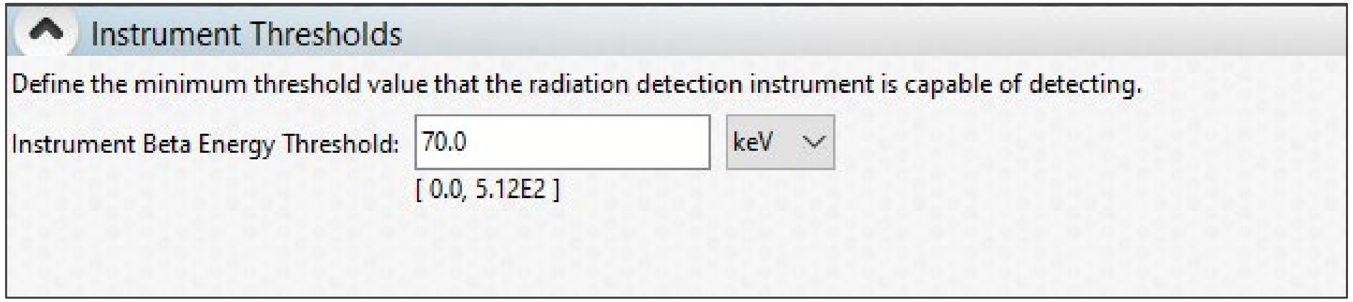
Tied to Required ICRP Panel

- For ICRP 30 runs, inhalation coefficient bases option is removed.
- ICRP 30 runs still default to ICRP Recommended Clearance Type. This must be changed manually to reflect the Maximum clearance type still used by NRC



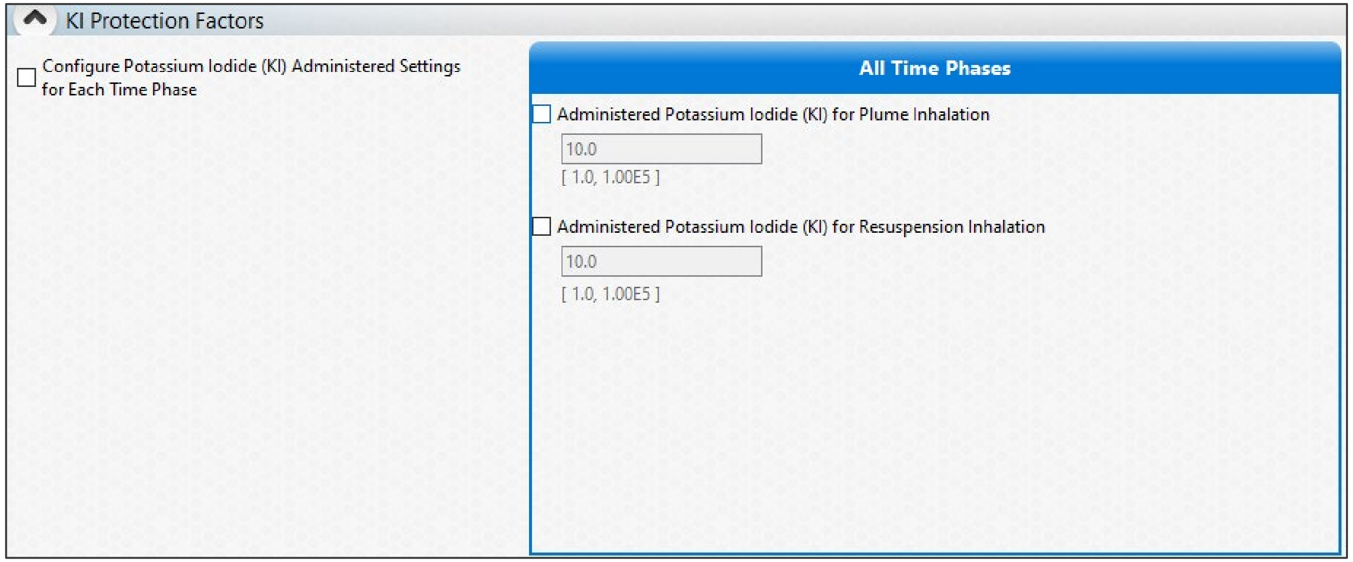
OTHER INPUTS – INSTRUMENT THRESHOLDS AND KI PROTECTION FACTORS

Given information on the detector used for a scenario, the user can change the energy threshold for detection



Public Protection DRL calculations can consider the administration of KI

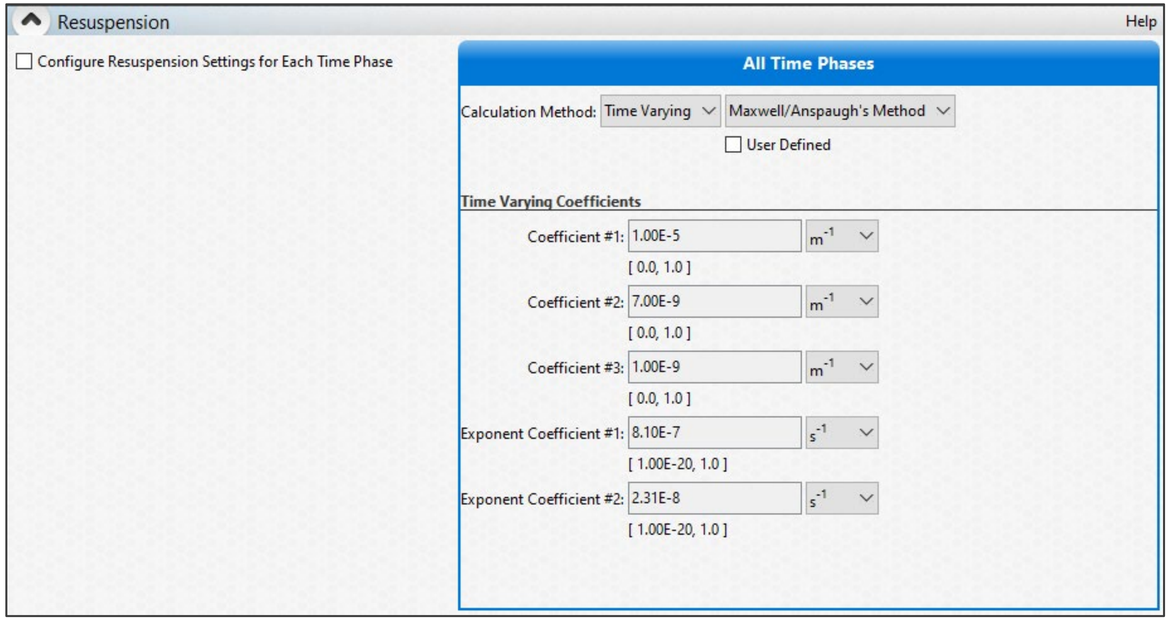
- For purely KI DRLs, the user should leverage the Administration of KI calculation

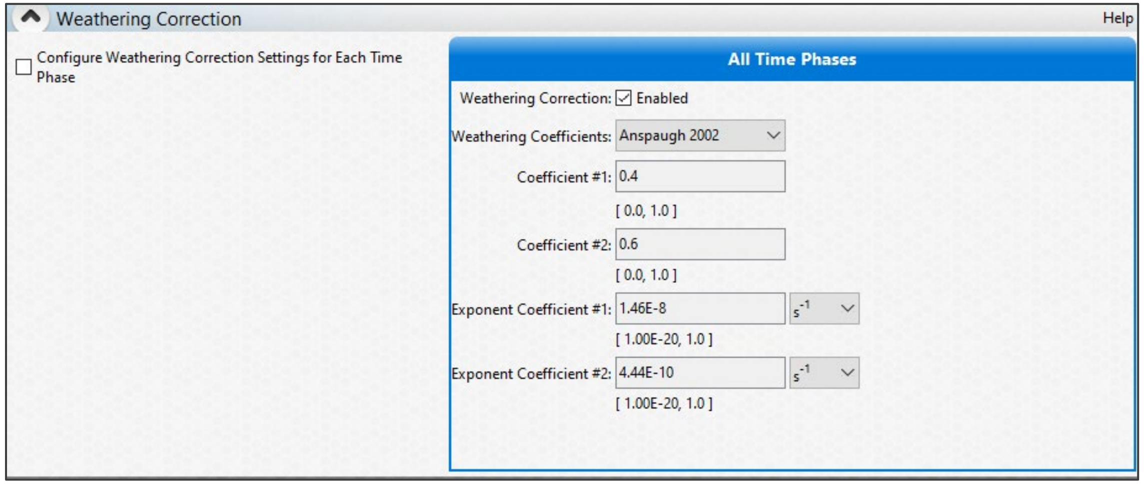


OTHER INPUTS – RESUSPENSION AND WEATHERING CORRECTIONS

Resuspension can vary with terrain, weather, and time

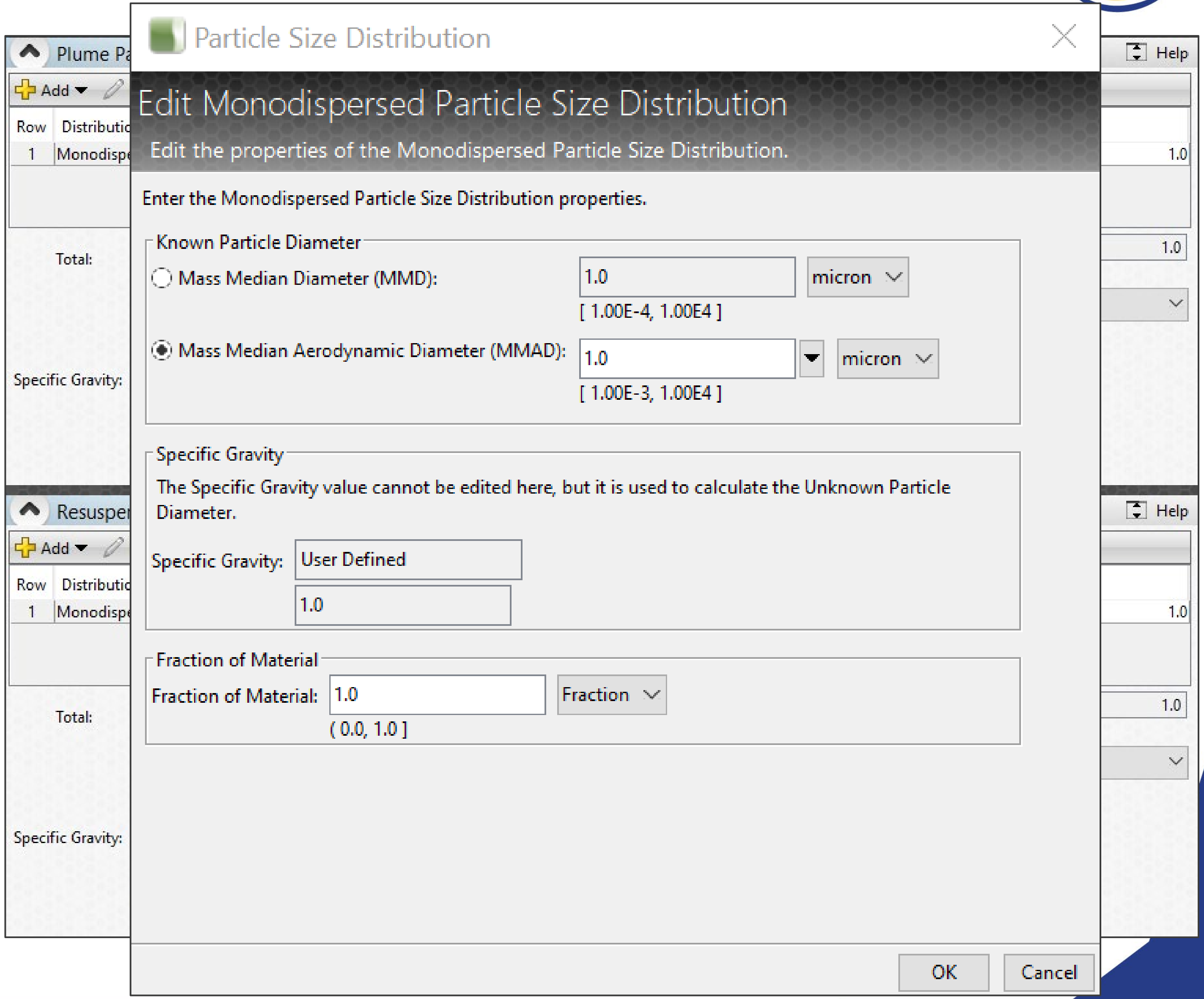
User can edit all coefficients to account for changing weathering and resuspension variables through the course of an incident





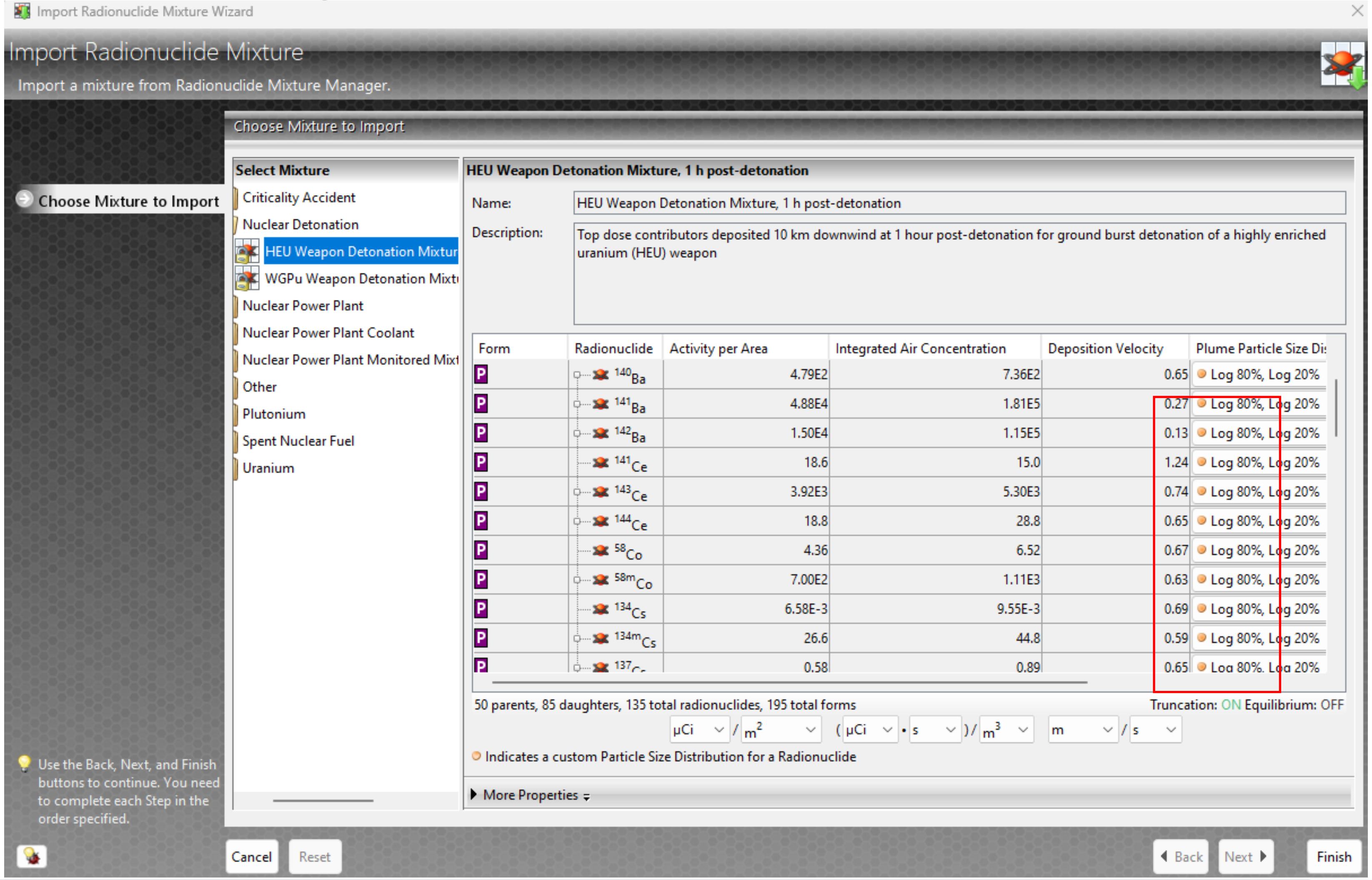
OTHER INPUTS – PLUME AND RESUSPENSION PARTICLE SIZE DISTRIBUTIONS

- Default assumption is 100% monodispersed 1 micron AMAD particulate
- User can change particle size based on mass median diameter or mass median aerodynamic diameter for all or a fraction of the material
- Important for lung dose calculations as changing the particle size changes the inhalation dose coefficient



SCENARIO SPECIFIC PSDS

Pre-assessed scenarios with specific PSDs will have the specific PSDs loaded in with the mixture in Mixture Manager



HOW TO READ THE PSD TABLE

These are NOT actual PSD distributions!

RDD Nuclide	Form	Distribution	Respirable Particles Lognormal MMAD = 2 GSD = 2 Min: 0.25 µm Max: 10 µm	Medium Particles Uniform Min: 10 µm Max: 100 µm	Large Particles Uniform Min: 100 µm Max: 500 µm	Fragments Uniform Min: 500 µm Max: 2000 µm
Ag	Metal	Created	0.2	0.2	0.1	0.5
		Aerosolized	0.5	0.5	-	-
Au	Metal	Created	0.3	0.1	0.6	-
		Aerosolized	0.75	0.25	-	-

Created: This is the particle size distribution created by the blast. Large Particles and Fragments are not expected to be transported atmospherically and are deposited in the immediate blast area. Therefore, for downwind assessments, the source term should be scaled to exclude the Large Particles and Fragments to calculate the amount of material that will be aerosolized and dispersed downwind.

Aerosolized: This is the distribution that should be used to calculate the DRLs based on the scaled source term, which excludes the larger particles that are not deposited outside the immediate blast area.

CREATED FRACTIONS

RDD Nuclide	Form	Distribution	Respirable Particles Lognormal MMAD = 2 GSD = 2 Min: 0.25 µm Max: 10 µm	Medium Particles Uniform Min: 10 µm Max: 100 µm	Large Particles Uniform Min: 100 µm Max: 500 µm	Fragments Uniform Min: 500 µm Max: 2000 µm
Ag	Metal	Created	0.2	0.2	0.1	0.5
		Aerosolized	0.5	0.5	-	-
Au	Metal	Created	0.3	0.1	0.6	-
		Aerosolized	0.75	0.25	-	-

Source Term: Suppose 1000 Ci of Ag-111 and 500 Ci of Au-198 were detonated in an RDD.

The “Created” rows tell us that for dose assessment purposes we should use a source term of:
400 Ci of Ag-111 [(0.2+0.2)*1000] and
200 Ci of Au-198 [(0.3+0.1)*500]

AEROSOLIZED FRACTIONS

RDD Nuclide	Form	Distribution	Respirable Particles Lognormal MMAD = 2 GSD = 2 Min: 0.25 µm Max: 10 µm	Medium Particles Uniform Min: 10 µm Max: 100 µm	Large Particles Uniform Min: 100 µm Max: 500 µm	Fragments Uniform Min: 500 µm Max: 2000 µm
Ag	Metal	Created	0.2	0.2	0.1	0.5
		Aerosolized	0.5	0.5	-	-
Au	Metal	Created	0.3	0.1	0.6	-
		Aerosolized	0.75	0.25	-	-

Source Term: Suppose Ag-111 and Au-198 were detonated in an RDD

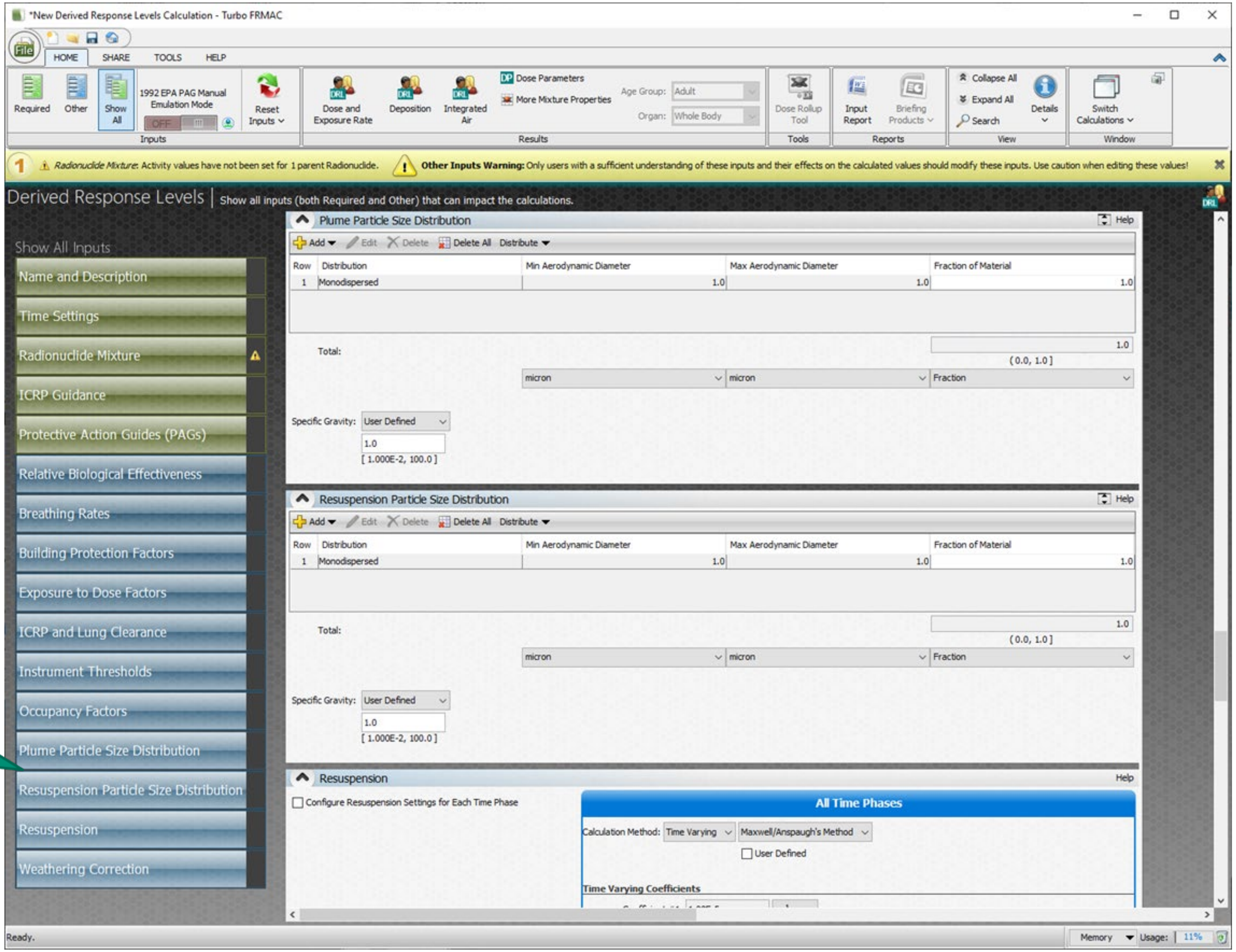
The “Aerosolized” rows tell us that for dose assessment purposes we should use PSDs of:
50% Respirable and 50% Medium for Ag-111 and
75% Respirable and 25% Medium for Au-198

CUSTOM PSD IN TURBO FRMAC

Can be entered in two places!

First is the "Master" PSD. This sets the PSD for all radionuclides in your mixture

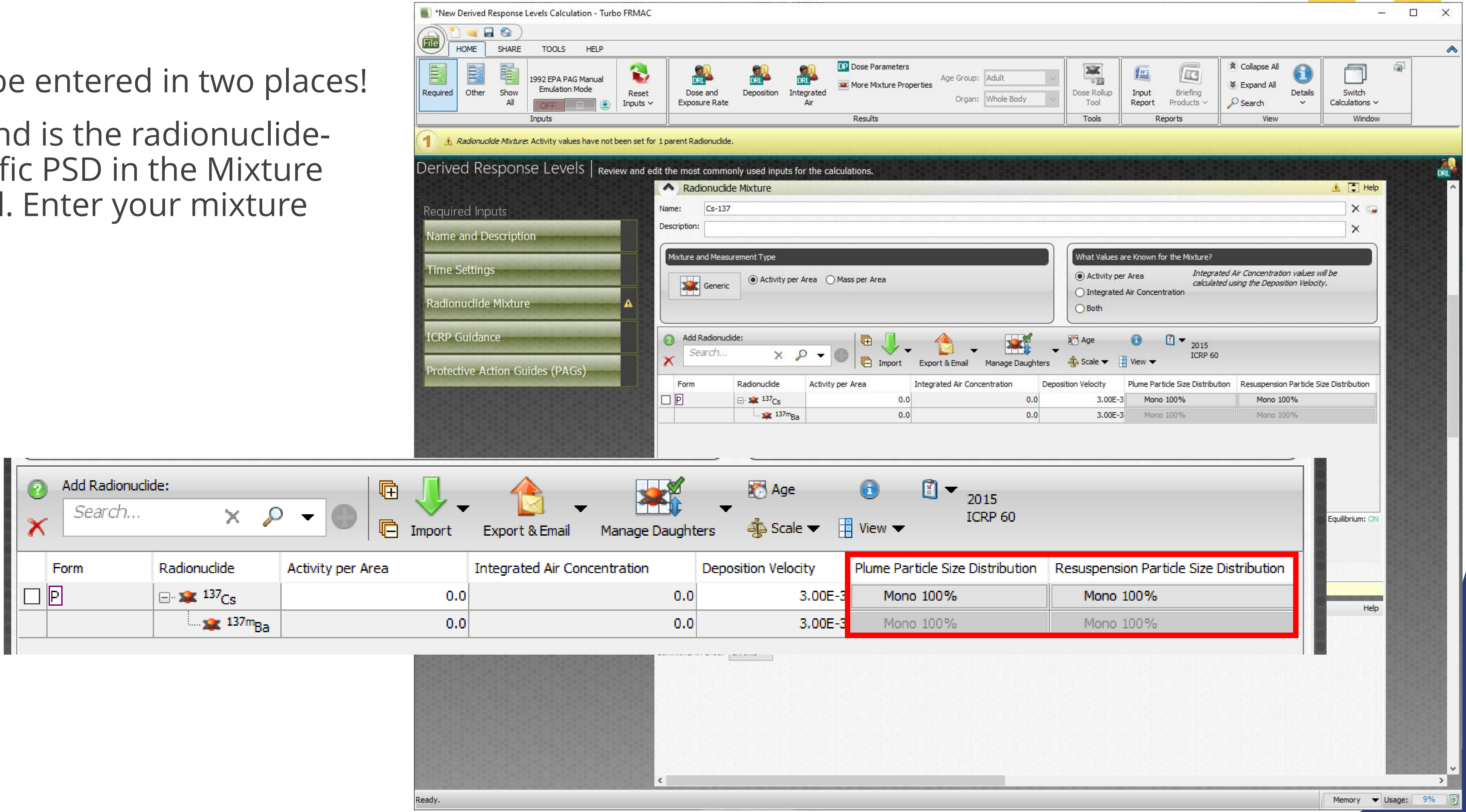
Select *Plume* or *Resuspension Particle Size Distribution*



CUSTOM PSD IN TURBO FRMAC

Can be entered in two places!

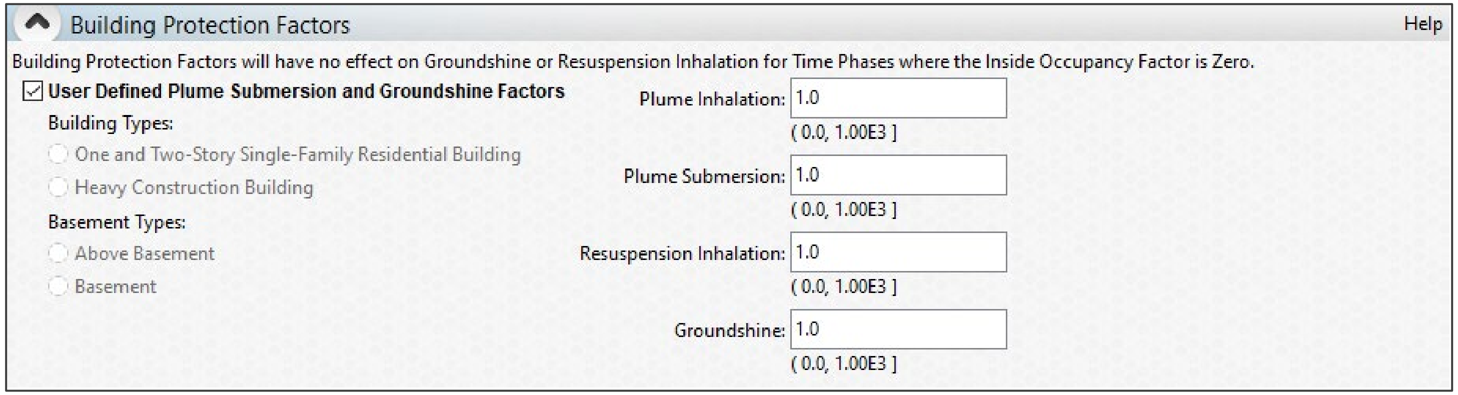
Second is the radionuclide-specific PSD in the Mixture panel. Enter your mixture first!



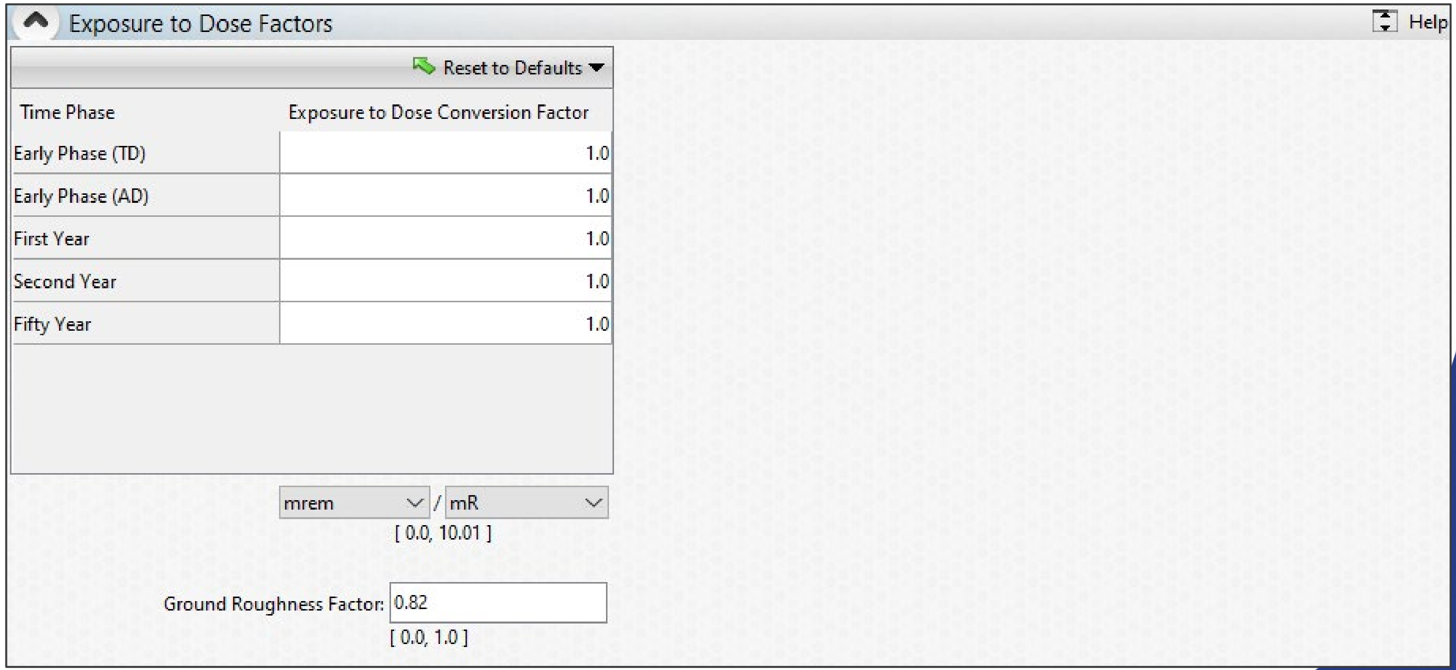
OTHER INPUTS – BUILDING PROTECTION FACTORS AND EXPOSURE TO DOSE CONVERSION FACTORS

Building protection factors allow users to determine the dose reduction based on sheltering

Works hand in hand with occupancy factors



Exposure to Dose Conversion Factors are used to convert a Self Reading Dosimeter reading to a total dose



OTHER INPUTS - BUILDING PROTECTION FACTORS (BPF)

FRMAC Assessment Manual, Appendix C, Table 6-1

Default Building Protection Factors for Public Protection Decisions

Building Type	Cloud Submersion Protection Factor	Deposition Protection Factor
One- and two- story single-family residential building[1]		
Above Basement	1.5	2.5
Basement	3	10
Heavy Construction Building[2,3,4]		
Above Basement	5 [3]	50 [4]
Basement	5 [3]	600 [4]

[1] Dixon & Hamby, Journal of Radiological Protection, 2016.

[2] Buildings constructed from brick or concrete with relatively thick (0.2 to 1+ m) walls and roofs and large, both in height and footprint. May include large multi-family (e.g., apartment), office and industrial buildings.

[3] Cloud Submersion - Protective Action Evaluation Part 1, EPA 520/1-78-001A

[4] Deposition - Dillon, et.al, LLNL-TR-684121

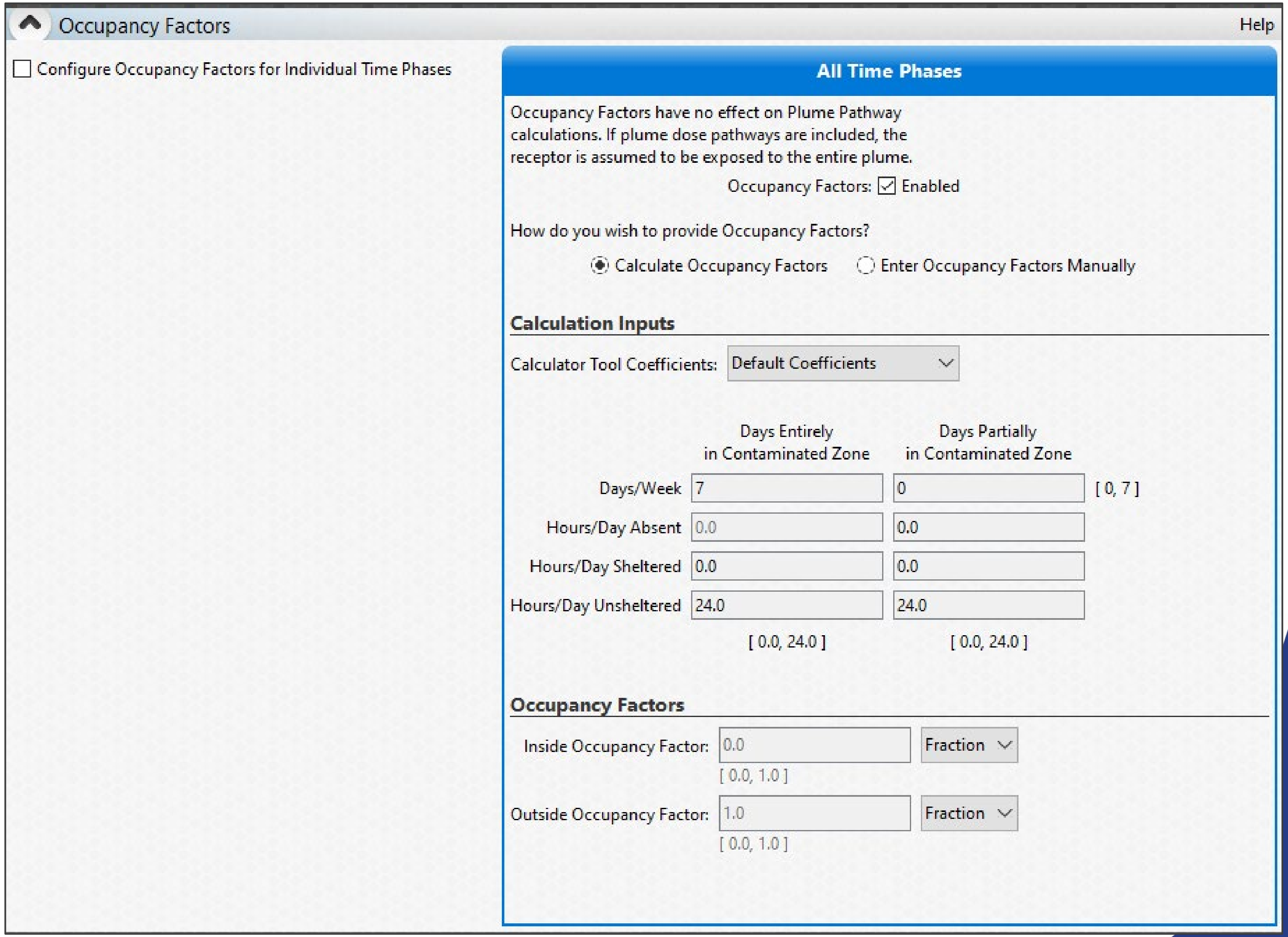
NOTE: Default BPFs are only provided for external exposure pathways. Defaults for the inhalation pathway have not been determined and are assumed to be 1.

OTHER INPUTS - OCCUPANCY FACTORS

Public Protection methods assume the receptor is outside in the Contaminated Area <u>continuously without protection</u> during the Time Phase

More realistic – some form of shelter and/or some time spent outside of the contaminated area

FRMAC Assessment Manual Method 4.7



OTHER INPUTS – OCCUPANCY FACTORS

Primarily intended to determine potentially more realistic values for 1st & 2nd year Relocation DRLs, but can be applied any Time Phase

Can also be used to determine potential dose to individuals living outside a contaminated area and working inside

Occupancy Factors consider that, at different portions of the Time Phase, receptors may be:

- outdoors, unsheltered in the contaminated area
- sheltered inside a structure in the contaminated area
- absent from the contaminated area

OCCUPANCY FACTORS

OF_{out} = Outside Occupancy Factor, the fraction of the Time Phase spent outdoors in the contaminated area, unitless;

OF_{in} = Inside Occupancy Factor, the fraction of the Time Phase spent inside a building in the contaminated area, unitless;

NOTE: These Occupancy Factors will not sum to one (1) if the receptor is absent from the contaminated area during any part of the Time Phase under consideration.

MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Remember: Dose Parameters are integrated quantities calculating the dose over a certain time from a specific pathway. Which are then used to calculate applicable DRLs

In these examples, we will be considering the Deposition External Dose Parameter (Dp_ExDP), which represents the integrated External Dose from a deposited mixture over the Time Phase of interest.

MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Modifying Dp_ExDP for Sheltering Only:

Divide the default Dose Parameter by the Building Protection Factor (BPF) giving the Sheltered External Dose Parameter for the radionuclide, the Time Phase and the specific BPF

$$Dp\_ExDP_{i,TP,Sh} = \frac{Dp\_ExDP_{i,TP}}{BPF_{Dp,Ex}}$$

$$mrem = \frac{mrem}{unitless}$$

where:

$BPF_{Dp,Ex}$ = Building Protection Factor for Deposition External Exposure, a factor to account for the reduction in External Dose due to being inside a building, unitless

MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Modifying Dp_ExDP for Occupancy and Sheltering

The Inside Occupancy Factor is divided by the BPF and then summed with the Outside Occupancy Factor

$$Dp\_ExDP_{i,TP,Sh} = Dp\_ExDP_{i,TP} * \left(OF_{out} + \frac{OF_{In}}{BPF_{Dp,Ex}} \right)$$

$$mrem = mrem * \left(unitless + \frac{unitless}{unitless} \right)$$

where:

OF_{out} = Outside Occupancy Factor, fraction of Time Phase spent outside in a contaminated area, unitless;

OF_{in} = Inside Occupancy Factor, fraction of Time Phase spent sheltered in a contaminated area, unitless;

> **NOTE:** These Occupancy Factors will not sum to one (1) if the receptor is absent from the contaminated area during any part of the Time Phase under consideration.

$BPF_{Dp,Ex}$ = Building Protection Factor for Deposition External Exposure, a factor to account for the reduction in External Dose due to being inside a building, unitless

MODIFYING DOSE PARAMETERS TO ACCOUNT FOR OCCUPANCY AND SHELTERING

Example:

Assuming a ground concentration of 2 µCi/m^2 of Co-60, modify the 1st Yr Dp_ExDP (379 mrem) by including the effects of Occupancy and Sheltering

Assuming the receptor is:

- unsheltered (outdoors) in the contaminated area for 6 hours/day (OF_{Out} = 0.25)
- sheltered in a building in the contaminated area for 9 hours/day (OF_{In} = 0.375)
- absent from the contamination area for 9 hours/day

NOTE: The Occupancy Factors will not sum to 1 if the receptor is absent from the contaminated area during any part of the Time Phase.

The building has a Building Protection Factor for Deposition External Exposure of 2.5

$$Dp\_ExDP_{i,TP,Sh} = 379\ mrem * \left(0.25 + \frac{0.375}{2.5}\right)$$

$$Dp\_ExDP_{Co-60,\ 1st\ Year,Sh} = 152\ mrem$$

PUBLIC PROTECTION DO IT YOURSELF PRACTICE

OCCUPANCY AND SHELTERING EXAMPLE

Please take out your laptops to walk through the following examples with us.

SETTING THE STAGE

We have a request:

The Governor would like to know how applying Occupancy and Sheltering to the 1st Year DRL would change his potential order to relocate his downwind population.

Use the default 1st Year Time Phase with an Evaluation Time of 7 days

Assume the following Mixture

Radionuclide	Activity per Area ($\mu Ci/m^2$)
^{60}Co	2
^{148}Gd	1
^{90}Sr	3
^{90}Y [a]	3

[a] ^{90}Y included as a daughter in equilibrium

SETTING THE STAGE

We will make the following assumptions regarding Occupancy and Sheltering:

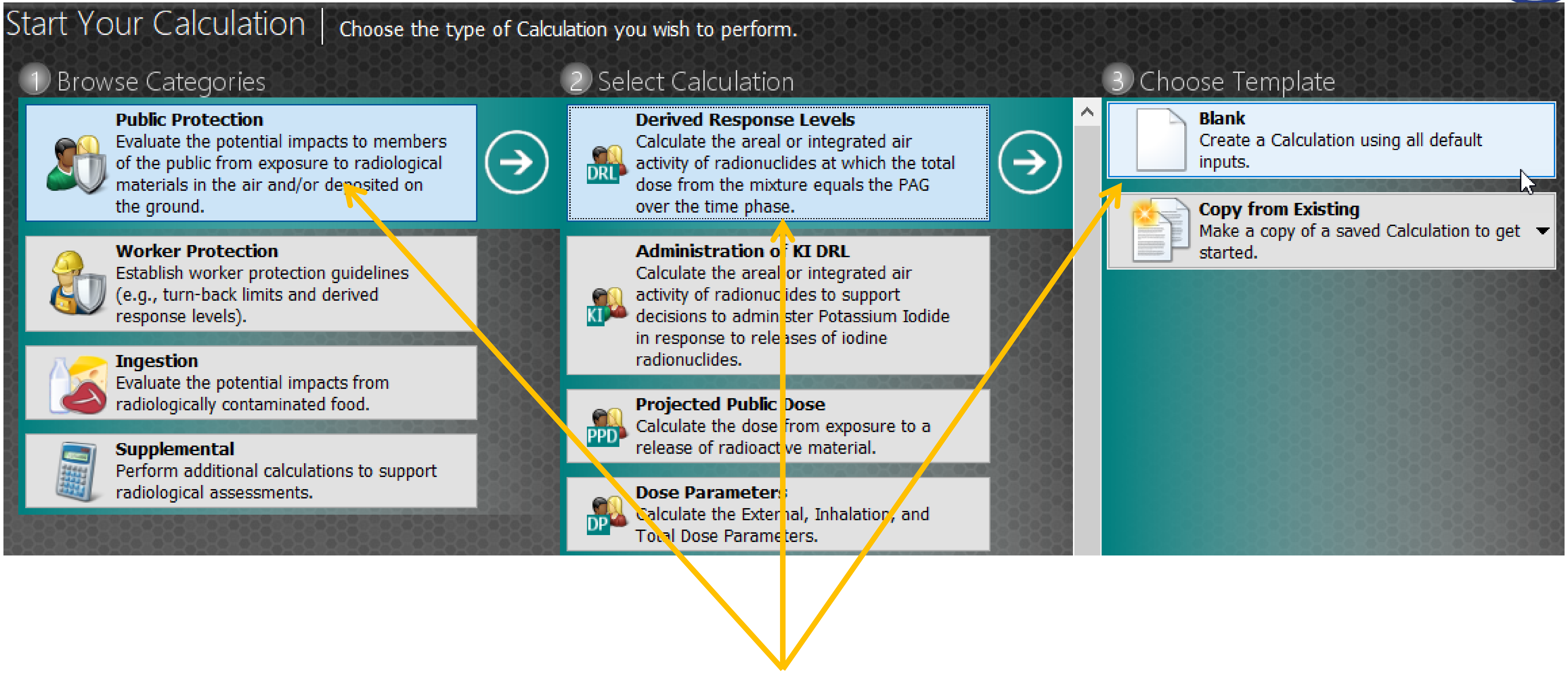
- An individual lives inside the contaminated area
- They work 5 days a week for 10 hrs/day (commute and work) outside the contaminated area
- They spend 12 hrs/day sheltered
- Their home is a 1-story residential building (deposition protection factor of 2.5)

	Days Entirely in Contaminated Zone	Days Partially in Contaminated Zone
Days/Week	2	5
Hours/Day Absent	0	10
Hours/Day Sheltered	12	12

OPEN TURBO FRMAC

Select New Calculation

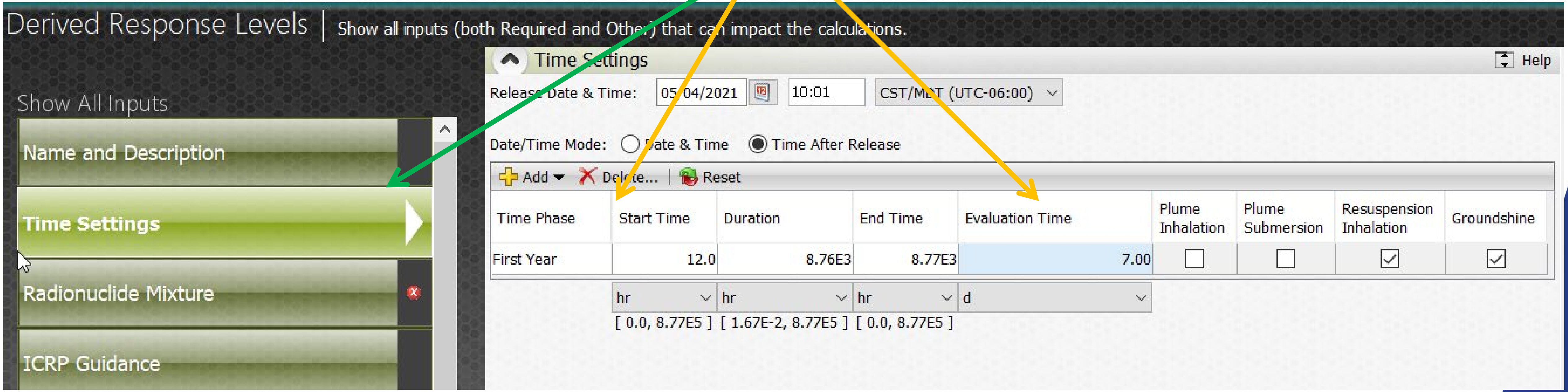
SELECT NEW CALCULATION



Select Public Protection, then Derived Response Level, then Blank

VERIFY TIME PHASES AND EVALUATION TIME

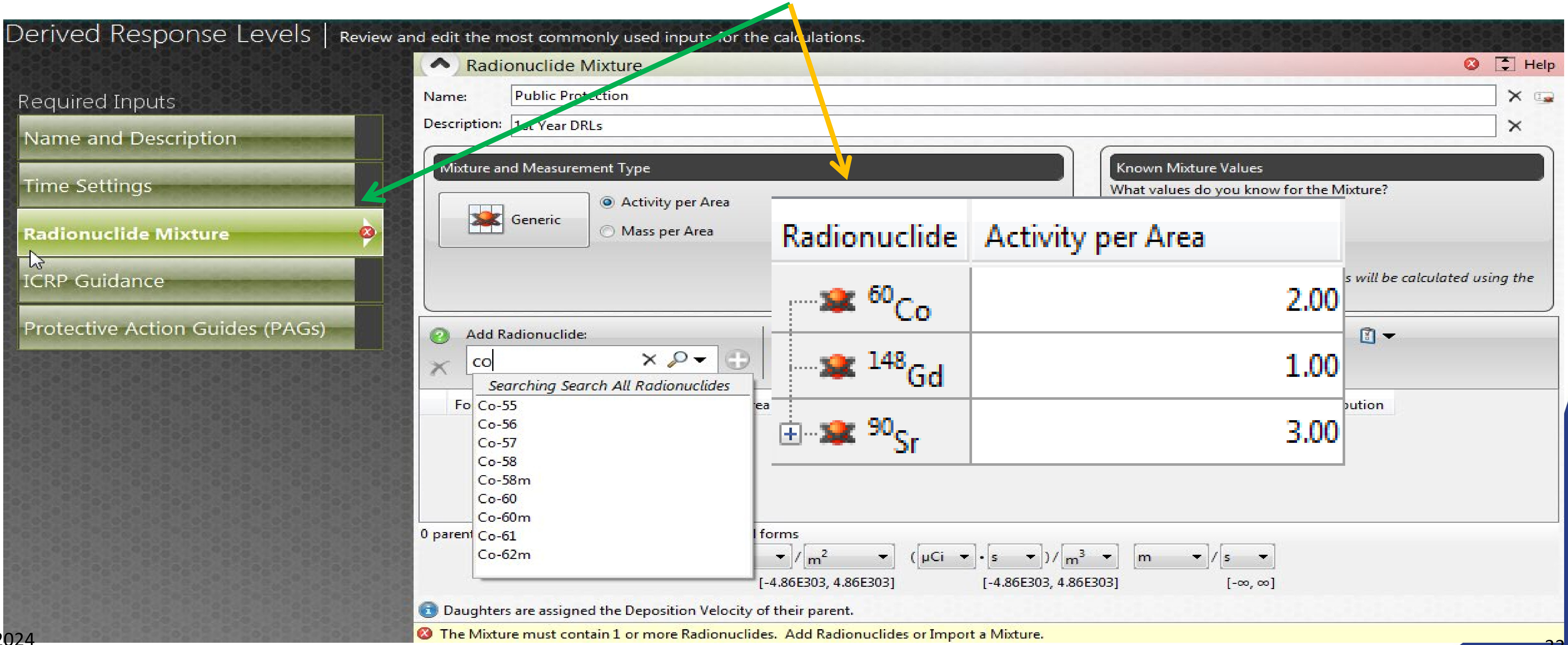
Click on Time Settings Button
Delete all but First Year Time Phase
Change Evaluation Time to 7 days



BUILD RADIONUCLIDE MIXTURE

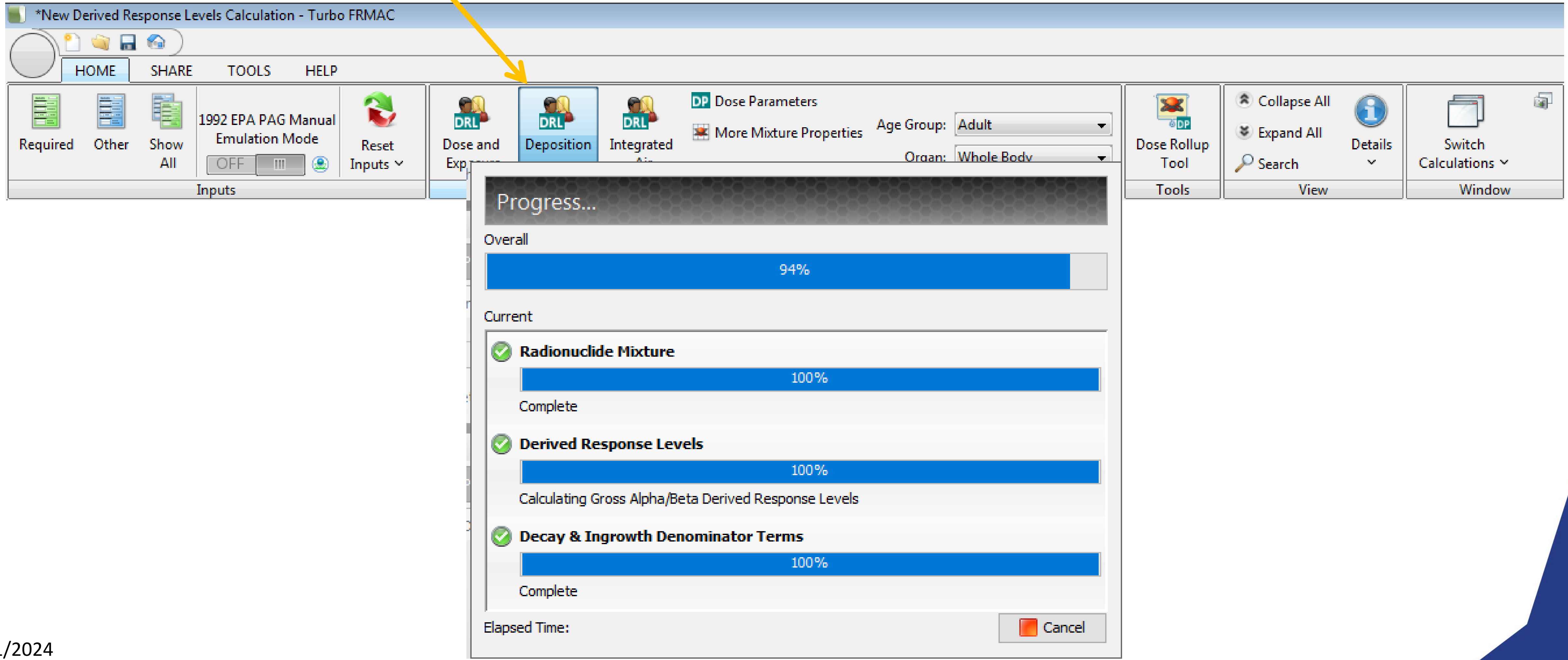
Click on Radionuclide Mixture Button

Search and Enter each Radionuclide in the mix and the Activity Concentration



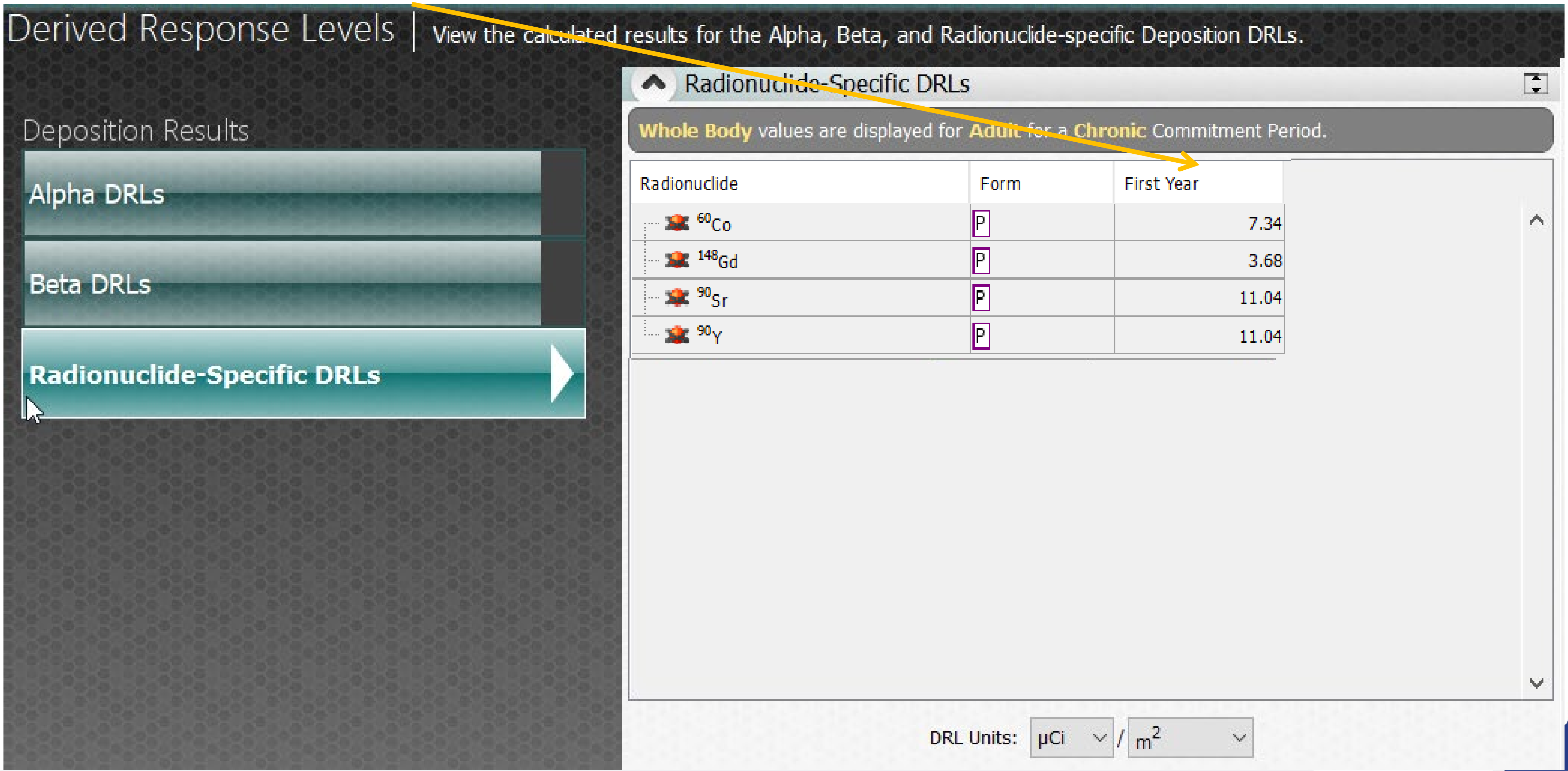
RUN CALCULATION - DEFAULT

Click the Deposition button



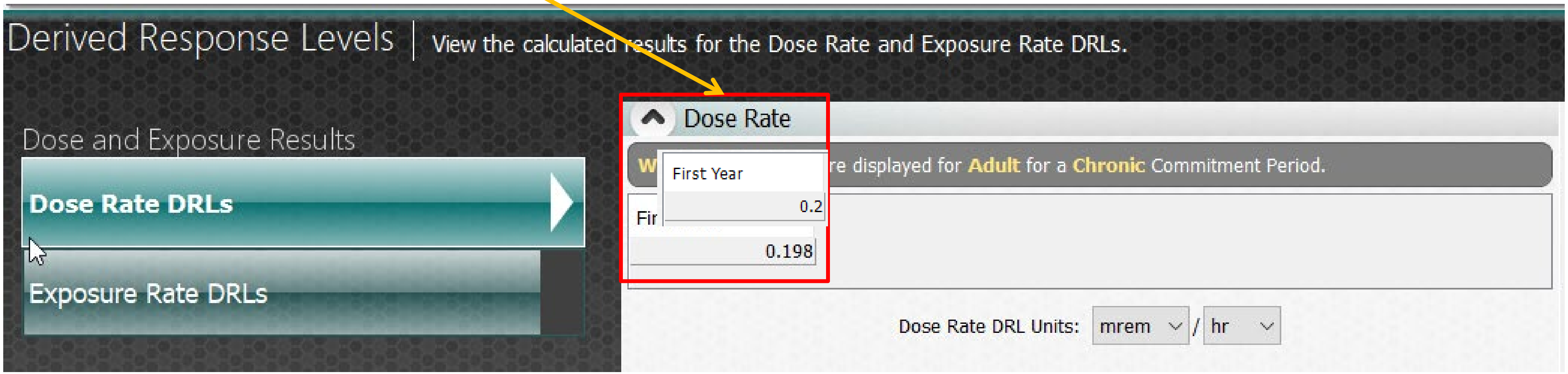
DEPOSITION DRLS - DEFAULT

Final Results displayed



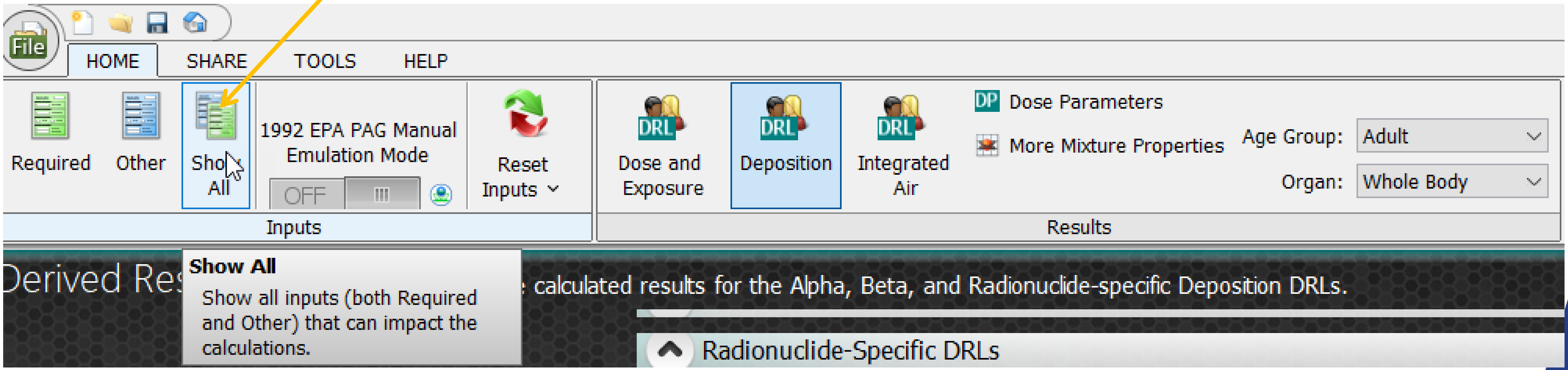
DOSE RATE DRL - DEFAULT

Final Results displayed



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Click on Show All

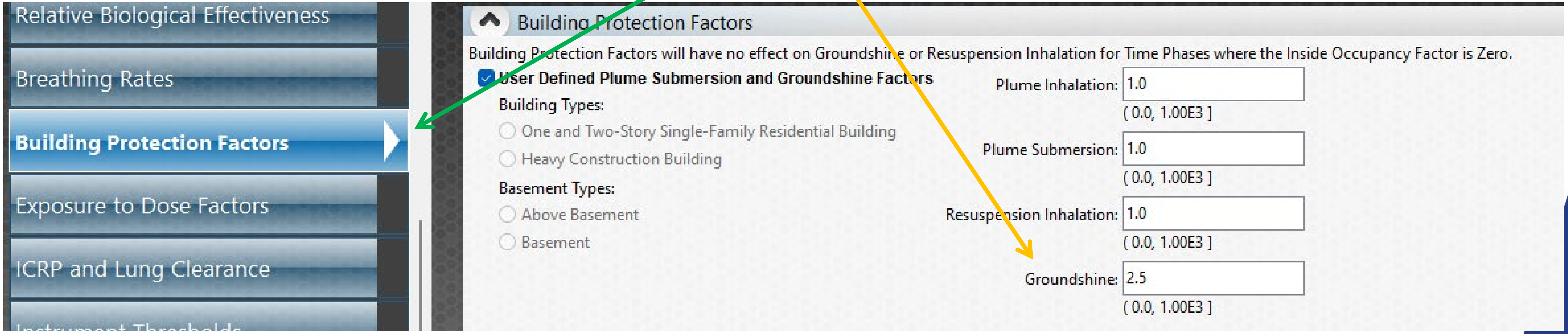


RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Click on Building Protection Factors

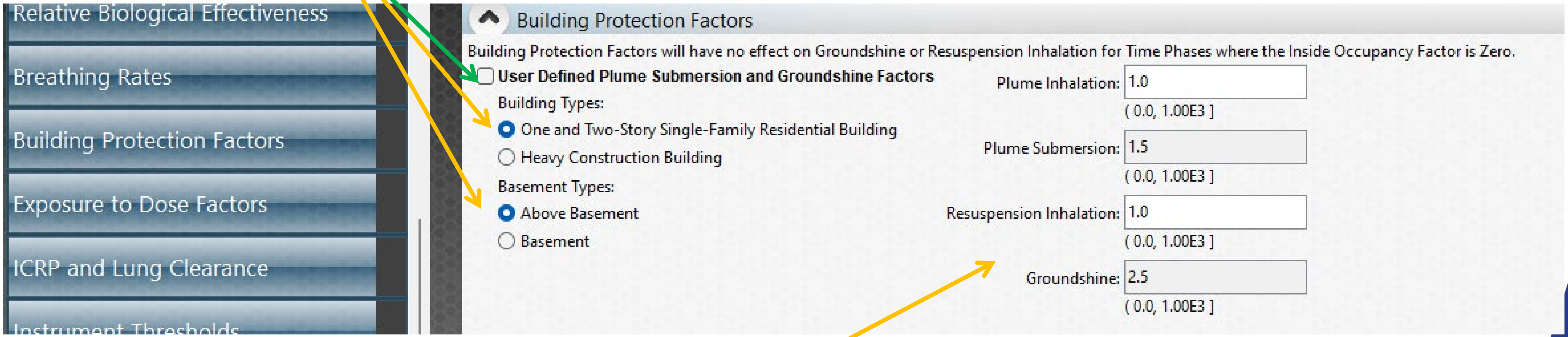
There are two modes of entering the BPF; manually and via the default radio buttons.

To manually adjust the BPF, enter 2.5 for Groundshine



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

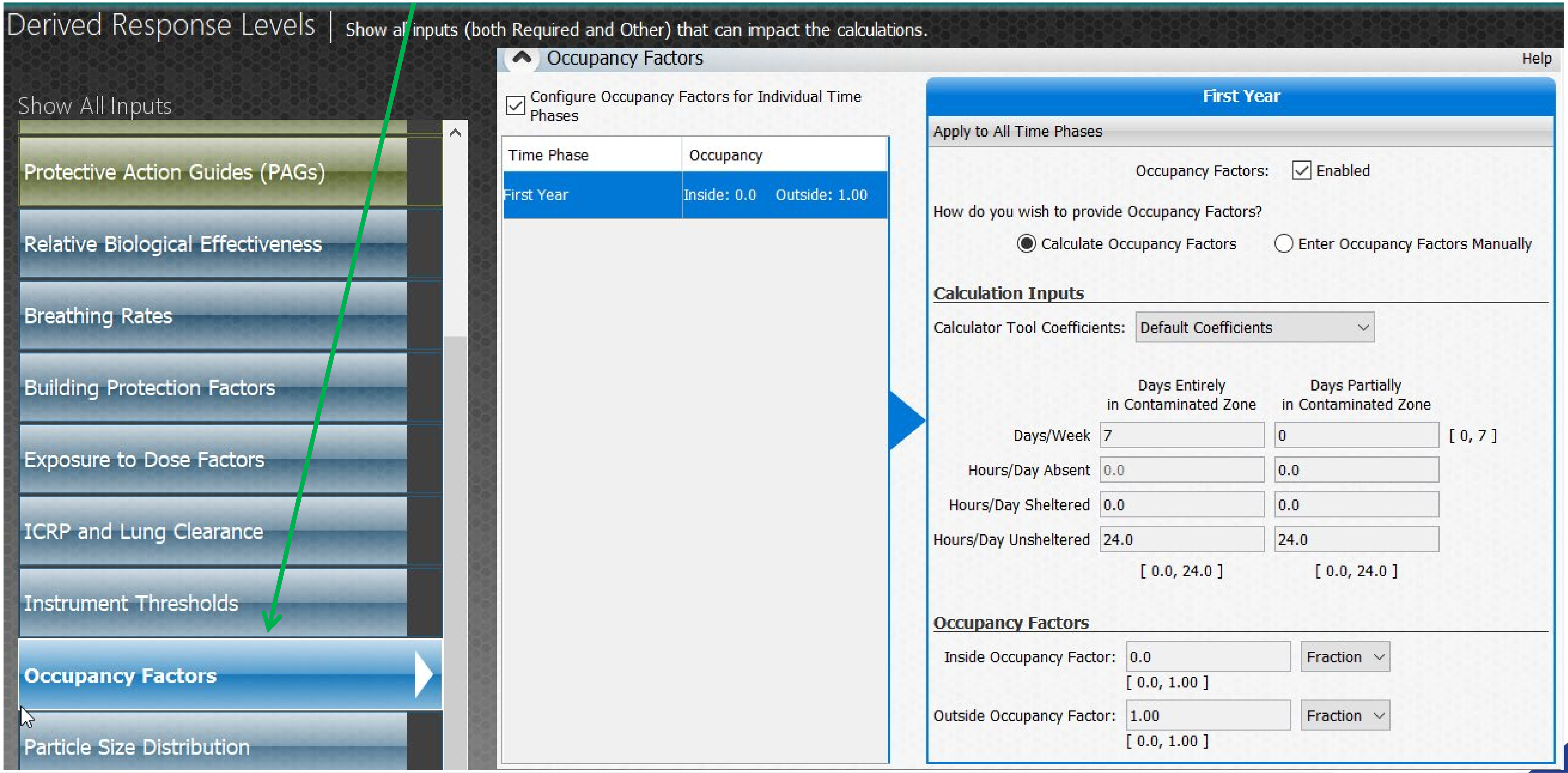
To adjust the BPF using the radio buttons, de-select the user defined box, and select “One and Two-Story Single-Family Residential Building” and “Above Basement”



Notice that the Groundshine submersion factor is 2.5

RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

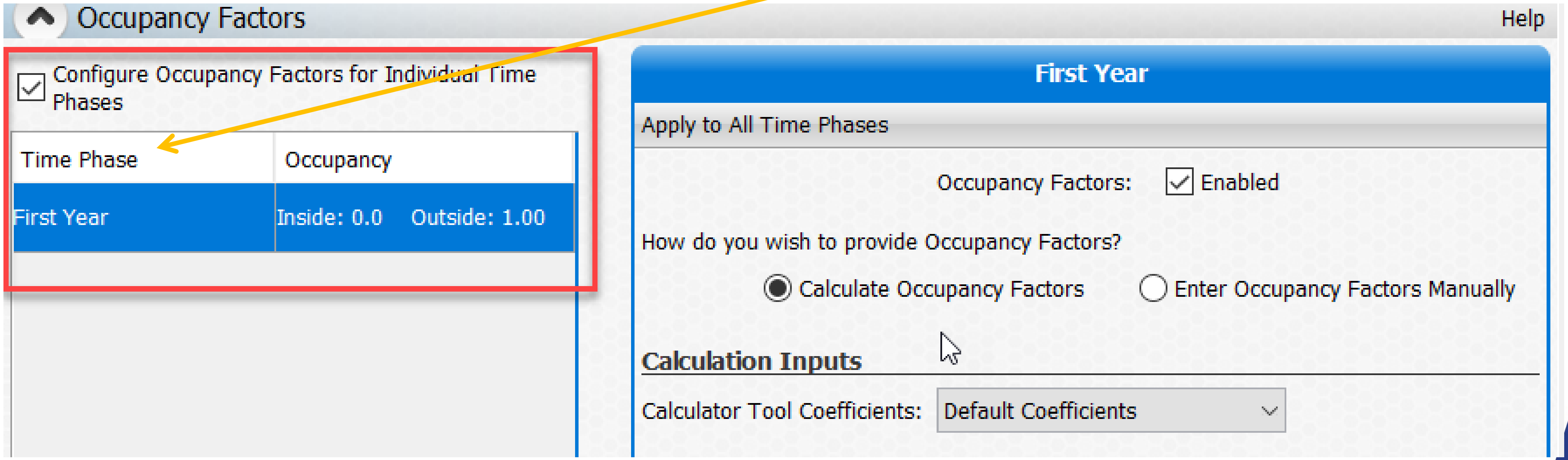
Click on Occupancy Factor



RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Ensure the Configure Occupancy Factors for Individual Time Phases is checked

If you deleted all the Time Phases EXCEPT First Year, the left side of the panel should show just the First Year

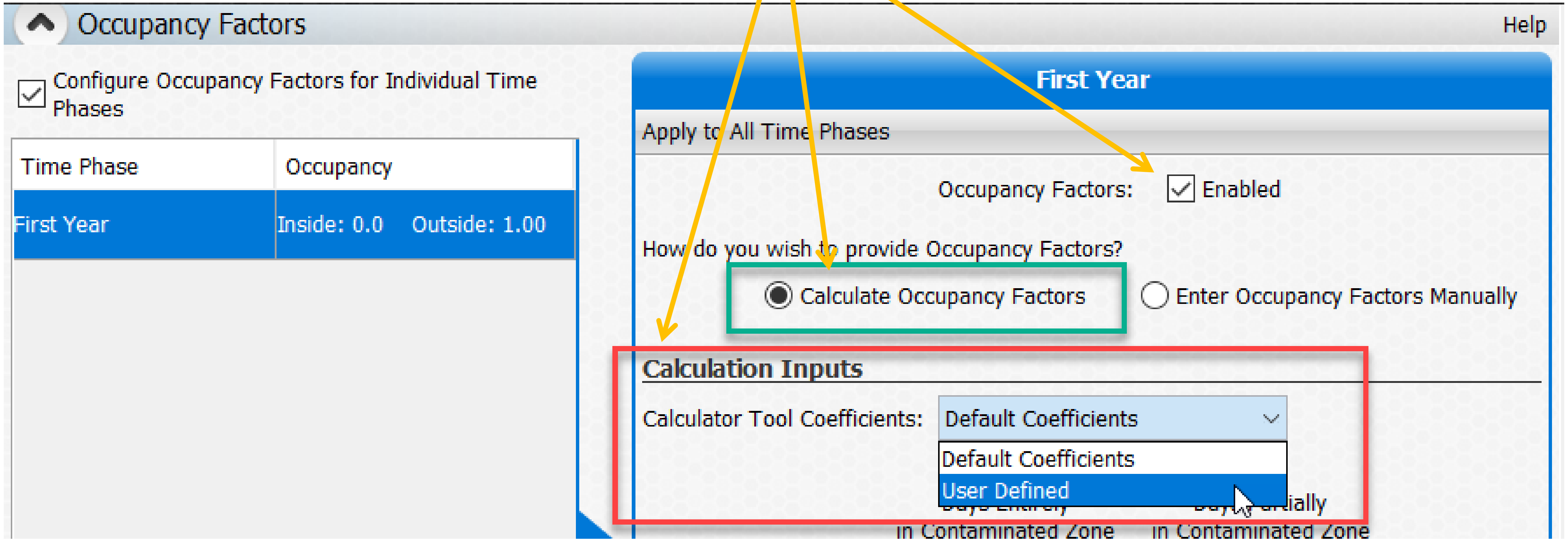


RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

Occupancy Factors should be checked – Enabled

Calculate Occupancy Factors button should be selected

Use the drop-down menu to select User Defined for Calculator Tool Coefficients

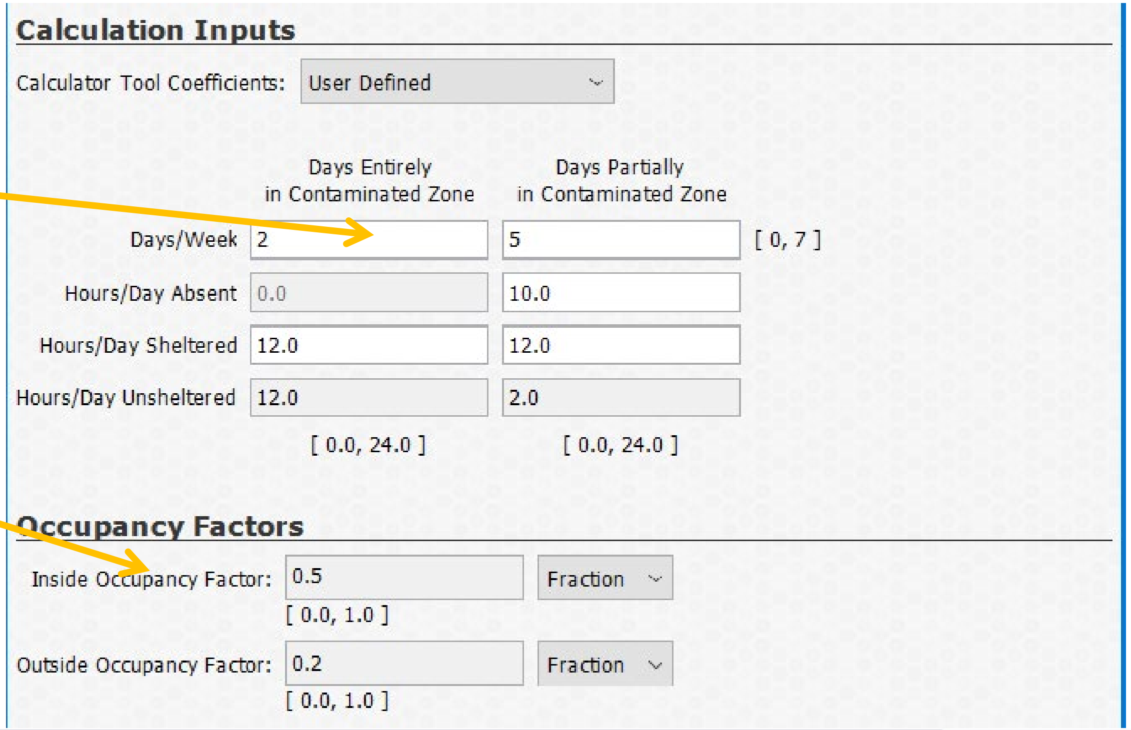


RERUN CALCULATION WITH SHELTERING AND OCCUPANCY FACTORS

	Days Entirely in Contaminated Zone	Days Partially in Contaminated Zone
Days/Week	2	5
Hours/Day Absent	0	10
Hours/Day Sheltered	12	12

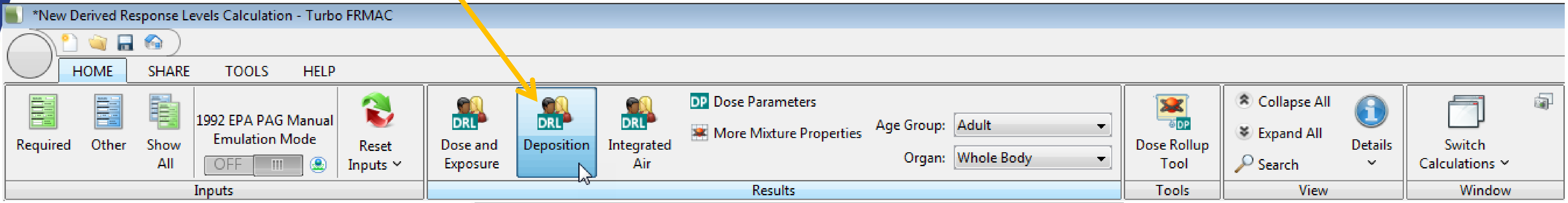
Using the data from the table fill in the appropriate values

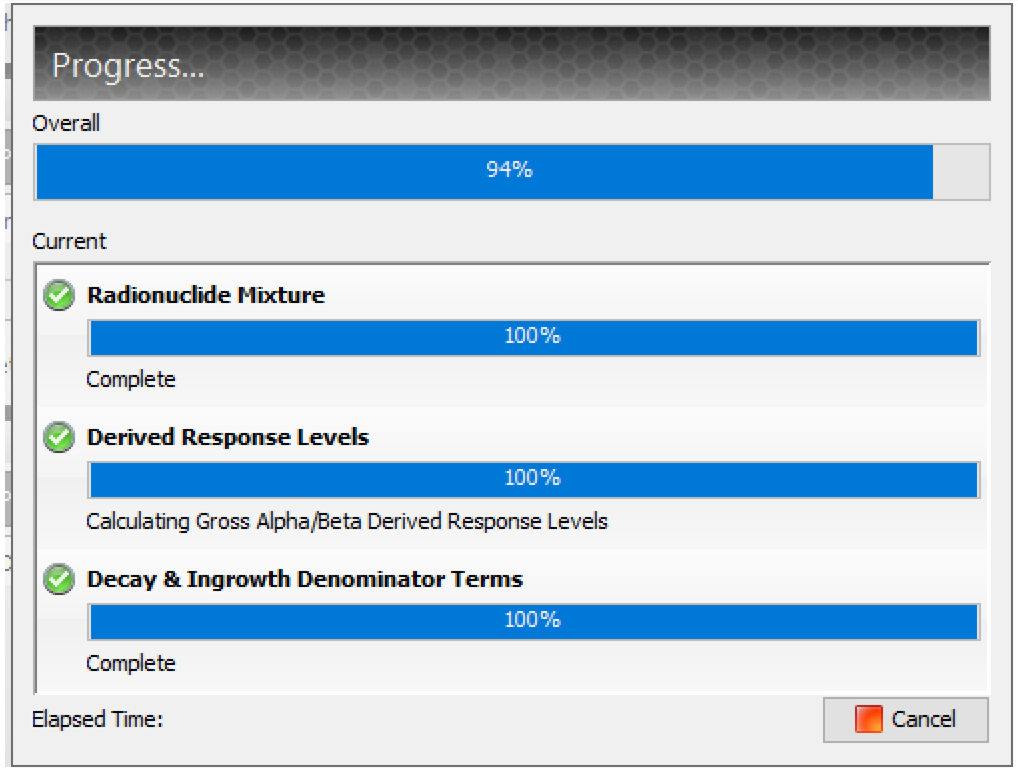
Notice that TF calculates the other values and determines the



RUN CALCULATION

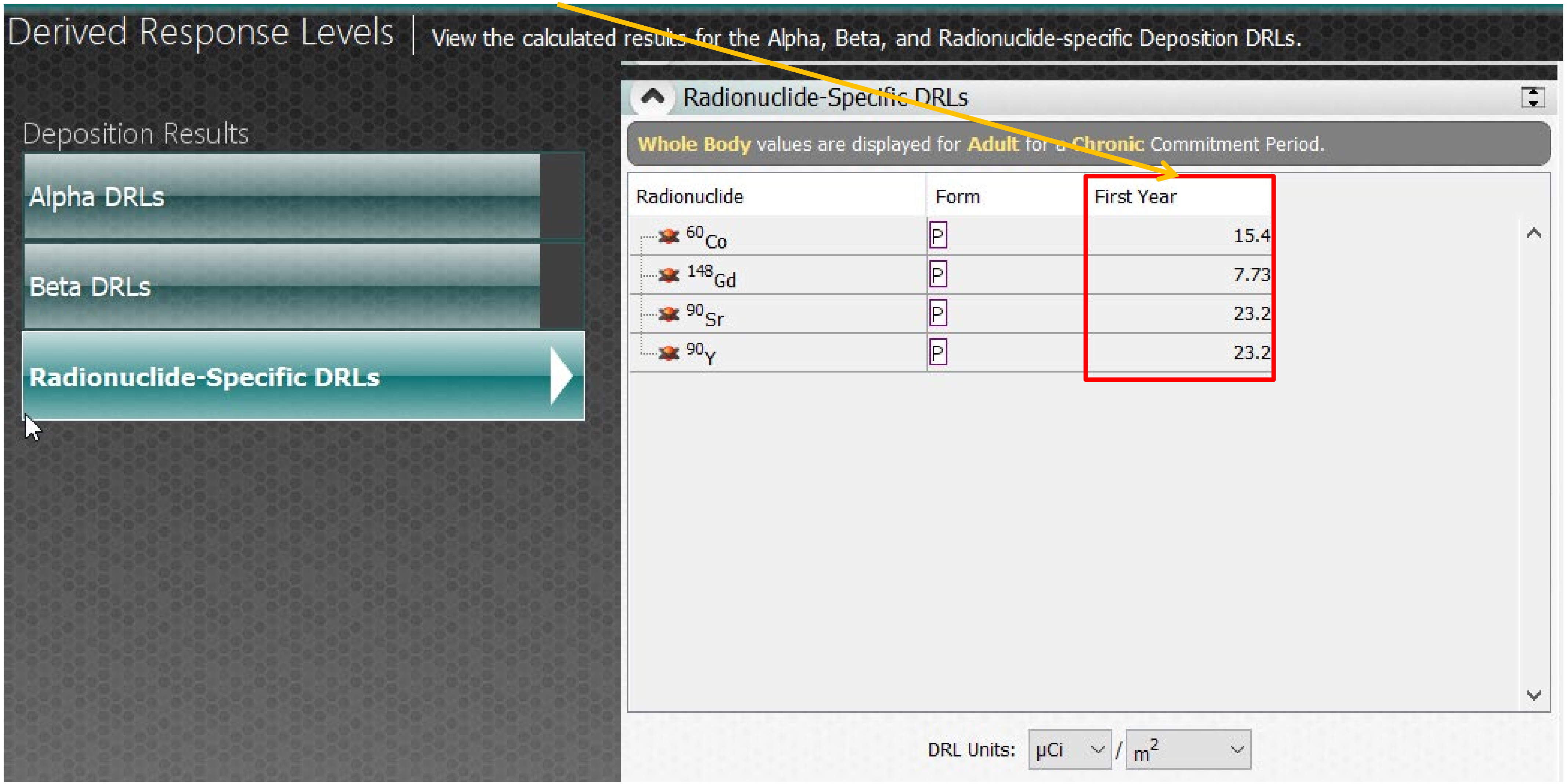
Click the Deposition button





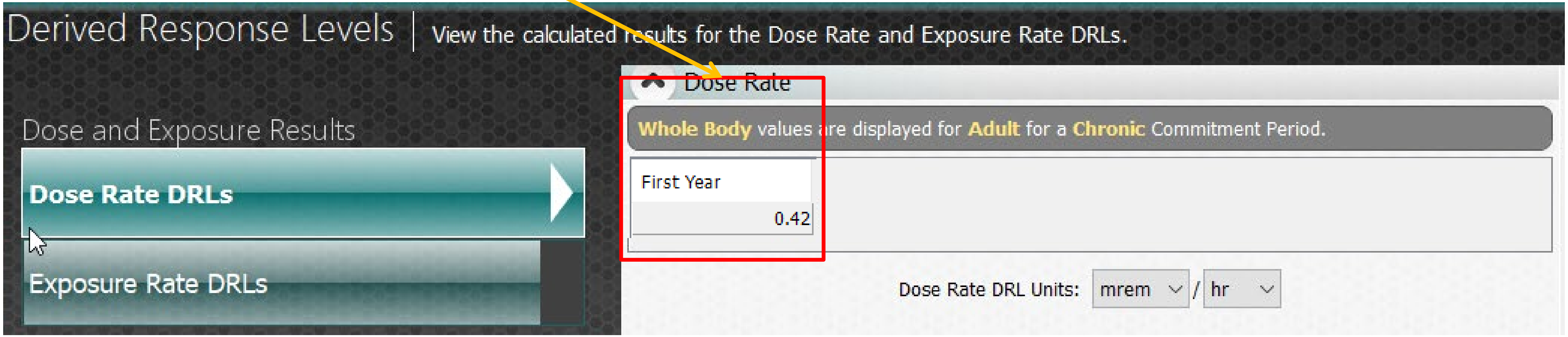
DEPOSITION DRLS - MODIFIED

Final Results displayed



DOSE RATE DRL - MODIFIED

Final Results displayed



INTERPRETING THE RESULTS

	First Year DRL Default Inputs		First Year DRL BPF and OF Applied	
Radionuclide	Deposition DRL μCi/m^2	Dose Rate DRL mrem/hr	Deposition DRL μCi/m^2	Dose Rate DRL mrem/hr
^{60}Co	7.34	0.2	15.41	0.42
^{148}Gd	3.68		7.73	
^{90}Sr	11.04		23.17	
^{90}Y	11.04		23.17	

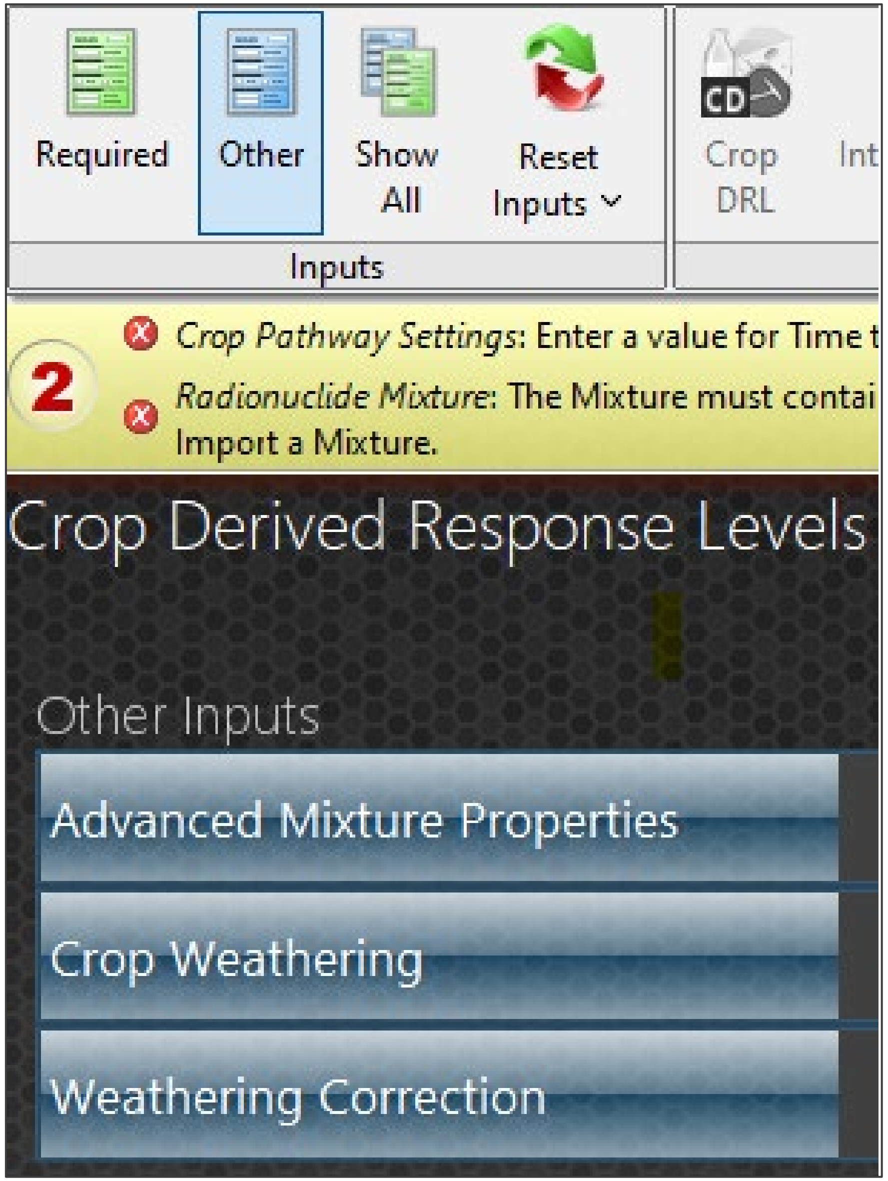
- By applying protection factors, Deposition and Dose Rate DRLs roughly double
- This implies it will take approximately twice as much radioactive material deposited on the ground before the PAG may be exceeded
- The decision makers may be able to **greatly reduce or even avoid a Relocation Protective Action Recommendation** depending on field measurements

ADVANCED INGESTION INPUTS AND CALCULATIONS

OTHER INGESTION INPUTS – CROP DRLS

Populated with default values, and do not **need** to be altered to run a calculation

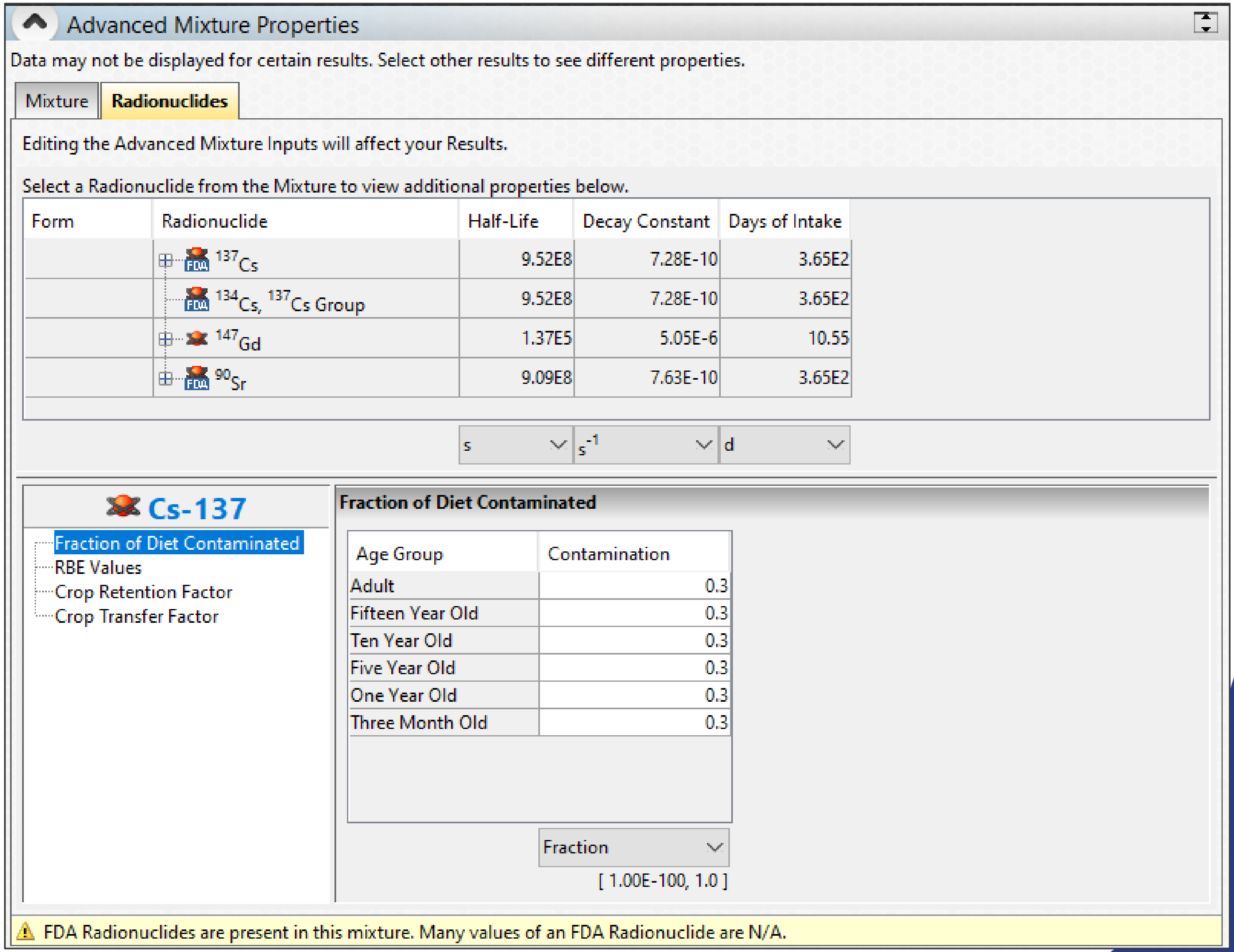
A thorough understanding of the inputs and scenario in question is recommended before the user changes values from the defaults



OTHER INGESTION INPUTS – CROP DRLS

Advanced Mixture Properties

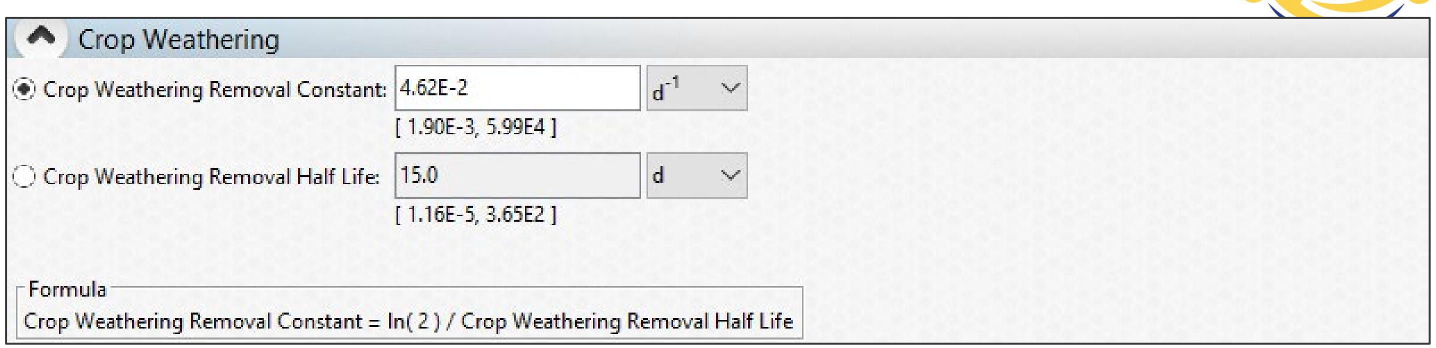
- Allows for the user to change the fraction of the diet contaminated, crop retention factor, and crop transfer factors for the selected radionuclides



OTHER INGESTION INPUTS – CROP DRLS

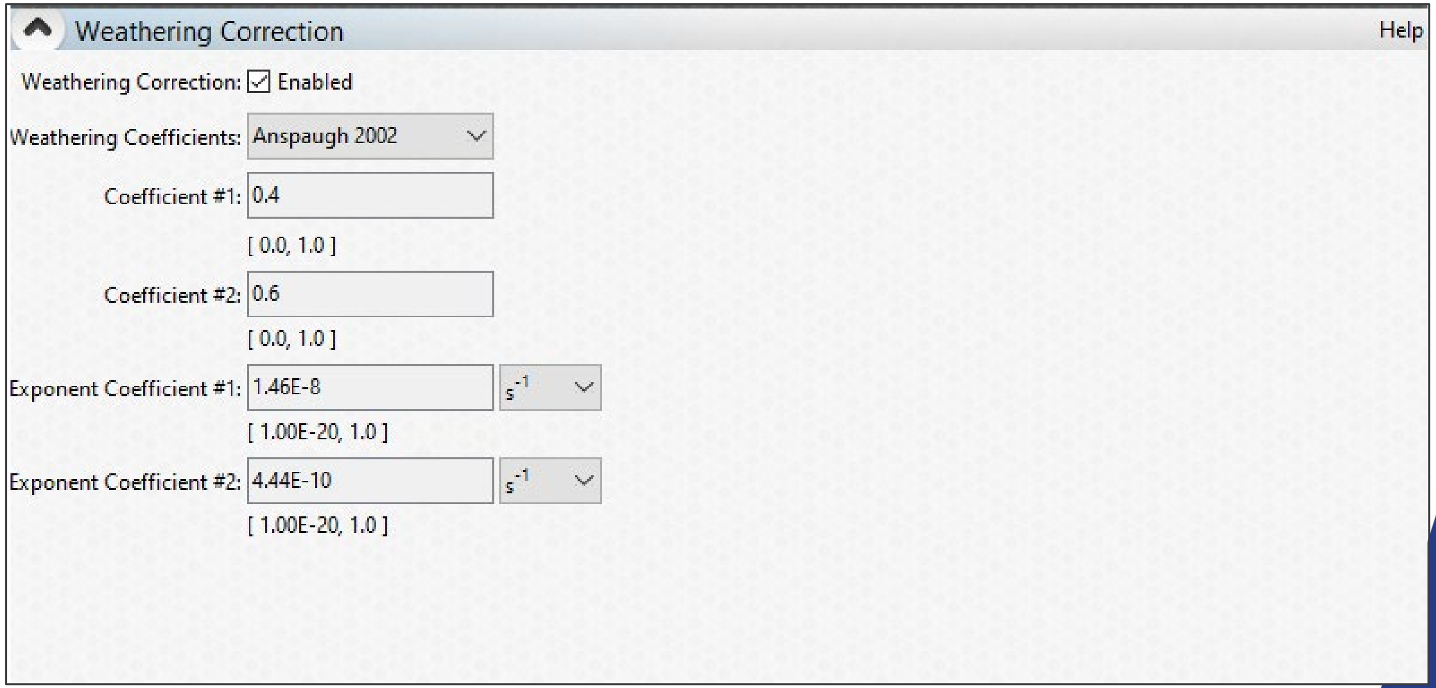
Crop Weathering

- Allows the user to adjust the rate at which the mixture is weathered from the surface of the crops **or** the removal half-life of the mixture from the crop surface



Weathering Correction

- Allows the user to change the coefficients of the weathering equation.
- This represents the movement of the radioactive material away from the area of concern either via migration into the soil column or through runoff.



EFFECTS OF CROP WEATHERING ON MILK AND MEAT DRLS

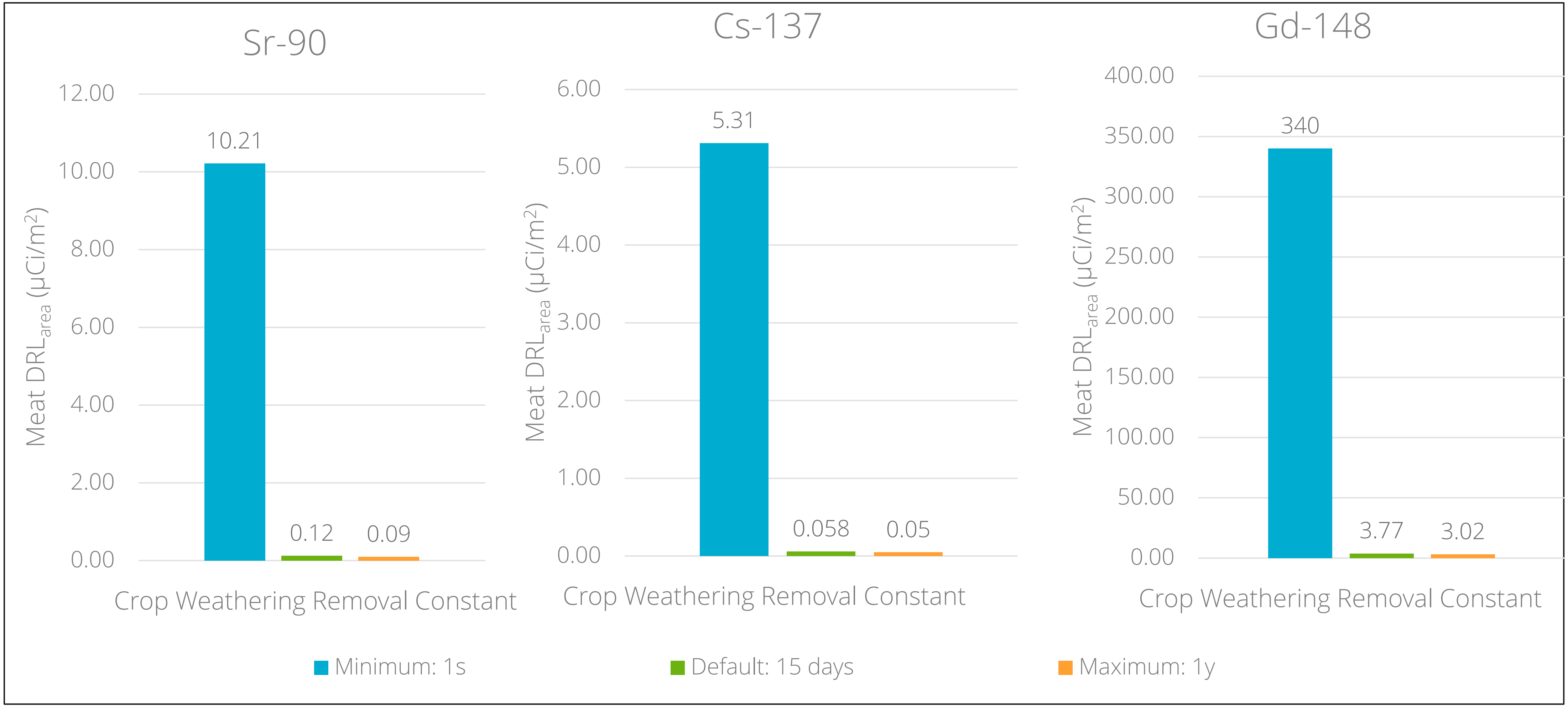
Assumptions

- Mixture: ^{90}Sr, ^{137}Cs, ^{148}Gd
- t_n = 0.5 d
- t_g = 5 d
- $t_{h,meat}$ = 15 d
- t_m = 20 d
- All other inputs set to the defaults

Crop Weathering Removal Half-Lives

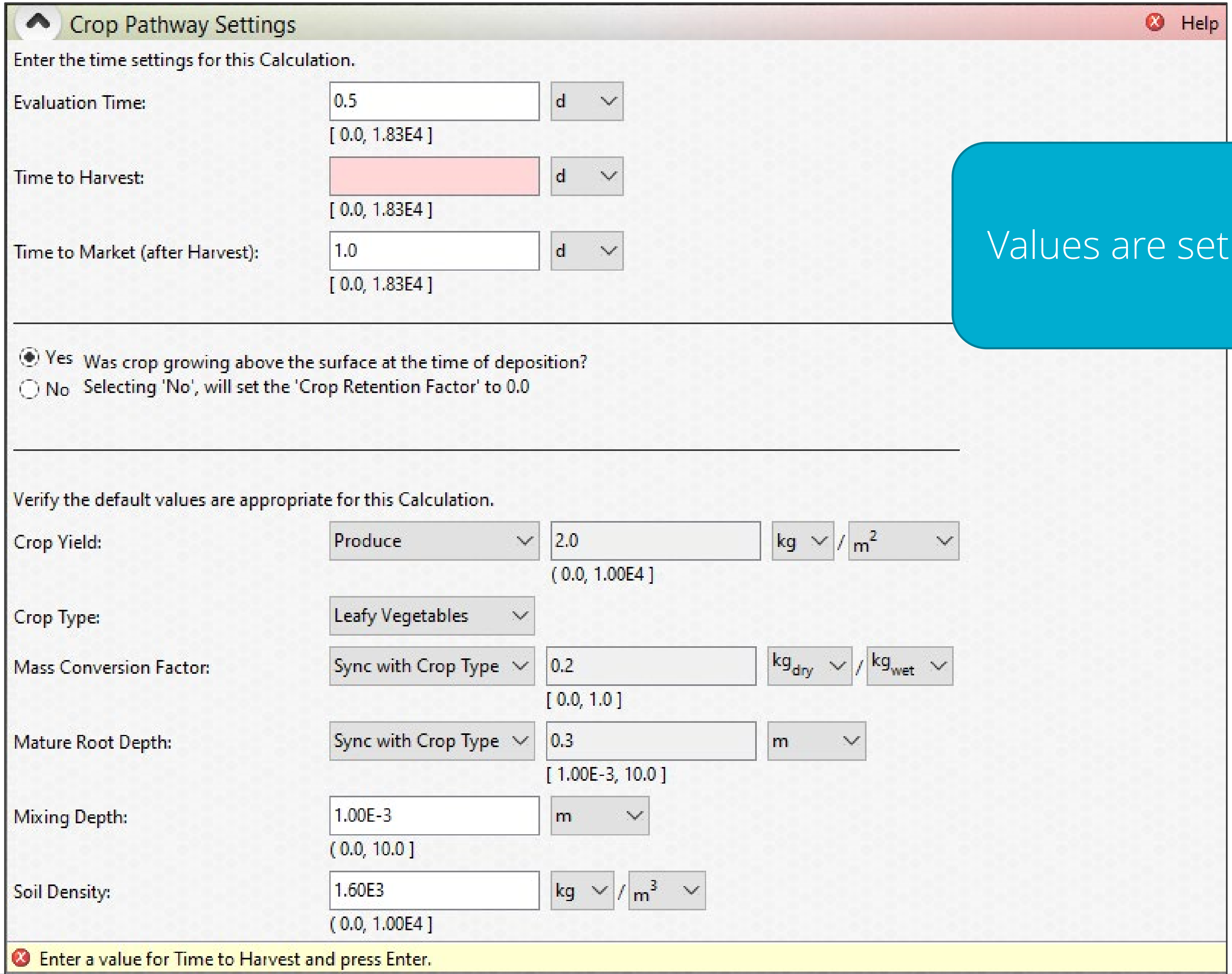
- Default: 15 d
- Min: 1 sec
- Max: 1 yr

RESULTS



Weathering off the crop can have a substantial effect on the meat DRL value

ADVANCED REQUIRED INPUTS – CROP DRLS



Values are set to the defaults

ADVANCED REQUIRED INPUTS – MILK AND MEAT DRLS

Verify the default values are appropriate for this Calculation.

Livestock:	Beef Cow		
Fodder Intake Rate:	50.0 (0.0, 1.00E3]	kg / d	
Forage Intake Rate:	50.0 (0.0, 1.00E3]	kg / d	
Soil Intake Rate:	0.5 (0.0, 1.00E3]	kg / d	
Water Intake Rate:	49.99 (0.0, 1.00E3]	L / d	
Fodder Contaminated:	1.0 [0.0, 1.0]	Fraction	
Forage Contaminated:	1.0 [0.0, 1.0]	Fraction	
Water Contaminated:	1.0 [0.0, 1.0]	Fraction	
Crop Yield:	Forage	0.7 (0.0, 1.00E4]	kg / m^2
Crop Type:	Forage		
Mass Conversion Factor:	Sync with Crop Type	0.22 [0.0, 1.0]	kg_{dry} / kg_{wet}
Mature Root Depth:	Sync with Crop Type	0.6 [1.00E-3, 10.0]	m
Mixing Depth:	1.00E-3 (0.0, 10.0]	m	
Soil Density:	1.60E3 (0.0, 1.00E4]	kg / m^3	

All values, including livestock type, are set to the defaults

ADVANCED REQUIRED INPUTS – MILK AND MEAT DRLS

Verify the default values are appropriate for this Calculation.

Parameter	Value	Units	Range
Livestock:	Goat		
Fodder Intake Rate:	6.0	kg / d	(0.0, 1.00E3]
Forage Intake Rate:	6.0	kg / d	(0.0, 1.00E3]
Soil Intake Rate:	6.00E-2	kg / d	(0.0, 1.00E3]
Water Intake Rate:	8.0	L / d	(0.0, 1.00E3]
Fodder Contaminated:	0.5	Fraction	[0.0, 1.0]
Forage Contaminated:	0.5	Fraction	[0.0, 1.0]
Water Contaminated:	0.5	Fraction	[0.0, 1.0]
Crop Yield:	Forage; 0.7	kg / m^2	(0.0, 1.00E4]
Crop Type:	Forage		
Mass Conversion Factor:	Sync with Crop Type; 0.22	kg_{dry} / kg_{wet}	[0.0, 1.0]
Mature Root Depth:	Sync with Crop Type; 0.6	m	[1.00E-3, 10.0]
Mixing Depth:	1.00E-3	m	(0.0, 10.0]
Soil Density:	1.60E3	kg / m^3	(0.0, 1.00E4]

Changing livestock type changes intake rates to match. User can also determine how much of the intake pathway is contaminated by changing the fractions below the intake rates

Adjusting for livestock type and fraction of diet contaminated allows for answering farm specific questions, including application of protective actions such as incorporation of uncontaminated feed, forage, and/or water

ADVANCE REQUIRED INPUTS – MILK AND MEAT DRLS

Milk and Meat pathways for cows assume that only one pathway is contaminated at any given time. This could be unrealistic.

In actuality, the "one contaminated pathway" assumption means that only one pathway's contamination is variable in the calculation.

It is possible to consider the contamination of multiple pathways simultaneously, but this requires additional computation outside of the Turbo FRMAC software.

ADVANCED ADDITIONAL INPUTS – MILK AND MEAT DRLS

Weathering

- Weathering when applied to Milk and Meat ingestion calculations does not just affect how much material is removed from the crop by processes such as wind.
- The weathering factor for Milk and Meat is a modifier in the ingested soil, so rate of weathering from the soil will also contribute to the amount of contamination in the cow over and above what was in or on the crop itself

EXAMPLE – BUT WHAT ABOUT THE REINDEER?

The March 2011 Fukushima Daiichi nuclear incident had agricultural impact that reached Alaska. Initial concern was any dairy and/or beef cows in the affected area. Assessment Scientists were informed that cows were kept sheltered during the winter months.

The follow-up question from local farmers: "But what about the Reindeer?"

Reindeer comprise a substantial portion of dairy and meat agriculture for Alaska, US.

Assessment Scientists had to account for this in their assessments.

What are some of the ways that you could account for animal products, like reindeer, not included in Turbo FRMAC?

THINGS TO CONSIDER IN NON-STANDARD ANIMAL PRODUCT CALCULATIONS

What do reindeer eat? How much?

Answer: 5 kg/d of Lichen

Is the transfer factor into reindeer milk or meat different than cows?

Answer: Yes. Transfer factors into reindeer milk is 1.9E-01 uCi/l per uCi/d

Is the crop yield of lichen different than other forage types?

Answer: Yes. $Y=0.75\ kg_{wet}/m^2$

Is the soil intake off of lichen different?

Answer: Yes. $ASDIR_{soil} = 0.3\ kg_{wet}/d$

THINGS TO CONSIDER IN NON-STANDARD ANIMAL PRODUCT CALCULATIONS

Does reindeer milk have a different density?

Answer: Not really. Density of reindeer milk is typically 1kg/L

Is the soil intake off of lichen different?

Answer: Yes. $ASDIR_{soil}$ = 0.3 kg_{wet}/d

References:

- Radiocesium Uptake in Reindeer on Natural Pasture, B.E.V. Jones, D. Eriksson, M. Nordkvist, The Science of the Total Environment, *5 (1989), 207 - 212.
- *Reindeer Health Aid Manual*, Dieterich, RA, Morton, JL et al.,AFES Misc. Pub 90-4, CES 100H-00046, Univ. of Alaska and U.S. Department of Agriculture, 1990
- Average, "Part II: An inventory of lichen species that are used by people," http://web.uvic.ca/~stucraw/part2AM.html
- *Transfer of 85Sr and 134Cs from the diet of reindeer feotises and milk*, l. Skuterud, H. Gjostein et al, Radiation Environ Biophysics (2005) 44:107-117.

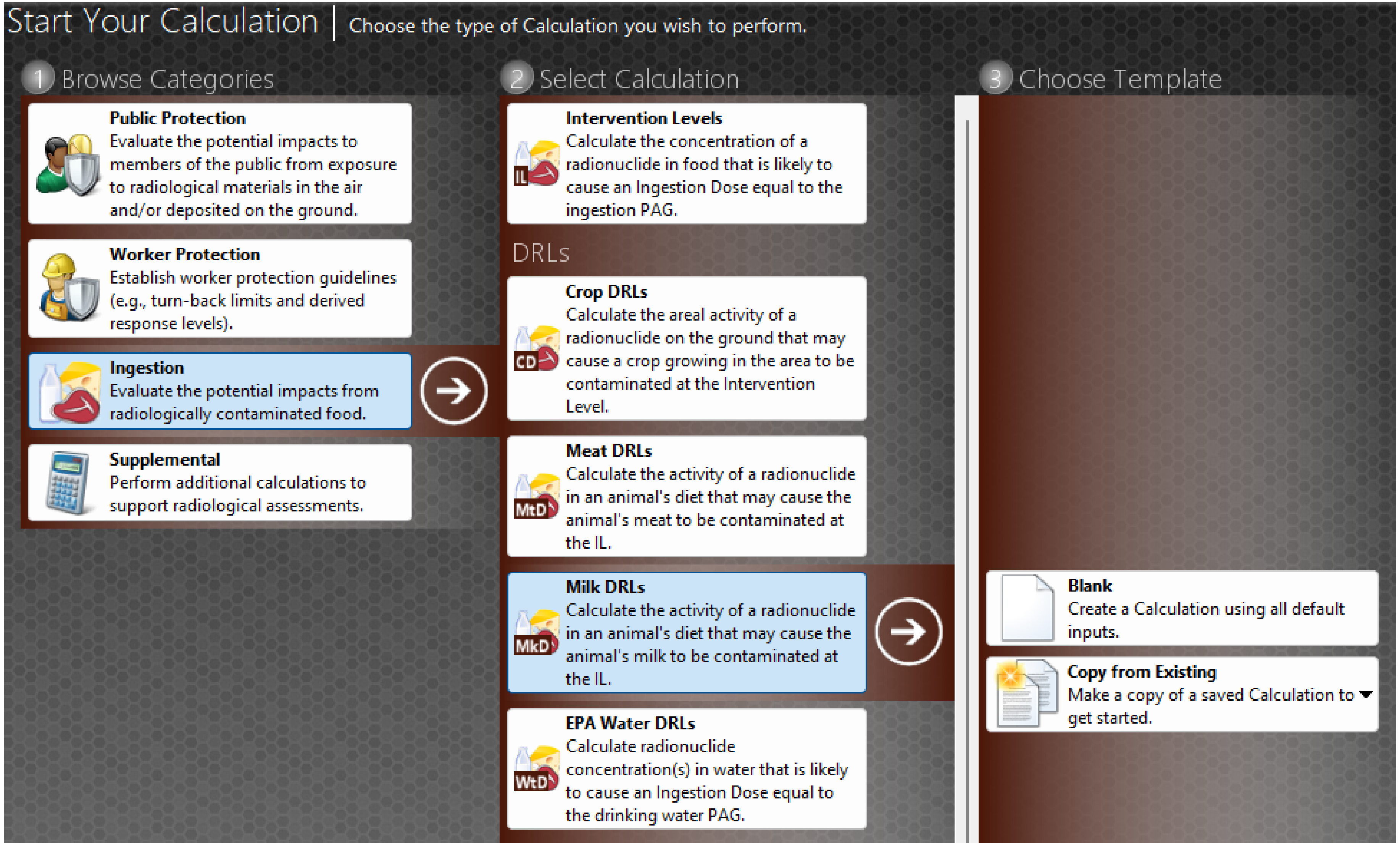
WORK THE PROBLEM

Assume the forage is contaminated with ^{137}Cs. Determine the $Milk\_DRL_{area}$ for the reindeer for ^{137}Cs.

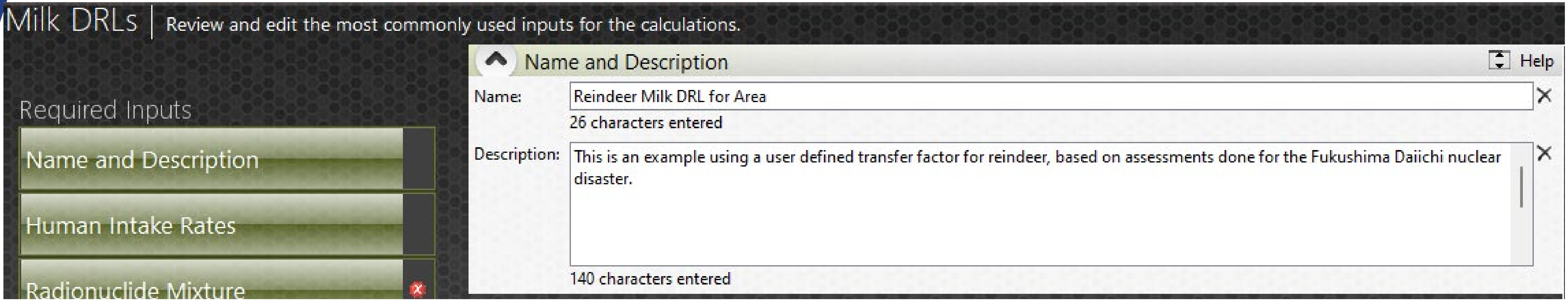
Use the following assumptions in your calculation

Transfer Factor	1.9E-01 (µCi/l per µCi/d)
Crop Retention Factor	0.5
Animal Forage Daily Intake Rate	5 (kg_{wet}/d)
Crop Yield	0.75 (kg_{wet}/m^2)
Animal Soil Daily Intake Rate	0.3 (kg_{soil}/d)
Fraction of Diet Contaminated	1
Time to Market	2 days
Time to Grazing	1 day
Time to Harvest	2 days
Milk Density	1 kg/L

START A NEW CALCULATION

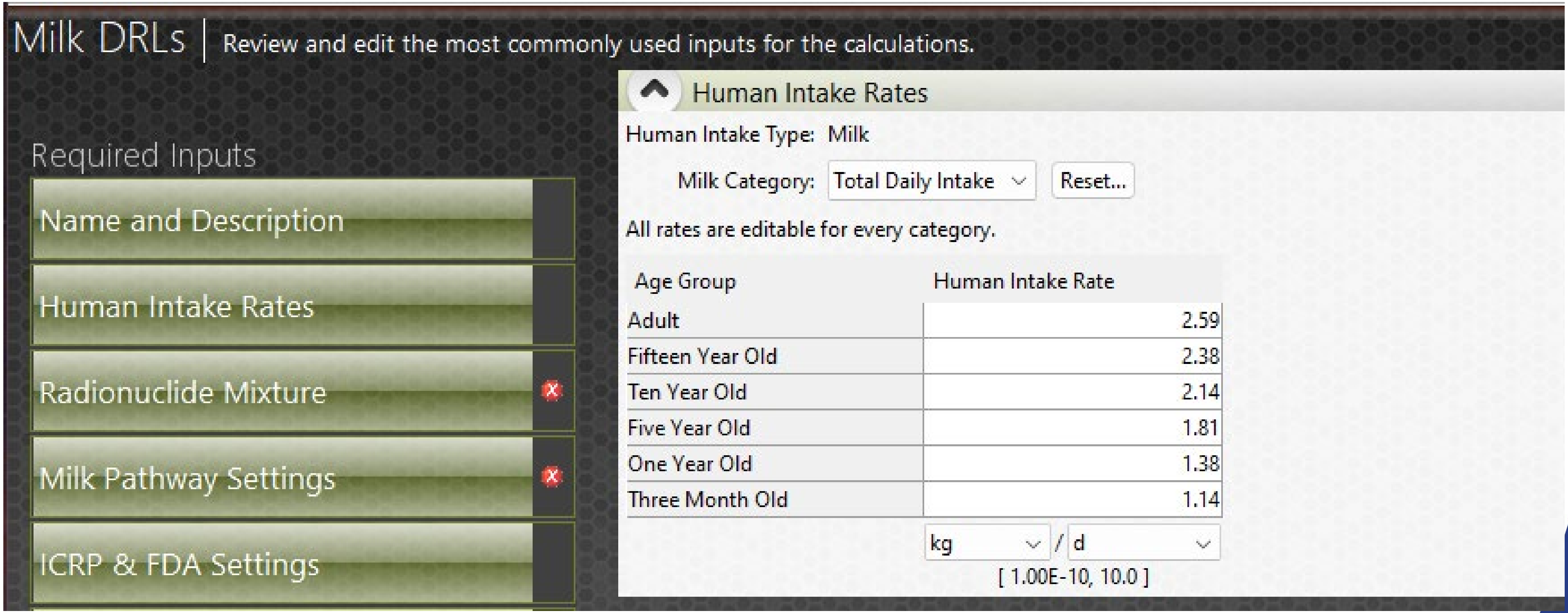


NAME AND DESCRIBE YOUR CALCULATION



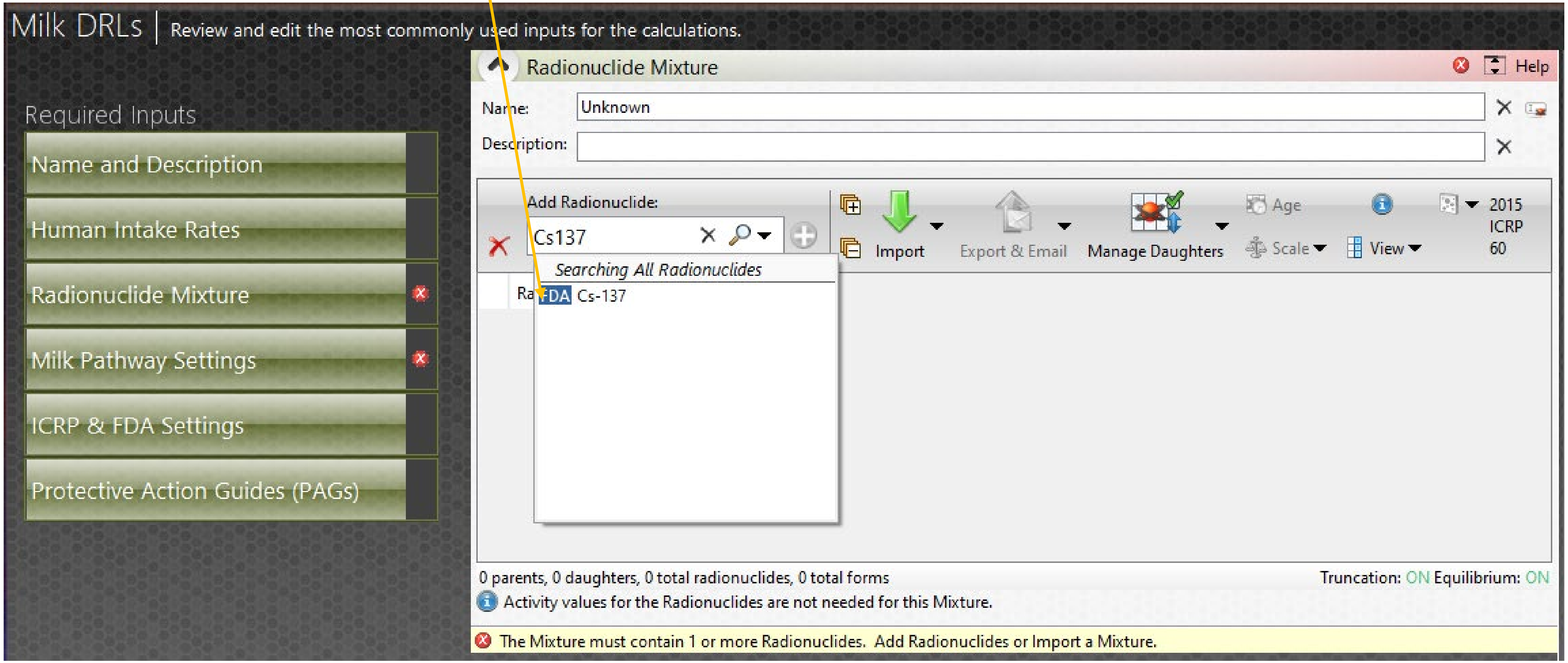
CONFIRM HUMAN INTAKE RATES

For this calculation, we will be using the default Human Intake Rates.



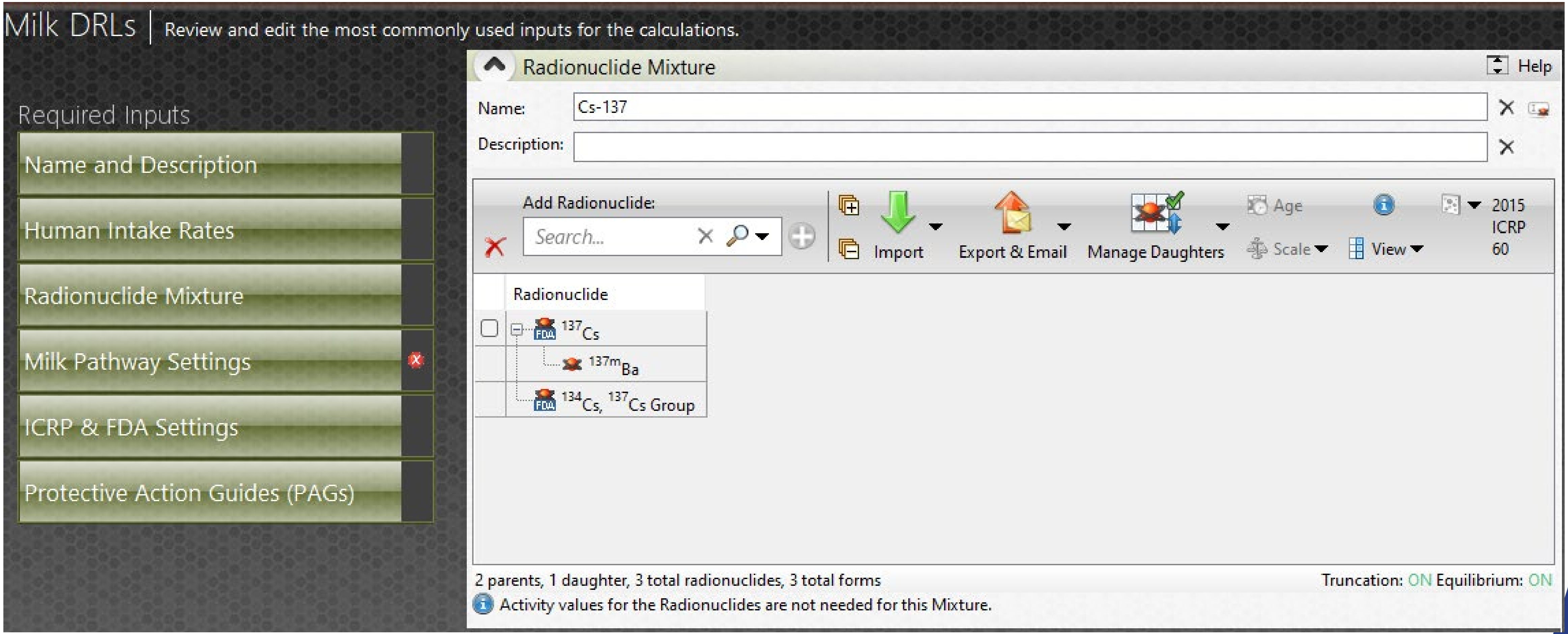
BUILD YOUR MIXTURE

Select ^{137}Cs from your drop down



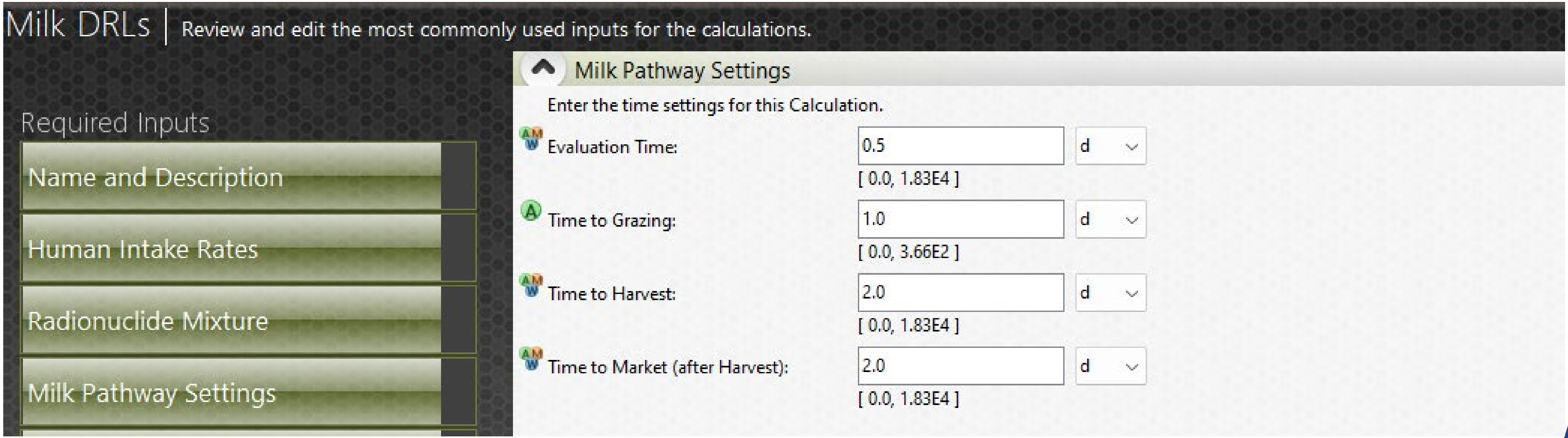
BUILD YOUR MIXTURE

Since ^{137}Cs is an FDA radionuclide, the mixture panel populates the cesium group

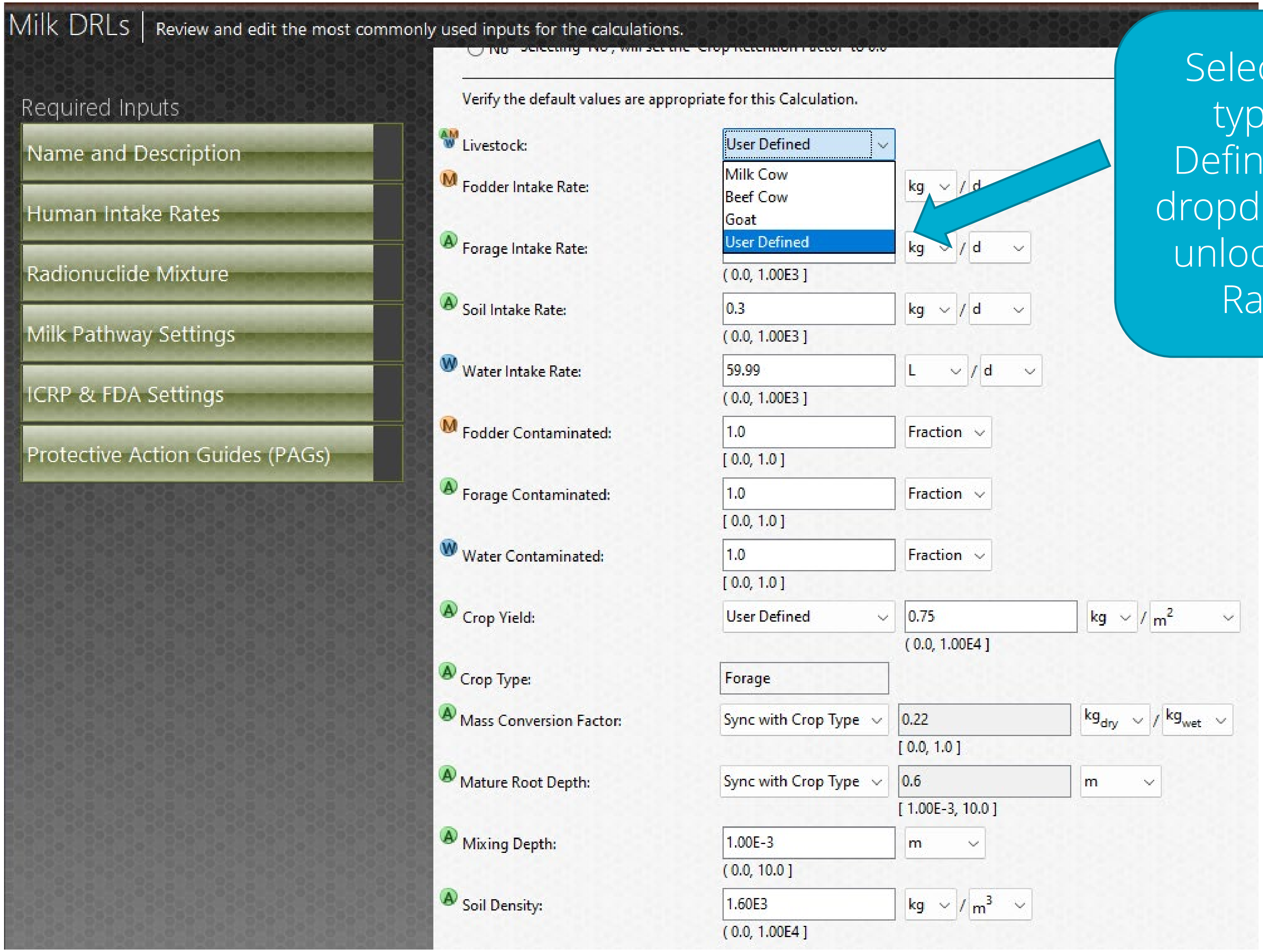


MILK PATHWAY TIME SETTINGS

Set your time settings

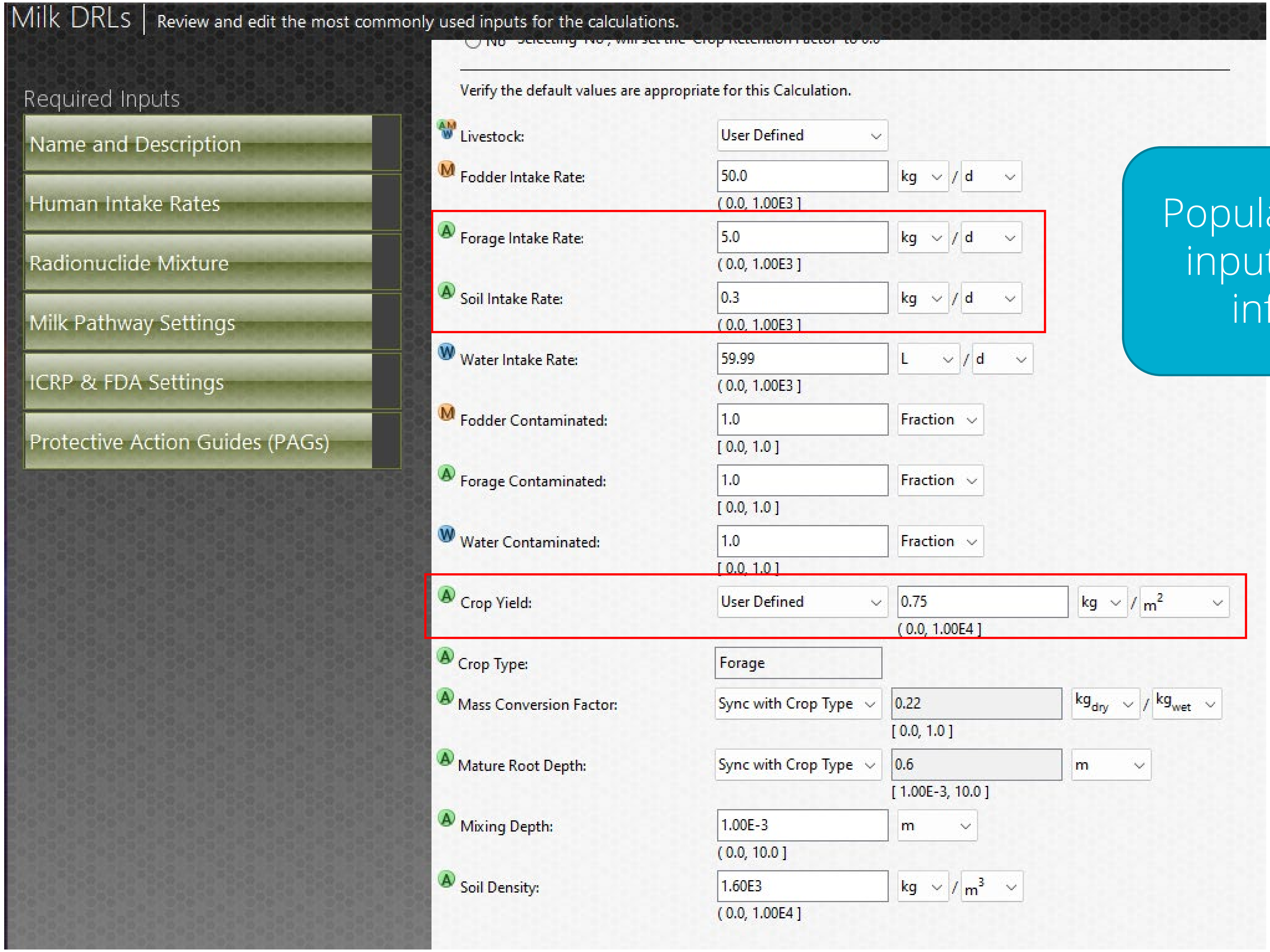


MILK PATHWAY SETTINGS



Select Livestock type as User Defined from the dropdown. This will unlock the Intake Rate boxes.

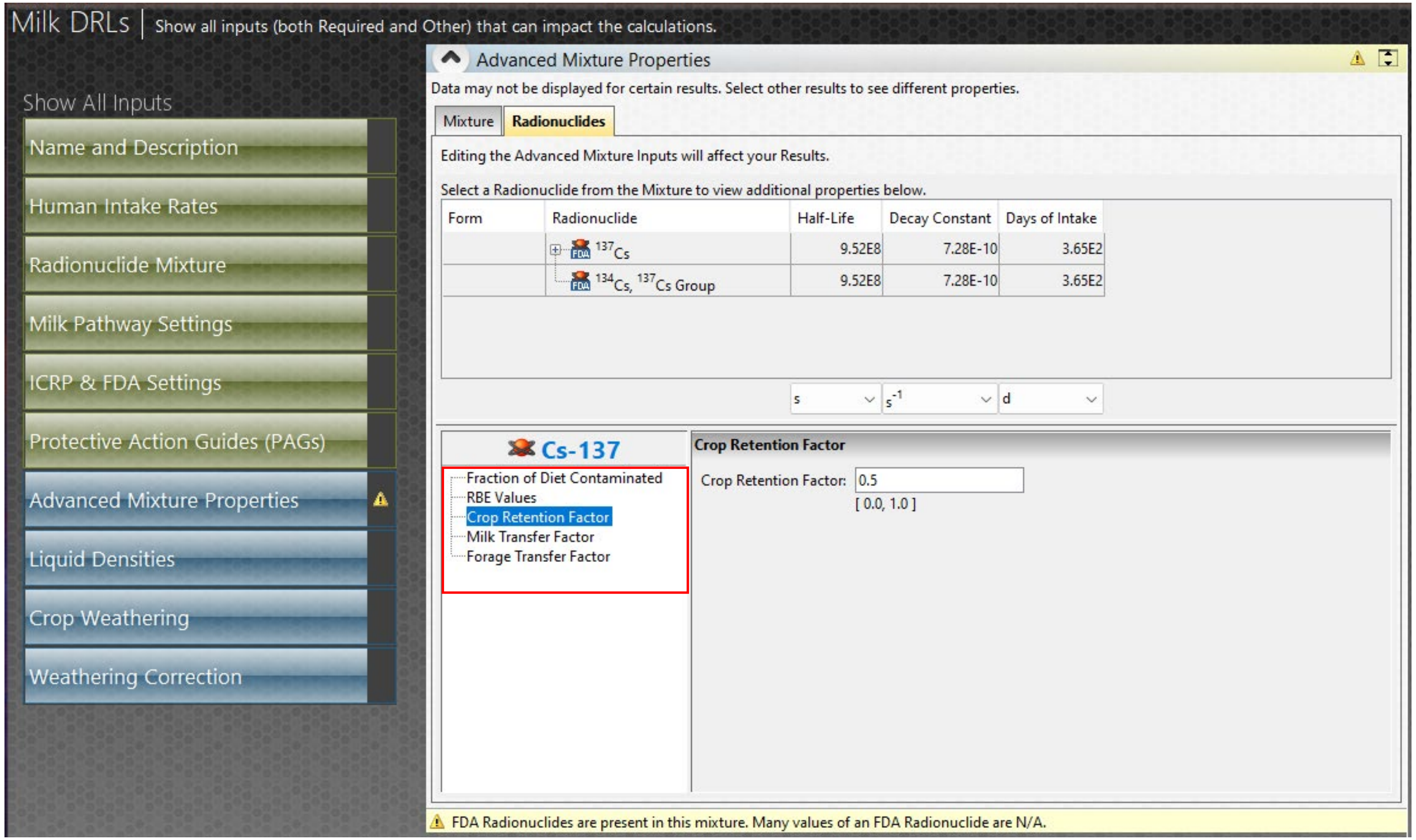
MILK PATHWAY SETTINGS



Populate necessary inputs with given information

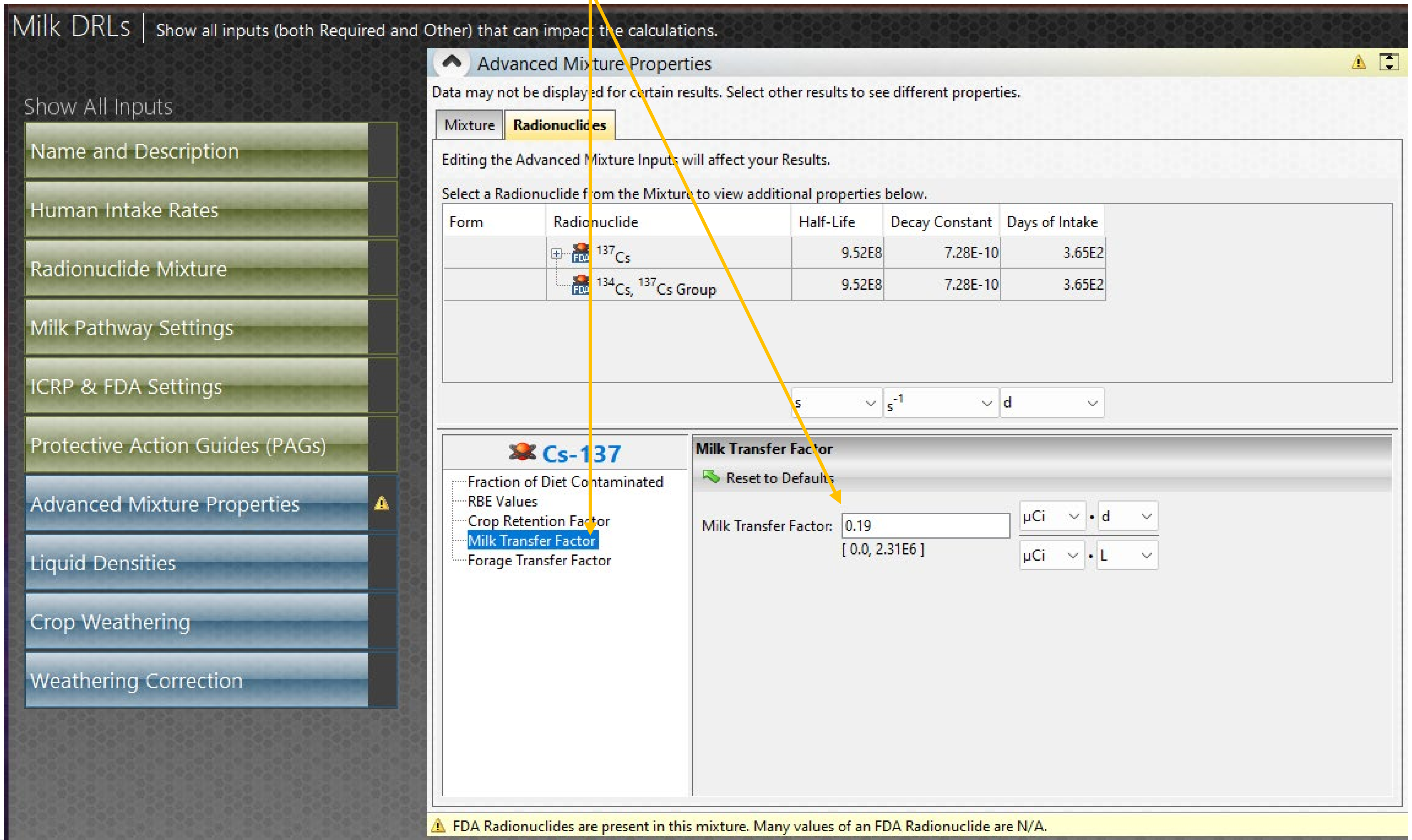
CHANGING THE CROP RETENTION AND TRANSFER FACTOR

Crop retention factors and transfer factors are found in the Other Inputs and can be changed for each radionuclide individually



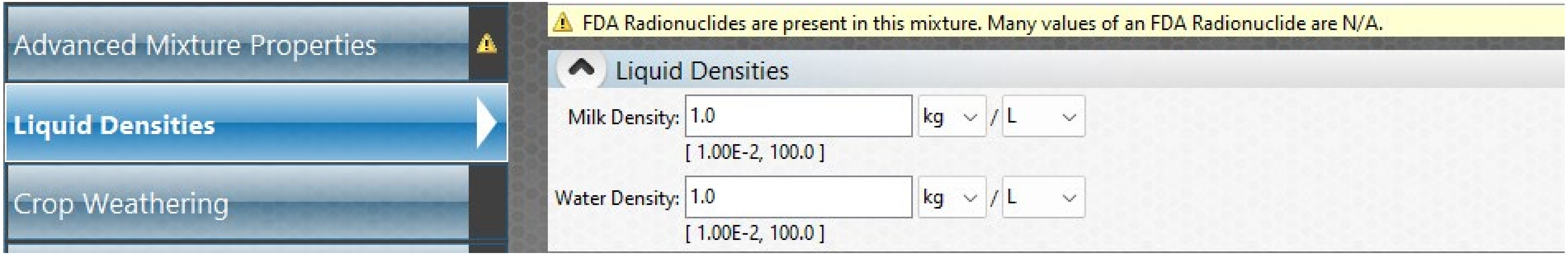
CHANGING THE TRANSFER FACTOR

Select Milk Transfer Factor and input the given value



LIQUID DENSITIES

Milk density is specific to the animal. To change this, click on the Liquid Densities button. Change the Milk Density to 1 kg/L



RUN CALCULATION

RESULTS DISPLAYED

Milk DRLs | View the calculated results for Milk Derived Response Levels for Area.

Milk DRL for Area Results

Ingestion Derived Response Levels

Ingestion Derived Response Levels

Most Conservative Organ values are displayed for **Most Conservative** Age Group **(excludes Three Month Old for non-FDA radionuclides)** for a **Chronic** Commitment Period.

Radionuclide	Age Group	Organ	DRL Value
FDA ^{137}Cs	Adult	Whole Body	5.74E-2
FDA ^{134}Cs, ^{137}Cs Group	Adult	Whole Body	2.09

µCi / m^2

FINAL EXERCISE

Questions

INSTRUCTIONS

With the remaining time, we will be completing a Do It Yourself exercise that will touch on the concepts learned through the two completed training sessions. If everyone has completed the exercise before the end of the session, we will go over the answers together.

If we run out of time, please email your answers to Autumn at aekalin@sandia.gov we will review your answers and return the solutions to you!

Have fun, and good luck!

PART 1 – GENERAL TRIVIA

1. What is a PAG?
2. What is a DRL?
3. How many Dose Pathways are considered by FRMAC Public Protection Methods?
4. The point in time, relative to the start of the event for which the calculation is being performed is called what?
5. What is the default consumption period for determining an Ingestion Intervention Level?
6. True or False: it is not possible to adjust Crop/Milk/Meat DRL calculation inputs to customize the calculation to crops and livestock not included in the Turbo FRMAC software.

PART 2 – TURBO FRMAC EXERCISE

Scenario:
The Springfield Nuclear Power Plant (PWR) declared a General Emergency due to a main steam line rupture. The rupture resulted in an uncontrolled, short-term release to the environment.

Use the following source inventory (mixture) for all the Turbo FRMAC calculations. Include all daughters:

Radionuclide	Activity per Area ($\mu Ci/m^2$)
Ba-140	6500
Ce-144	200
Cs-134	1600
Cs-137	1000
I-131	18100
Sb-127	600
Sr-90	200

PART 2 – TURBO FRMAC EXERCISE

1. What is the Early Phase Deposition DRL for Sr-90 in μCi/m^2?
2. Which Age Group does the DRL calculated in #22 apply to?
3. What is the 2^{nd} year Dose Rate DRL for the mixture in Rem/s?
4. Which FIL in μCi/kg would you recommend for Sb-127?
5. Which age group has the most restrictive IL for Cs-137?
6. What is the 1 Year Old Thyroid IL for I-131 in μCi/kg?
7. What is the $Milk\_DRL_{area}$ for Ba-140 in pCi/cm^2 (Assume an Evaluation Time of 5 days, a Time to Grazing of 14 days and a Time to Harvest of 16 days)?
8. What is the Crop DRL for I-131? (Assume a wheat (Grain) crop, an Evaluation Time of 30 days and a Time to Harvest of 50 days) ?

PART 1 - ANSWERS

1. Protective Action Guide
2. Derived Response Level
3. 1-4 pathways
4. Evaluation time
5. 1 year
6. False. Ingestion calculations can be customized based on data the user has to fit non-included crops an animals

PART 2 - ANSWERS

1. 7.88 μCi/m^2
2. Adult
3. 2.66E-07 Rem/s
4. 4.54 μCi/kg
5. Adult
6. 4.59E-03 μCi/kg
7. 1250 pCi/cm^2
8. 2.23 μCi/m^2

Thank you!

Questions?

REVISING THE SOURCE TERM

SOURCE TERM ESTIMATES

Early in a response, it may be necessary to provide our best guess for the release source term

Nuclear Power Plant or Facility Accidents

- Nuclear Regulatory Commission (NRC)
  - Facility/Reactor Inventory
  - RASCAL models of potential accident scenarios
- Subject Matter Experts
  - For "what if" scenarios at nuclear facilities

SOURCE TERM - RASCAL MODELS

Primary uses for Assessment

- Model release scenario to estimate source term and release fractions
- Examine dose & consequence projections from local licensee and regulator
    - Examine what other information has be generated locally
    - Compare facility generated projections to RASCAL projections, if applicable

INCORPORATING ATMOSPHERIC MODELING

Establish communication with NARAC analyst or response coordinator

- Identify any models that have been created already
- Review source term and release scenario information in model(s)

Provide source term to NARAC for modeling

- Communicate key assumptions for calculations with NARAC
  - Observation time, shelter assumptions, source term used, etc.
  - Typically, providing the RASCAL file for the event is a good starting point

FRMAC DATA REVIEW PROCESS

As an event progresses and data is collected, this data must be reviewed and integrated into the existing Common Operating Picture (COP) to update the source term.

Data Quality (DQ) Review: Was the data collected properly?

- Correct metadata: date/time, location, equipment used
- Find entry errors: correct unit/prefix, units match radiation type, etc.
- Performed by Monitoring Division with assistance from Assessment as needed

Data Integration (DI) Review: Does the data make sense?

- Compare data against the COP
- Compare data from all sources for consistency
- Performed by Assessment Division

DATA INTEGRATION REVIEW

Data Integration Review and the COP

- The data integration review compares collected data against the models and previous data incorporated into the COP
- Comparison with COP serves 2 purposes:
  - Evaluation of data against all models and data collected to identify outliers or potential issues with measurements (bad detectors, etc.)
  - Evaluation of the models in the COP to ensure they are correlated with real-world measurements and samples

Potential Outcomes of Data Integration Review

- New data consistent with existing data and COP: Approved
- New data inconsistent with existing data and COP
  - Collect additional data to investigate: Under Review
  - If sufficient data present to confirm new measurement is an outlier: Reject
- New data inconsistent with COP
  - Collect additional data to investigate: Under Review
  - Data sufficient to confirm COP needs to be revised: Revise COP and repeat review

DATA INTEGRATION (DI) REVIEW – SOURCE TERM

Evaluate data against the source term model (mixture)

- Are Isotopic Ratios Consistent?
- Are Alpha/Beta, Alpha/Gamma, Beta/Gamma Ratios Consistent?
- Compare Isotopic Activity Concentration vs. Dose Rate or Contamination Values

Importance to evaluating data

- Determine if the modeled source term is complete
  - Are there any missing isotopes?
  - Is there fractionation of released inventory during transport or deposition?

DI REVIEW – SOURCE TERM, LABORATORY RESULTS

Laboratory Analysis is essential to confirm isotopic ratios in the soil and air

- Deposition and in-situ sample analysis
  - Most common samples for evaluating deposition & source term
  - If available, air samples collected during plume passage can also be used to evaluate the released inventory and predict deposition
- Identify Marker Isotope for evaluation
  - Marker radionuclide is one that is easy to measure and identify (e.g. Cs-137)
- Calculate ratio of each isotope result per sample to marker isotope result and compare to expected isotope ratios from source term

DI REVIEW – SOURCE TERM, SURVEY RESULT MIXTURE RATIOS

Calculate alpha/beta, beta/gamma, and alpha/gamma ratios

- Calculate net values for all survey measurements
- Calculate ratios for each survey location using the net measurements

Note: Do not calculate ratios for radiation types not emitted by source mixture (e.g., no alpha/beta ratio for a Cs-137 release)

Calculate expected ratios for source mixture

- Using Turbo FRMAC, calculate DRLs using an evaluation time corresponding to the data being reviewed
- The expected ratio for the source term at the observation time used is the ratio of the DRLs
  - Alpha/Beta ratio should be the Alpha DRL/Beta DRL

DI REVIEW – SOURCE TERM, EVALUATING RATIO RESULTS

Compare ratios for samples or surveys to expected ratio

- Look for trends
  - e.g., Alpha/Gamma ratio is consistently higher than expected
  - Consistent trends are an indication to consider revising COP source term
- Identify potential outliers
  - Ratios are very sensitive to measurement uncertainty and variance
    - There should be a random distribution of ratios around the expected value
  - Choose trigger levels to investigate ratios
    - For example, in the recovery phase a variance greater than 30% from expected values might be flagged

α/β

DI Review for source term

- Ratios in agreement with expected values from COP: No action.
- Ratios do not agree with expected values based on COP
  - Data is sufficient to suggest revision of COP: Recommend revision of COP
  - Data not sufficient: Flag as under review and request additional sampling/measurements
- For apparent outliers
  - Flag as under review and determine if discrepancies can be explained or if more data is needed

TYPES OF DATA THAT INFORM THE SOURCE TERM

- Particle size distribution
- Weather/weather changes
- Ground deposition measurements
- Changes to the release
    - Short term versus long term
    - Content of release
    - Energy of the release
        - E.g. fire is put out **OR** fire turns to an explosion
- Air sampler measurements