

## APPENDIX O - Uncertainty and Sensitivity Analysis

### O.1 Introduction

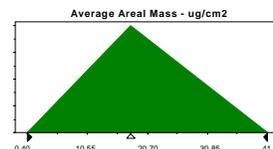
To address the uncertainty and sensitivity analysis of the test data parameters used in this exposure assessment and health risk characterization, a probabilistic analysis, using Monte Carlo Simulation (Crystal Ball, Ver 4.0) was used to obtain a statistical basis for a more robust statement of the assessment results and conclusions.

### O.2 Input Parameters (Crystal Ball Assumption Cells)

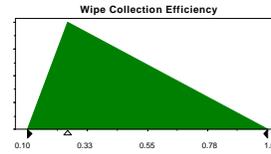
The input parameters or assumption cells that were modeled for Assumption 1 and Assumption 2 are presented below. Charts displaying the input probability distribution along with the mean value from each Crystal Ball simulation are included in the charts.

- **Assumption 1 Input Parameters**

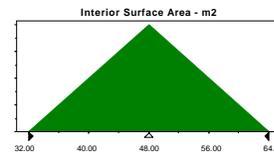
<b>Assumption: Average Areal Mass - mg/cm<sup>2</sup></b>		
<b>Cell: B5</b>		
Triangular distribution with parameters:		
	Minimum	0.40
	Likeliest	17.90
	Maximum	41.00
Selected range is from 0.40 to 41.00		
Mean value in simulation was 19.77		



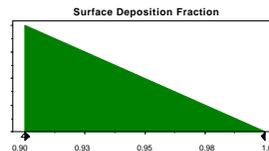
<b>Assumption: Wipe Collection Efficiency</b>		
<b>Cell: B6</b>		
Triangular distribution with parameters:		
Minimum		0.10
Likeliest		0.25
Maximum		1.00
Selected range is from 0.10 to 1.00		
Mean value in simulation was 0.45		



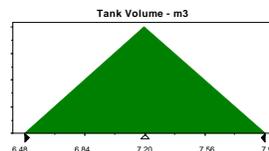
<b>Assumption: Interior Surface Area - m<sup>2</sup></b>		
<b>Cell: B8</b>		
Triangular distribution with parameters:		
Minimum		32.00
Likeliest		48.00
Maximum		64.00
Selected range is from 32.00 to 64.00		
Mean value in simulation was 47.96		



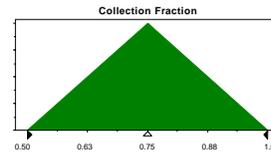
<b>Assumption: Surface Deposition Fraction</b>		
<b>Cell: B9</b>		
Triangular distribution with parameters:		
Minimum		0.90
Likeliest		0.90
Maximum		1.00
Selected range is from 0.90 to 1.00		
Mean value in simulation was 0.93		



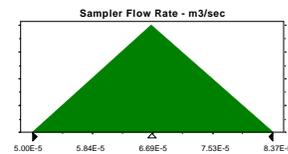
<b>Assumption: Tank Volume - m<sup>3</sup></b>		
<b>Cell: B11</b>		
Triangular distribution with parameters:		
Minimum		6.48
Likeliest		7.20
Maximum		7.92
Selected range is from 6.48 to 7.92		
Mean value in simulation was 7.20		



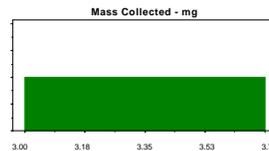
<b>Assumption: Collection Fraction</b>		
<b>Cell: Collection Fraction</b>		
Triangular distribution with parameters:		
	Minimum	0.50
	Likeliest	0.75
	Maximum	1.00
Selected range is from 0.50 to 1.00		
Mean value in simulation was 0.75		



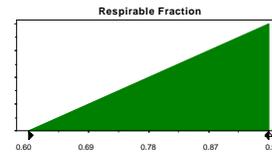
<b>Assumption: Sampler Flow Rate - m<sup>3</sup>/sec</b>		
<b>Cell: B13</b>		
Triangular distribution with parameters:		
	Minimum	5.00E-05
	Likeliest	6.67E-05
	Maximum	8.37E-05
Selected range is from 5.00E-5 to 8.37E-5		
Mean value in simulation was 6.67E-5		



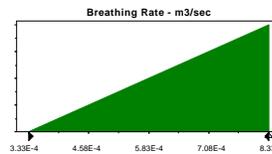
<b>Assumption: Mass Collected - mg</b>		
<b>Cell: B10</b>		
Uniform distribution with parameters:		
	Minimum	3.00
	Maximum	3.70
Mean value in simulation was 3.35		



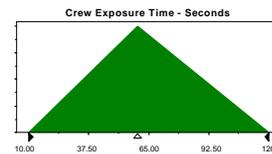
<b>Assumption: Respirable Fraction</b>		
<b>Cell: B19</b>		
Triangular distribution with parameters:		
	Minimum	0.60
	Likeliest	0.96
	Maximum	0.96
Selected range is from 0.60 to 0.96		
Mean value in simulation was 0.84		



<b>Assumption: Breathing Rate - m<sup>3</sup>/sec</b>		
<b>Cell: B20</b>		
Triangular distribution with parameters:		
	Minimum	3.33E-04
	Likeliest	8.33E-04
	Maximum	8.33E-04
Selected range is from 3.33E-04 to 8.33E-04		
Mean value in simulation was 6.66E-04		

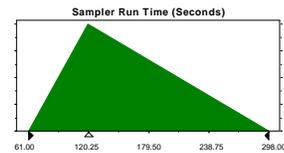


<b>Assumption: Crew Exposure Time - Seconds</b>		
<b>Cell: B21</b>		
Triangular distribution with parameters:		
	Minimum	10.00
	Likeliest	60.00
	Maximum	120.00
Selected range is from 10.00 to 120.00		
Mean value in simulation was 63.18		

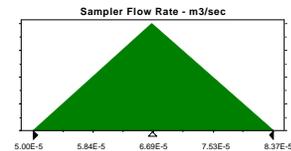


- Assumption 2 Input Parameters

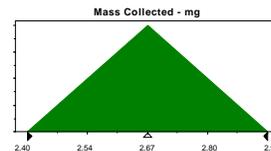
<b>Assumption: Sampler Run Time (Seconds)</b>		
<b>Cell: B6</b>		
Triangular distribution with parameters:		
Minimum		61.00
Likeliest		120.00
Maximum		298.00
Selected range is from 61.00 to 298.00		
Mean value in simulation was 159.87		



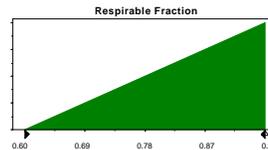
<b>Assumption: Sampler Flow Rate – m<sup>3</sup>/sec</b>		
<b>Cell: B7</b>		
Triangular distribution with parameters:		
Minimum		5.00E-05
Likeliest		6.67E-05
Maximum		8.37E-05
Selected range is from 5.00E-05 to 8.37E-05		
Mean value in simulation was 6.68E-05		



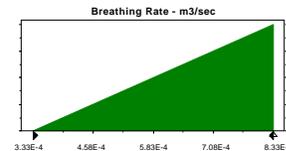
<b>Assumption: Mass Collected – mg</b>		
<b>Cell: B5</b>		
Triangular distribution with parameters:		
Minimum		2.40
Likeliest		2.67
Maximum		2.94
Selected range is from 2.40 to 2.94		
Mean value in simulation was 2.67		



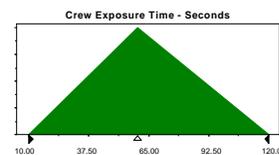
<b>Assumption: Respirable Fraction</b>		
<b>Cell: B11</b>		
Triangular distribution with parameters:		
	Minimum	0.60
	Likeliest	0.96
	Maximum	0.96
Selected range is from 0.60 to 0.96		
Mean value in simulation was 0.84		



<b>Assumption: Breathing Rate - m<sup>3</sup>/sec</b>		
<b>Cell: B12</b>		
Triangular distribution with parameters:		
	Minimum	3.33E-04
	Likeliest	8.33E-04
	Maximum	8.33E-04
Selected range is from 3.33E-04 to 8.33E-04		
Mean value in simulation was 6.67E-04		



<b>Assumption: Crew Exposure Time - Seconds</b>		
<b>Cell: B13</b>		
Triangular distribution with parameters:		
	Minimum	10.00
	Likeliest	60.00
	Maximum	120.00
Selected range is from 10.00 to 120.00		
Mean value in simulation was 63.05		

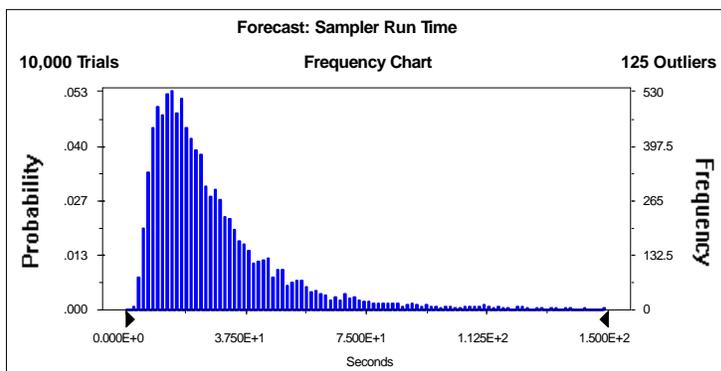


**O.3 Statistical Results (Crystal Ball Forecast Cells)**

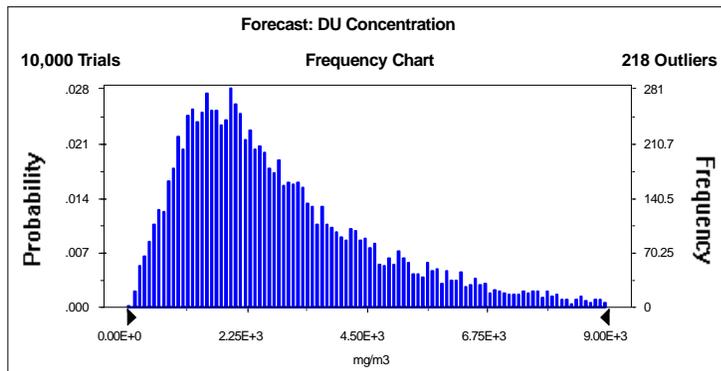
The statistics from the Crystal Ball simulations for Assumption 1 and Assumption 2 are presented below for each forecast cell in each simulation. A forecast cell is a cell that contains a formula and uses one or more assumption cells.

- Assumption 1 Simulation Forecasts**

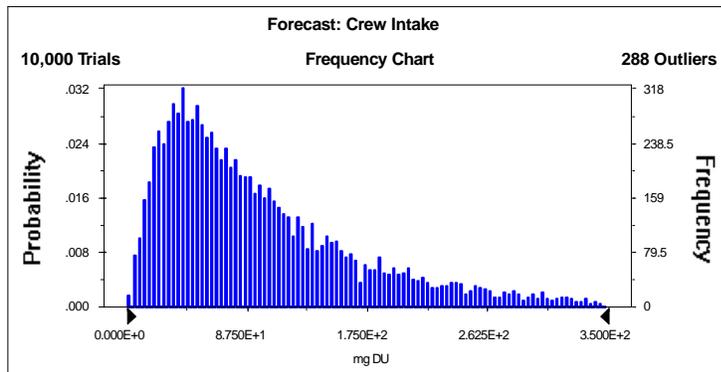
Forecast: Sampler Run Time		
Cell: D15		
Summary:		
Display Range is from 0.000E+0 to 1.500E+2 Seconds		
Entire Range is from 2.251E+0 to 1.170E+3 Seconds		
After 10,000 Trials, the Std. Error of the Mean is 3.686E-1		
Statistics:		<u>Value</u>
	Trials	10000
	Mean	3.030E+01
	Median	2.123E+01
	Standard Deviation	3.686E+01
Percentiles:		
	<u>Percentile</u>	<u>Seconds</u>
	0.0%	2.251E+00
	2.5%	5.689E+00
	5.0%	7.068E+00
	50.0%	2.123E+01
	95.0%	7.959E+01
	97.5%	1.120E+02
	100.0%	1.170E+03



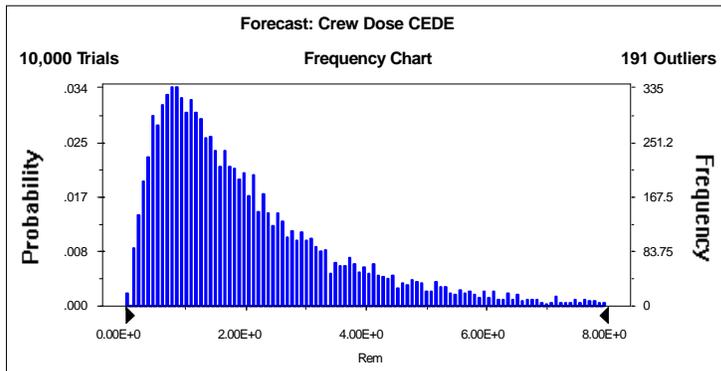
Forecast: DU Concentration		
Cell: D18		
Summary:		
Display Range is from 0.00E+0 to 9.00E+3 mg/m <sup>3</sup>		
Entire Range is from 4.94E+1 to 2.28E+4 mg/m <sup>3</sup>		
After 10,000 Trials, the Std. Error of the Mean is 2.17E+1		
Statistics:		Value
	Trials	10000
	Mean	2.99E+03
	Median	2.41E+03
	Standard Deviation	2.17E+03
Percentiles:		
	Percentile	mg/m <sup>3</sup>
	0.0%	4.94E+01
	2.5%	4.68E+02
	5.0%	6.52E+02
	50.0%	2.41E+03
	95.0%	7.22E+03
	97.5%	8.69E+03
	100.0%	2.28E+04



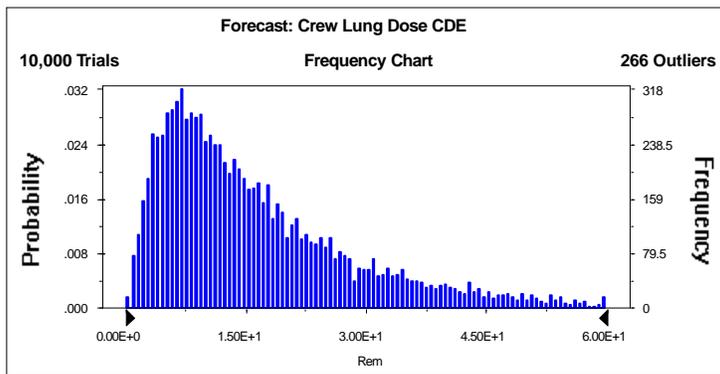
<b>Forecast: Crew Intake</b>		
<b>Cell: D23</b>		
Summary:		
Display Range is from 0.000E+0 to 3.500E+2 mg DU		
Entire Range is from 1.596E+0 to 8.202E+2 mg DU		
After 10,000 Trials, the Std. Error of the Mean is 9.331E-1		
Statistics:		
		<u>Value</u>
	Trials	10000
	Mean	1.056E+02
	Median	7.856E+01
	Standard Deviation	9.331E+01
Percentiles:		
	<u>Percentile</u>	<u>mg DU</u>
	0.0%	1.596E+00
	2.5%	1.186E+01
	5.0%	1.699E+01
	50.0%	7.856E+01
	95.0%	2.861E+02
	97.5%	3.660E+02
	100.0%	8.202E+02



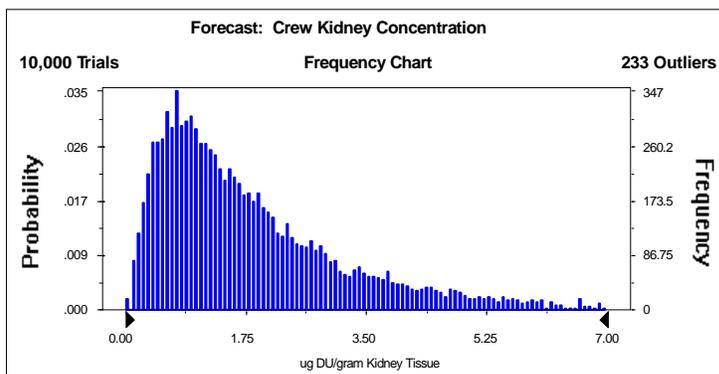
<b>Forecast: Crew Dose CEDE</b>		
<b>Cell: D28</b>		
Summary:		
Display Range is from 0.00E+0 to 8.00E+0 rem		
Entire Range is from 3.22E-2 to 1.66E+1 rem		
After 10,000 Trials, the Std. Error of the Mean is 1.88E-2		
Statistics:		<u>Value</u>
	Trials	10000
	Mean	2.13E+00
	Median	1.59E+00
	Standard Deviation	1.88E+00
Percentiles:		
	<u>Percentile</u>	<u>rem</u>
	0.0%	3.22E-02
	2.5%	2.40E-01
	5.0%	3.43 <sup>E</sup> -01
	50.0%	1.59 <sup>E</sup> +00
	95.0%	5.78 <sup>E</sup> +00
	97.5%	7.39E+00
	100.0%	1.66E+01



<b>Forecast: Crew Lung Dose CDE</b>		
<b>Cell: D31</b>		
Summary:		
Display Range is from 0.00E+0 to 6.00E+1 rem		
Entire Range is from 2.68E-1 to 1.38E+2 rem		
After 10,000 Trials, the Std. Error of the Mean is 1.57E-1		
Statistics:		<u>Value</u>
	Trials	10000
	Mean	1.78E+01
	Median	1.32E+01
	Standard Deviation	1.57E+01
Percentiles:		
	<u>Percentile</u>	<u>rem</u>
	0.0%	2.68E-01
	2.5%	2.00E+00
	5.0%	2.86E+00
	50.0%	1.32E+01
	95.0%	4.81E+01
	97.5%	6.16E+01
	100.0%	1.38E+02

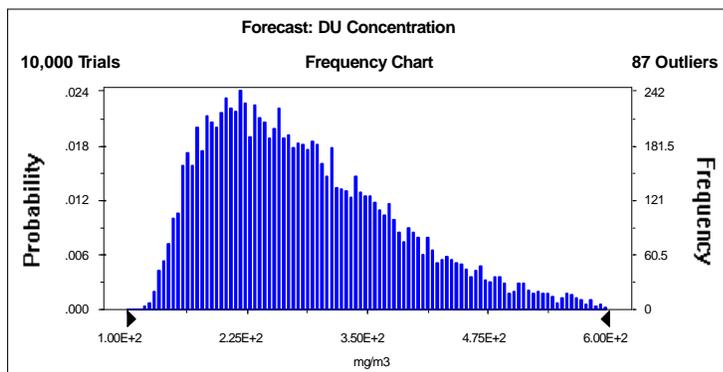


Forecast: Crew Kidney Concentration		
Cell: D41		
Summary:		
Display Range is from 0.00 to 7.00 µg DU/gram of Kidney Tissue		
Entire Range is from 0.03 to 15.29 µg DU/gram of Kidney Tissue		
After 10,000 Trials, the Std. Error of the Mean is 0.02		
Statistics:		<u>Value</u>
	Trials	10000
	Mean	1.97
	Median	1.46
	Standard Deviation	1.74
Percentiles:		
	<u>Percentile</u>	<u>µg DU/gram of Kidney Tissue</u>
	0.0%	0.03
	2.5%	0.22
	5.0%	0.32
	50.0%	1.46
	95.0%	5.33
	97.5%	6.82
	100.0%	15.29

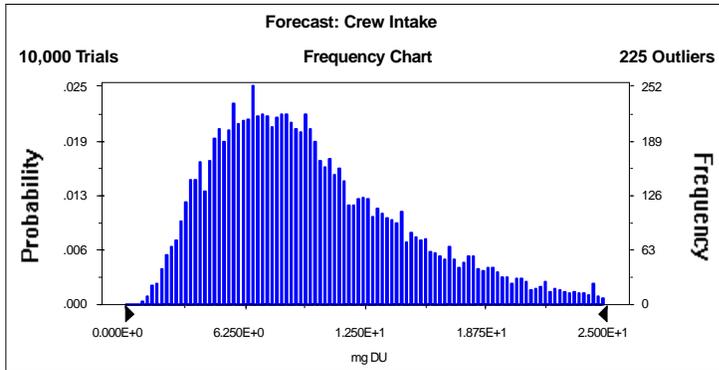


- Assumption 2 Simulation Forecasts

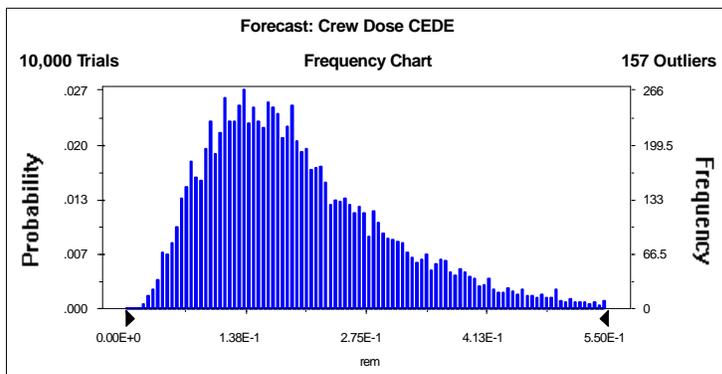
Forecast: DU Concentration		
Cell: D10		
Summary:		
Display Range is from 1.00E+2 to 6.00E+2 mg/m <sup>3</sup>		
Entire Range is from 1.09E+2 to 8.22E+2 mg/m <sup>3</sup>		
After 10,000 Trials, the Std. Error of the Mean is 1.02E+0		
Statistics:		Value
	Trials	10000
	Mean	2.86E+02
	Median	2.67E+02
	Standard Deviation	1.02E+02
Percentiles:		
	<u>Percentile</u>	<u>mg/m<sup>3</sup></u>
	0.0%	1.10E+02
	2.5%	1.47E+02
	5.0%	1.58E+02
	50.0%	2.67E+02
	95.0%	4.81E+02
	97.5%	5.30E+02
	100.0%	8.22E+02



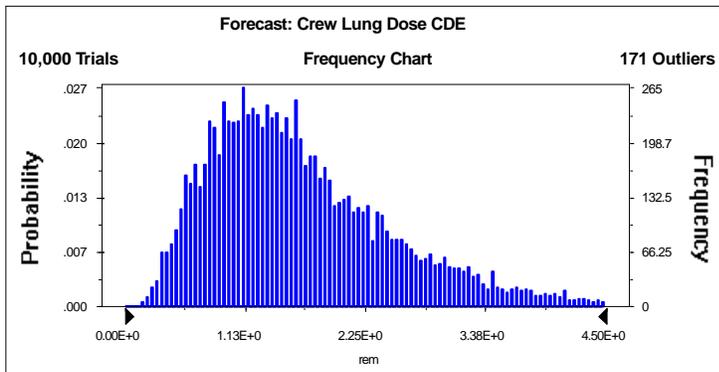
<b>Forecast: Crew Intake</b>		
<b>Cell: D15</b>		
Summary:		
Display Range is from 0.000E+0 to 2.500E+1 mg DU		
Entire Range is from 7.231E-1 to 5.282E+1 mg DU		
After 10,000 Trials, the Std. Error of the Mean is 5.741E-2		
Statistics:		
		<u>Value</u>
	Trials	10000
	Mean	1.007E+01
	Median	8.871E+00
	Standard Deviation	5.741E+00
Percentiles:		
	<u>Percentile</u>	<u>mg DU</u>
	0.0%	7.231E-01
	2.5%	2.553E+00
	5.0%	3.212E+00
	50.0%	8.871E+00
	95.0%	2.093E+01
	97.5%	2.440E+01
	100.0%	5.282E+01



<b>Forecast: Crew Dose CEDE</b>		
<b>Cell: D20</b>		
Summary:		
Display Range is from 0.00E+0 to 5.50E-1 rem		
Entire Range is from 1.46E-2 to 1.07E+0 rem		
After 10,000 Trials, the Std. Error of the Mean is 1.16E-3		
Statistics:		
		<u>Value</u>
	Trials	10000
	Mean	2.03E-01
	Median	1.79E-01
	Standard Deviation	1.16E-01
Percentiles:		
	<u>Percentile</u>	<u>rem</u>
	0.0%	1.46E-02
	2.5%	5.16E-02
	5.0%	6.49E-02
	50.0%	1.79E-01
	95.0%	4.23E-01
	97.5%	4.93E-01
	100.0%	1.07E+00



Forecast: Crew Lung Dose CDE		
Cell: D23		
Summary:		
Display Range is from 0.00E+0 to 4.50E+0 rem		
Entire Range is from 1.21E-1 to 8.89E+0 rem		
After 10,000 Trials, the Std. Error of the Mean is 9.66E-3		
Statistics:		Value
	Trials	10000
	Mean	1.69E+00
	Median	1.49E+00
	Standard Deviation	9.66E-01
Percentiles:		
	<u>Percentile</u>	<u>rem</u>
	0.0%	1.22E-01
	2.5%	4.30E-01
	5.0%	5.41E-01
	50.0%	1.49E+00
	95.0%	3.52E+00
	97.5%	4.11E+00
	100.0%	8.89E+00



Forecast: Crew Kidney Concentration		
Cell: D33		
Summary:		
Display Range is from 0.00 to 0.50 µg DU/gram of Kidney Tissue		
Entire Range is from 0.01 to 0.98 µg DU/gram of Kidney Tissue		
After 10,000 Trials, the Std. Error of the Mean is 0.00		
Statistics:		<u>Value</u>
	Trials	10000
	Mean	0.19
	Median	0.17
	Standard Deviation	0.11
Percentiles:		
	<u>Percentile</u>	<u>µg DU/gram of KidneyTissue</u>
	0.0%	0.01
	2.5%	0.05
	5.0%	0.06
	50.0%	0.17
	95.0%	0.39
	97.5%	0.45
	100.0%	0.98

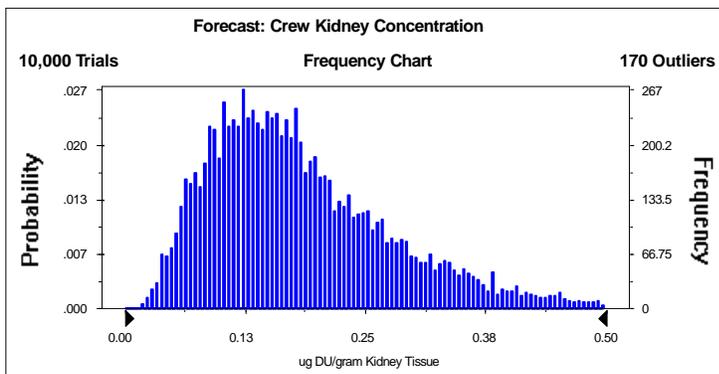


Table 33 of Part IV, Section 4.11.2 provides a summary of the Assumption 1 and Assumption 2 statistical results from the Crystal Ball Monte Carlo simulations. The  $\sigma_g$  calculated as (95 %tile/50 %tile)<sup>0.5</sup>. The  $\sigma_g$  for the crew intake of DU is 1.9 mg (286.1/78.56)<sup>0.5</sup>.

#### O.4 Selection of Upper-Bound Values for Level I Scénarios

There are several measures of central tendency. One of the most useful measures is the mean; in this case, it is the arithmetic mean. Another measure of central tendency is the median, also known as the midpoint, where exactly half of the probability distribution is less than the median value and half is greater than the median value. The median value is generally a more robust measure of central tendency, because it is not sensitive to the shape of the “tail” of a probability distribution or to the occurrence of outliers in a data set, as is the arithmetic mean. The third measure of central tendency is the mode. The mode is often referred to as the “MLV”. The mode of a continuous random variable is the value that is associated with the maximum of the probability density function.

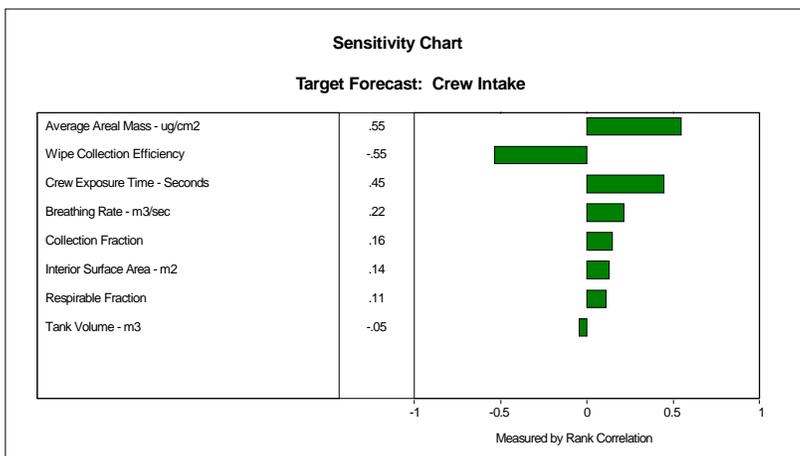
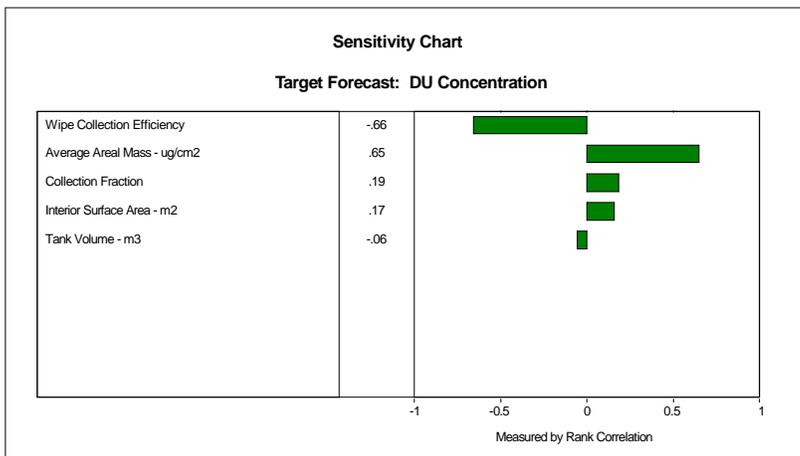
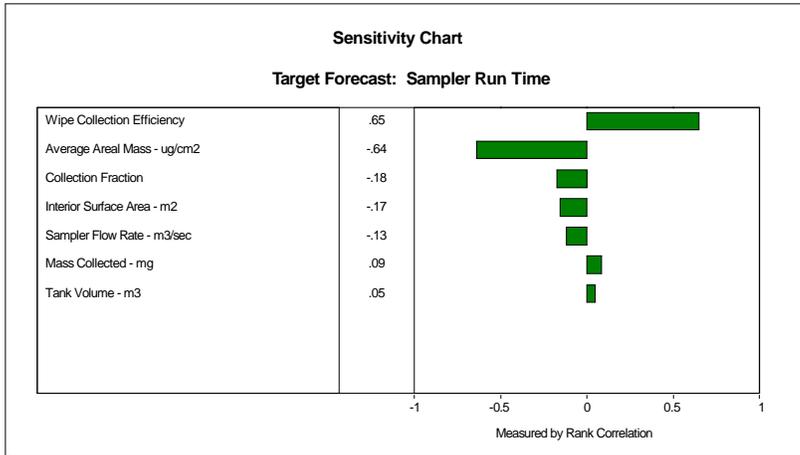
As seen in the forecast for the intake of DU (Cell D23) by the crew for Assumption 1, the display range is from 0 mg of DU to 350 mg of DU; however, the entire range is from 1.6 mg of DU to 820 mg of DU. The arithmetic mean for this distribution is 106 mg of DU, and the median is 79 mg of DU. From a review of the forecast cumulative probability distribution for 10,000 trials (or iterations), there are 288 outliers or about 3 percent of the trials. These outliers will increase the value of the mean because of the positively skewed, unimodal probability distribution. Based on this discussion and professional judgment, the 79 mg median intake of DU for Assumption 1 was used as the upper-bound value for OSAGWI Level 1 scénarios.

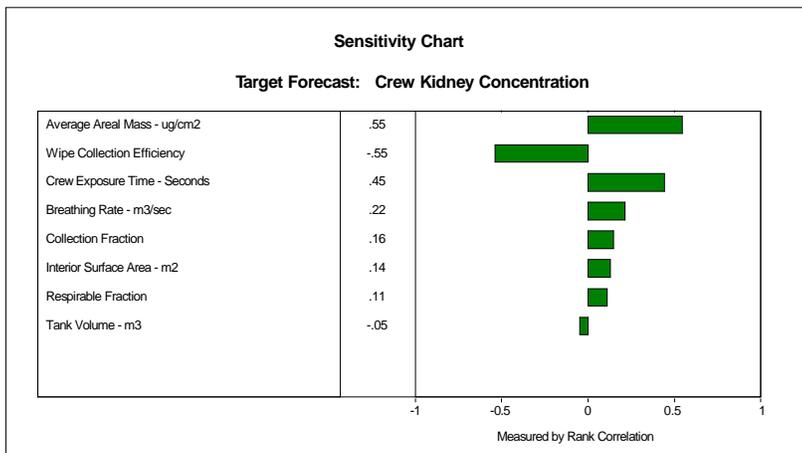
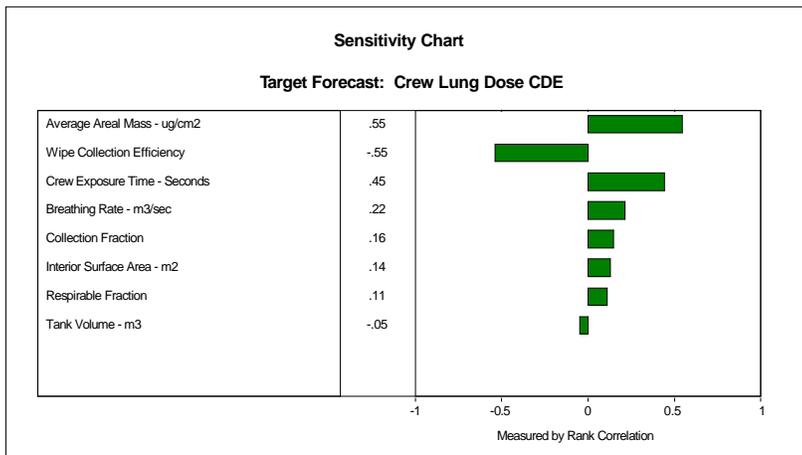
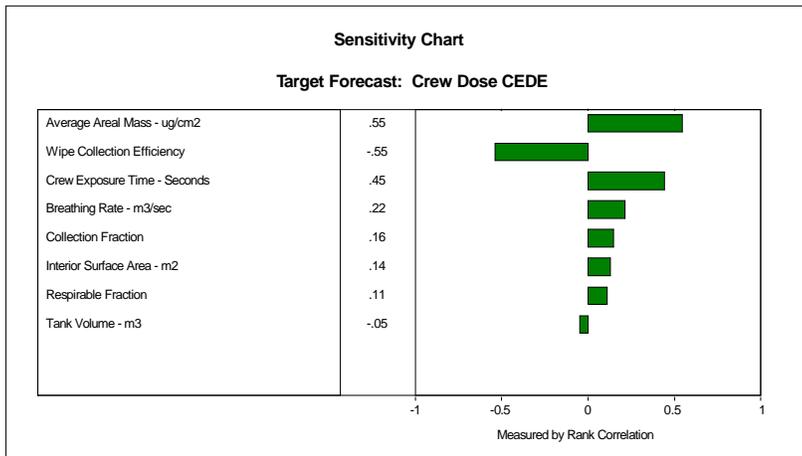
From a review of the air sampler run-times in Cell D15, the display range is from 0 minutes to 2.5 minutes, while the entire range is from 0.04 minutes to 19.5 minutes. From a review of actual reported air sampler run-times in Tables 20 and 23 for the Driver's Compartment of 2 minutes and the run-times for the air sampler above the gun breech of 248 minutes, it is reasonable to assume that a tank crewmember that was evacuating a tank involved in a fratricide incident would have received a 2-minute exposure.

### **O.5 Sensitivity Analyses**

The Sensitivity Chart provides the ability to judge the influence each assumption cell has on a particular forecast cell. During a simulation, Crystal Ball ranks the assumptions according to their importance to each forecast cell. The sensitivity chart displays these rankings as a bar chart, indicating which assumptions are the most important or least important in the model. The sensitivity charts for the various Assumption 1 and Assumption 2 forecasts are presented below.

• Assumption 1 Forecast Sensitivity Charts





- Assumption 2 Forecast Sensitivity Charts

