ALARA Assessment of Settler Sludge Sampling Methods

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL

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Purpose:

The purpose of this assessment is to compare underwater and above water settler sludge sampling methods to determine if the added cost for underwater sampling for the sole purpose of worker dose reductions is justified. Initial planning for sludge sampling included container, settler and knock-out-pot (KOP) sampling. Due to the significantly higher dose consequence of KOP sludge, a decision was made to sample KOP underwater to achieve worker dose reductions. Based on the perception that doses would be prohibitive for settler sludge also, initial plans were to utilize a similar underwater sampling apparatus for the settler sludge. Since there are no longer plans to sample KOP sludge, the decision for underwater sampling for settler sludge needs to be revisited. The present sampling plan calls for spending an estimated \$1,977,000 to design and construct a new underwater sampling system, these costs are shown in Table 9 of this document. This evaluation will compare and contrast the present method of above water sampling to the underwater method that is planned by the Sludge Treatment Project (STP) and determine if settler samples can be taken using the existing sampling cart (with potentially minor modifications) while maintaining doses to workers As Low As Reasonably Achievable (ALARA) and eliminate the need for costly redesign, testing, personnel retraining and new operating procedures.

Background:

The sludge material has been collected from various areas in the KE and KW basins and is being stored in the engineered containers (SCS-CON-210,-220,-240,-250 and -260). The project requires that samples be taken of the sludge material so that appropriate safety and operational features can be built into the transportation, storage and processing equipment to verify that the waste forms will meet the various state and federal requirements.

The present location of the six sludge containers is in the center and east bay of the K West Basin. Three containers (SCS-CON-240, -250, and -260) are filled with sludge that originated in the K East Basin. Two containers (SCS-CON-210 and -220) are filled with sludge from K West Basin. The remaining container (SCS-CON-230, presently empty) will be used for sludge that is scheduled to be transferred from the 10 settler tanks. The material that will be transferred to SCS-CON-230 is referred to as "settler" sludge, and the material from the other 5 containers (SCS-CON-210, -220, -240, -250, and -260) is referred to as "container" sludge.

Prior to the collection of settler sludge samples from SCS-CON-230, container sludge samples will be taken from SCS-CON-210, -220, -240, -250, and -260. The method scheduled to be used to conduct sampling of these first 5 containers is an above water sampling cart which is very similar to the equipment that has been used during previous sampling campaigns (see Figure 1).

The next phase of the sludge sampling will entail the sampling of the settler sludge which will have been transferred into SCS-CON-230. The method presently planned to complete settler sampling (see figure 2) differs from the container sampling method in the following ways:

- Sample bottles will be filled underwater in the basin.
- The guide, isolation, and extraction tubes will change to allow the sample material to be diverted to the sample bottles while maintaining a water cover (see Figure 3 for representation of container with isolation and guide tubes)
- A larger sample bottle set will be used so that bottles do not have to be changed during the sampling of one location
- A shielded shipping container (pig) with additional shielding is planned due to the anticipated radiological content of the sludge

The sludge that will be transferred into engineered container SCS-CON-230 is still located in the settler tanks (See Figure 4 for view of settler tanks). The material from the settler tanks is anticipated to have higher curie content and be denser than sludge that is in the remaining containers. Once the settler contents have been relocated into the engineered container, sampling will be performed. The planned sample method will use an underwater method to provide the required shielding and maintain worker dose ALARA. The resulting sample bottles will be transferred from KW Basin to the analytical laboratory using a PAS-1 cask.

While the settler sludge sampling campaign has not yet been designed, the sampling process for the remaining container sludge (SCS-CON-210,-220,-240,-250 and -260) is well understood and employs a system for above water sampling that has been successfully employed during previous sludge sampling campaigns at the K-basins (see Figure 1). Some of the ALARA features incorporated into design and operations of the container sludge sampling system include the following (these items will also be applicable to above water settler sludge sampling):

- The use of the MASF Building for mockup training.
- In Basin (dry run) Testing.
- Shielded sample cart pigs to house sample bottles, while in cart
- HEPA filters used on pump outlet and vacuum breaker vents.
- Vacuum system that precludes spray leaks during sampling and a sample cart that contains any spill that maybe encountered during sampling.
- Radiological controls have been placed into the operating procedure that include dose limits, backflushing of lines, and provisions for handling sample bottles with excessive dose rates.
- Radiological survey requirements have been incorporated in the procedure when there is a potential for individuals to encounter dose rates ≥ 100 mrem/hr. In addition, radiological action limits have been incorporated into the procedure to reduce the chance of exceeding RWP void limits.
- An engineered frame is available to cover the above water sludge sampling line with shielding.
- Handling of filled sample bottles will be minimized (no decanting of samples). A T-bar will be used to maximize the distance between the worker and the filled sample bottles, when transferring bottles from the sampling cart.

Figure 3 - Grating Level Work Platforms with isolation tubes in place

Figure 4 – Settler Tanks

Assessment:

Calculations completed during this assessment were performed using a Dell Optiplex 755, Intel Core 2 Duo processor, CHPRC Computer #WC95262. The calculations were performed using site wide licensed Microshield, version 7.02, issued under document #CHPRC-00064. The proper installation and functionality of Microshield, Version 7.02 on CHPRC computer #WC95262 has been documented in the STP Radiological Engineers field logbook by successful completion of the installed Verification and Validation, results are attached to revision 0 of KBC-40179.

This assessment performs a number of calculations to evaluate dose rates for settler sludge during various sampling activities. The methods used in this calculation are the same as were used in ALARA report KBC-37814 to determine dose rates for container sludge sampling. The dose rates calculated using methods outlined in the ALARA report were then used to determine expected person-rem doses for the settler sludge sampling evolution. This same process is outlined in Letter #09-100K-GLH-003 for container sludge. The processes outlined in these two documents were used for this assessment to determine the dose that can be anticipated if settler samples are taken above water using existing sampling equipment.

The following assumptions were used throughout this assessment and for the calculations associated with this assessment.

Assumptions:

- All samples were assumed to be based on 400 ml of sludge contained in the 4 L Nalgene bottle with 2.6 liters of basin water. The number of sample bottles per core sample will vary depending on sludge depth in the container. A total of 4 core samples will be taken with each core assumed to not exceed 1 liter, for a total of 4 liters of sludge, at a maximum of 400 ml per bottle, it is therefore assumed 10 bottles will be necessary. The 400ml is based on past sampling campaign. Since this analysis assumes a constant concentration for the sludge, varying the number of samples has little affect on the total dose received during the sampling and any difference would be bounded by the contingency already in place in this assessment.
- Source terms for settler sludge and container sludge is as described in HNF-SD-SNF-TI-015 Rev.14, Spent Nuclear Fuel Project Technical Data Book, Vol. 2, Sludge, Table 4-21 and 5-3. The resulting values have been condensed in Figure 5.0 below.
- Standard densities were used for common items: water 1.0 gm/cm³, steel 7.86 gm/cm³, air 0.00122 gm/cm³
- Settler tanks dimensions: 20 in diameter; 16 feet long; walls are schedule 10 pipe (0.25 inch thickness).
- The settler tanks are assumed to be 54% full, per the HNF-SD-SNF-TI-015 data book.
- Settler tanks contain 5.4 m³ of sludge. %volume = 5.4m³ / V (volume of single settler tank) where $V = \pi r^2 h$
- Settler tank dose measurements taken per work package 1K-07-03241 used an RO-07 with distance to center of detector of 1 inch. The 1 inch will be used as the "Contact" distance for any Microshield measurements.
- A Dose Decision Value for Optimization of \$25,000/person-rem was used.
- KW basin general area background dose rate assumes ~1mr/hr.
- The neutron dose rate from this source term is negligible compared to the photon dose rate and was not included (see calculation A21C-N-003).
- One settler sample bottle per PAS-1 Cask shipment.

- The dimensions for the KW basin sludge sample bottle are Height 54.61 cm and the OD is 16.193 cm.
- The primary exposure occurs during the sample pull and transferring of samples from the sample cart to the SSC for shipment. Minimal exposure will result from KW basin background (~1.0 mrem/h).

Figure 5.0 Sludge Source Term

STP SOURCE TERMS FOR SHIELDING AND DOSE RATE CALCULATIONS DURING CONTAINER AND SETTLER SLUDGE SAMPLING ACTIVITIES				
03/05/2009 rev 1				
Isotope	Containers 240,250 and 260 ^{2,4}	Containers 210 and 220 ^{2,4}	Settler Tanks (Container 230) ^{2,3}	K-Basin Water ^{2,7}
Am-241	1.9e+01	6.7e+01	4.8e+02	2.2e-04
Np-237	4.5e-03	7.2e-03	2.9e-02	*
Pu-238	3.5e+00	1.2e+01	6.8e+01	4.3e-05
Pu-239	1.4e+01	4.1e+01	2.9e+02	2.6e-04
Pu-240	7.7e+00	2.5e+01	1.7e+02	2.6e-04
Pu-241	4.1e+02	1.0e+03	5.9e+03	*
Pu-242	3.7e-03	1.0e-02	6.3e-02	*
Co-60	9.9e-01	1.1e+00	7.8e-01	3.4e-04
Cs-134	7.6e-02	2.5e+00	2.9e+00	1.9e-03
Cs-137	3.1e+02	1.3e+03	7.8e+03	1.2e+00
(Ba-137m) ¹	See Note 1	See Note 1	See Note 1	See Note 1
Eu-152	*	*	*	<8.0e-03
Eu-154	2.8e+00	9.4e+00	3.4e+01	<2.2e-04
Eu-155	1.4e+00	2.8e+00	1.2e+01	<5.0e-03
Sr-90	3.0e+02	1.3e+03	8.7e+03	1.5e-02
(Y-90) ¹	3.0e+02	1.3e+03	8.7e+03	See Note 1
Tc-99	1.3e-01	3.3e-01	2.1e+00	*
Sm-151	7.6e-02	2.5e+00	2.9e+00	*

- 1) Ba-137m and Y-90 assumed to be in equilibrium with parent materials Cs-137 and Sr-90, respectively, if values are not listed in table above the user can calculate values using standard health physics formulas or use values obtained when grouping photons, if using the Microshield program.
- 2) All Result are in Ci/m³ and have been rounded to 2 significant digits.
- 3) Settler Sludge is based on KW Canister sludge from Table 4-21 of HNF-SD-SNF-TI-015 rev 13A, "Spent Nuclear Fuel Project Technical Databook, Vol.2, Sludge"
- 4) Values based on source term contained in table 5-3 of HNF-SD-SNF-TI-015 rev 14 Draft, "Spent Nuclear Fuel Project Technical Databook, Vol.2, Sludge"
- 5) *= No data provided
- 6) Density values, Containers 240,250,260 - 1.43g/cm³, Containers 210,220 – 1.59 g/cm³ (from KBC-37814 rev0), Settler Sludge Density 3.0 g/cm³ (from HNF-SD-SNF-TI-015 rev 13A, table 4-1), K-basin Water Density 1.0 g/cm³ (based on conservative assessment of standard pure water density)
- 7) Values are from Table 4-1 of SNF-SD-SNF-TI-009, rev4 "105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Facilities, Volume 2, Sludge", Radiological values are conservative and are not representative of bulk basin water, for those values use HNF-SD-SNF-TI-015 table 4-22 values.
- 8) Values in tables have not been decayed and are assumed to be produced on 5/31/1998, see section 3.4 of HNF-SD-SNF-TI-015 rev 13A, "Spent Nuclear Fuel Project Technical Databook, Vol.2, Sludge"
- 9) "<" symbol identifies data that were reported as "less than" values.
- 10) Values are reference only, the values shall be verified against the source document prior to formalizing in shielding/dose rate calculations.

To compare the two calculations it was first necessary to verify that source terms identified in Figure 5 are the same and that the geometry of the source will yield similar results as are found in KBC-37814 (this is especially important in this case since different shielding codes are being employed, Microshield vs. MCNP). To accomplish this, calculations were conducted assuming an unshielded sample bottle containing 400 ml of settled sludge from each of the three defined source terms (containers 210/220, 240/250/260 and settler sludge, see Microshield runs KBC40179_1,2 and 3). Results from these runs were compared against the results in KBC-37814 and are outlined in Table 1 below:

Table 1 - Comparison of Unshielded Sample Bottle Dose Rates

Results for	Dose Rate (mr/hr)	Container 210/220	Container 240/250/260	Settler Sludge
KBC-40179_1	1 inch	18520	4541	91770
KBC-40179_2	1 foot	989.8	244.3	4569
KBC-40179_3	1 meter	122.6	30.3	557.7
	10 feet	14.5	3.58	65.4
Results from	1 cm*	23491	5196	N/A
ALARA Report	1 foot	1001	220.7	N/A
KBC-37814	1 meter	141.4	30.9	N/A
(Table 15)	10 feet	15.5	3.4	N/A

* MCNP allows for calculation of contact dose rates, the Microshield code is unreliable at distances less than 1 inch. Items N/A'ed were not part of the ALARA report calculations. It should be noted that KBC-37814 document contains an error that was discovered during the review of this document, the calculation incorrectly reports the Ba-137m levels for settler sludge, though it does not affect the results used for this calculation.

A review of the results of Table 1 shows, that the source term and geometry are comparable with results that have been calculated in the sampling of KW sludge containers ALARA report. These results allow it to be said with some certainty, that this is a good model to work from and we can scale results obtained from the ALARA report, when necessary.

With the model validated, the next step was to determine a dose reduction factor (DRF) for the settler tanks, as was completed in Table 14 of KBC-37814. The dose reduction factor is used to relate calculated doses to those that have been found with field deployed survey equipment. The dose reduction factor is determined by calculating the expected dose using the maximum source term for settler sludge, as identified in Table 2, below and modeling it in the configuration of the settler tanks. The dose reduction factor is then the ratio of the highest dose rate calculated to the highest that was obtained using underwater radiation detection equipment. The dose rate results were obtained 08/28/07 under work package 1K-07-03241 and ranged from 3.2 to 33 R/hr, the calculation will use the 33 R/hr as this yields the most conservative dose reduction factor.

To complete the calculation to determine the highest calculated dose rate, a Microshield run was completed modeling the settler tanks as follows: 20 in diameter, 16 feet long, with walls of schedule 10 steel (0.25 inches). The model was then filled with settler sludge with an assumed maximum activity that was multiplied by 54%(see assumptions). This is a conservative assessment since the model has more self shielding than would normally be evident and lowers the maximum dose rate obtained, thus reducing the dose reduction factor (see Microshield run KBC40179_4). Table 2 shows the dose reduction factor that was calculated for the settler tanks, the table also lists for comparison, the dose reduction factors calculated in KBC-37418 for the container sludge.

Table 2 Dose Reduction Factor DFR's

Container Material	Calculated Dose Rate, rem/hr	Maximum measured dose rate, rem/hr	Dose reduction factor
Settler Tank (Container 230)	363.9	33	11.0
Container 210/220	37.1	4	9.3
Container 240/250/260	12.5	9	1.4

The next portion of this assessment deals with calculating various dose rates that can be anticipated from the unshielded sludge sample bottle (USSB) containing settler sludge. This was done by modeling a source in the shape of a Nalgene bottle, that contains 400 ml of settler sludge, and evaluating it at similar distances as were modeled in calculation, KBC-37418 (see Microshield run KBC-40179_3). This same Microshield model was then used in a separate calculation that has the USSB surrounded in lead shielding that simulates the bottle being placed in the sample cart shielded containers (see Microshield run KBC-40179_5). The results are presented in Table 3 below:

Table 3 Container Dose Rates Compared to Settler Dose Rates

Source and dose point locations	Containers 210 and 220****		Containers 240/250, and 260****		Settler Sludge (Container 230)	
	Calculated Dose Rate, mrem/h***	With Dose Reduction Factor, mrem/h	Calculated dose rate, mrem/h***	With Dose Reduction Factor, mrem/h	Calculated Dose Rate, mrem/hr***	With reduction factor, mrem/h
Unshielded Sludge Sample Bottle (USSB)						
1cm/1in*	23,491.0	2,531.2	5,196.5	3,749.3	91770	8342.7
1 ft	1,001.9	108.0	220.7	159.2	4569	415
1 m	141.4	15.2	30.9	22.3	557.7	50.7
10 ft	15.5	1.7	3.4	2.5	65.4	5.9
Shielded Sample Bottle in Cart (PIG)						
1cm/1in*	165.7	17.8	35.1	25.3	469.7	42.7
1 ft	22.3	2.4	4.7	3.4	40.4	3.7
1 m	1.3	0.1	0.3	0.2	5.4	0.5
10 ft	0.2	0.0	0.0	0.0	0.6	0
Unshielded Sludge Sample Hose (USSL)**						
1cm/in*	8,388.7	903.9	1,783.4	1,286.7	38252	3477.5
1 ft	693.2	74.7	146.2	105.5	3161.0	287.4
1 m	131.7	14.2	27.9	20.2	600.5	54.6
10 ft	15.6	1.7	3.4	2.4	71.1	6.5

* Dose rates calculated using Microshield over estimate dose rates at very close distances ≤ 1 inch to the source, and should be evaluated closely prior to use.

** Unshielded sludge sample hose dose rates were determined by ratio of the ALARA report and Microshield calculation done for this assessment, the most conservative value of 4.56 was used to determine settler sludge unshielded sludge sample hose (USSL) dose rates.

***It is unlikely any dose rates will meet or exceed the calculated values, this calculation employs very conservative source terms and geometries

**** Results are from KBC-37418 and are for comparison to results found in Microshield KBC40179_1 and 2 to verify validity of model.

Using the information provided in Table 3 above, the values have been incorporated into the following tables so that the total collective doses for the workers can be compared for above water sampling of container sampling and settler sampling. The spreadsheet was developed initially to calculate the collective dose for the container sampling activities (see letter 09-100K-GLH-003). The tables below utilize the same methodology, quantity of personnel, and times for the settler sampling, only substituting dose rates calculated for settler sludge to determine the total collective dose.

Table 4
Collective Dose for Preparation of the Work Area and Setup of Sampling Equipment

	NCO's	5
	RCT's	2
	FWS	1
	Engineer	1
	TOTAL	9
<i>This does not take into account the installation of the Extraction/Isolation tubes. Which is performed under a separate work package.</i>	Hours per day for this activity =	1.0
	Shifts worked per day =	1
	Total Days Worked =	5
	Total Person-Hours =	45
	Highest Projected Dose Rate (2mr/hr) assigned (2 minutes) =	3 mrem
	Average Projected Dose Rate (1mr/hr) assigned (8 minutes) =	6 mrem
	Lowest Projected Dose Rate (0.5mr/hr) assigned (50 minutes) =	19 mrem
	Person-Dose in mrem =	28

Table 5
Collective Dose for Sample Collection

<i>Supports the collection of 2 samples/day, changing out of bottle cap assembly unit, transferring of sample bottles to SSC, and transfer of SSC to Storage/Staging area.</i>	NCO's	5
	RCT's	2
	FWS	1
	Engineer	1
	TOTAL	9
	Hours per day for this activity =	2.0
	Shifts worked per day =	1
	Total Days Worked =	5
	Total Person-Hours =	90
	Highest Projected Dose Rate (415mr/hr) assigned (2 minutes) =	1245 mrem
	Average Projected Dose Rate (50.7mr/hr) assigned (8 minutes) =	608 mrem
	Lowest Projected Dose Rate (2mr/hr) assigned (50 minutes) =	150 mrem
	Person-Dose in mrem =	2003

Table 6
Collective Dose for Sample Measurement and Shipment

<i>If core is completed, remove T-handle from extraction tube. Confirm sludge depth, lift sample bottle from SSC after 12 hrs, measure sludge height, and perform required surveys.</i>	NCO's	5
	RCT's	2
	FWS	1
	Engineer	1
	TOTAL	9
	Hours per day for this activity =	1.0
	Shifts worked per day =	1
	Total Days Worked =	5
	Total Person-Hours =	45
	Highest Projected Dose Rate (415mr/hr) assigned (2 minutes) =	622mrem
	Average Projected Dose Rate (50.7mr/hr) assigned (2 minutes) =	76 mrem
	Lowest Projected Dose Rate (2mr/hr) assigned (56 minutes) =	84 mrem
	Person-Dose in mrem =	782

Table 7
Collective Dose for Contingency Work

Assume an extra 30 days for any additional installation of extraction and isolation tubes, complications, or work delays, which do not perform sludge sampling.	NCO's	5
	RCT's	2
	FWS	1
	Engineer	1
	TOTAL	9
	Hours per day for this activity =	4.0
	Shifts worked per day =	1
	Total Days Worked =	30
	Total Person-Hours =	1080
	Highest Projected Dose Rate (2mr/hr) assigned (2 minutes) =	72 mrem
	Average Projected Dose Rate (1mr/hr) assigned (8 minutes) =	144 mrem
	Lowest Projected Dose Rate (0.5mr/hr) assigned (50 minutes) =	450 mrem
	Person-Dose in mrem =	666

Note: contingency dose accounts for work stoppages, delays, additional samples (not additional sample volume).

Table 8
Collective Dose Results

<ul style="list-style-type: none"> Assumes 10 samples pulled from Container SCS-CON-230. Assume a maximum of 5 days to pull 10 sludge samples. Average basin entry time for workers is ~4 hr/shift. Assume an extra 30 days for any additional installation of extraction and isolation tubes, complications, additional samples or work delays. Assume only day shift will support the KW Basin Sludge Sampling campaign. Spreadsheet is based letter 09-100K-GLH-003 	Activity	Collective Dose
	Preparation of the Work Area and Setup of Sampling Equipment – Table 4	28 person-mrem
	Sample Collection – Table 5	2003 person-mrem
	Sample Measurement and Shipment – Table 6	782 person-mrem
	Contingency Work – Table 7	666 person-mrem
	Total Collective Dose	3479 person-mrem
	Average Dose per Sample	348 person-mrem
	Total person-hours	1260 hours

Table 9

COST COMPARISON OF OLD PLANNED VS NEW PLAN (UTILIZING EXISTING DESIGN)

ACTIVITY DESCRIPTION		ROM TOTAL COST	REDUCED RETRIEVAL	STILL NEEDED FOR SAMPLING
		RETRIEVAL/SAMPLING	SAMPLING	NOW
SETTLER RETRIEVAL/SAMPLING BASIS OF ESTIMATE	RET/SAM	Date 10/07	Date 10/07	Date 2/09
STS0005/STS0010, Engineering Work Plans	RET/SAM	\$0	\$0	0
STT0465-STTT0525 Conceptual Design Retrieval Equipment for Sample	RET	\$518,200	\$0	0
STS0025, Conceptual Design for Settler Sampling	SAMP	\$400,000	\$400,000	0
STT0530, 535, 540 Review and Approve Test and Conceptual Design			\$0	0
STS0030, Finalize Settler Retrieval/Sampling Design	RET/SAM	\$761,200	\$380,600	\$67,320
STS0230, Design Review and Technical Support	RET/SAM	\$70,500	\$35,250	10,200
STS0035 KW Basin Prep/JCS wk pkg/ Operating Procedures	RET/SAM	\$78,300	\$39,150	\$30,600
STS0170/STS0180/STS0027 Hazard Analysis	elsewhere	\$0	\$0	0
STS0185 USQ	elsewhere	\$0	\$0	0
STS0040 Fab/Procure Retrieval/Sampling Equip	RET/SAM	\$518,000	\$259,000	192,000
STS0045 Install/Prep Equipment in basin for Settler	RET/SAM	\$702,000	\$351,000	220,320
STS0195 Readiness Review (MSA)	RET/SAM	\$324,000	\$162,000	0
STS0050 Retrieve Settler sludge	RET	\$270,000	\$0	0
STT0355, Sample Settler Container and transport	SAMP	\$350,000	\$350,000	\$350,000
SETTLER SLUDGE SAMPLING SUBTOTAL		\$3,992,200	\$1,977,000	\$870,440
TOTAL NET SAVINGS				\$1,106,560

BASIS OF NEW ESTIMATE:	FTE	DAYS	COST PER HOUR	HOUR PER DAY	TOTAL COST
FMP NEEDED TO SHOW CONFIGURATION TOP OF SCS-CON-230	3	33	\$85.00	8	\$67,320
DESIGN REVIEW (ASSSUME NO REVISION TO THERMAL/GAS)	15	1	\$85.00	8	\$10,200
WORK PACKAGE DEVELOPMENT/AJHA/EWP/WALKDOWNS	1.5	30	\$85.00	8	\$30,600
FAB PROCURE EQUIPMENT					\$0
SHIPPING PIGS 6 X 12,000					\$68,000
ISOLATIONS TUBES/EXTRACTION TUBES 4 EACH					\$12,000
GUIDE TUBES (4 EACH)					\$12,000
SAMPLE BAG/BOTTLES, CLEANING STATIONS (24)					\$10,000
WORK PLATFORM AND FRAMES AND COVERS					\$25,000
TUBING ASSEMBLIES/VALVES					\$25,000
SPARES (20) /UNKNOWN (20)					\$40,000
INSTALLATION ASSUME 18 DAYS + 3 CM/SAF/FWS	18	18	\$85.00	8	\$220,320
SYSTEM OPERATION					\$350,000
TOTALS					\$870,440

This assumes the same system that was used for container sampling will be used for settler sampling.
No 325 Building Cost, Sample receipt cost or Lab analysis cost are Included in either estimate.

Cost/Benefit Analysis:

The total collective dose anticipated for settler sampling, Table 8 above, is 3.479 person-rem, with the average per sample dose being 0.348 person-rem. This dose compares to the total anticipated collective dose for the container sludge sampling using similar sampling methods, of 5.453 person-rem, with the average per sample dose being 0.101 person-rem.

For the purpose of this assessment it is assumed that the retrieval of settler sludge via the underwater method will result in no personnel dose (most conservative estimate possible). Therefore, the cost-benefit analysis will use a total calculated person-dose for above water settler sludge sampling of 3.479 person-rem. The ALARA dose decision value for optimization is procedurally established at \$25,000/person-rem (per PRO-24889). Therefore, expenditure of funds of up to \$86,975 could be justified to avoid an estimated collective dose of 3.479 person-rem.

As a validation measure the same assessment was performed above not assuming any dose reduction factor (ie 4569 vs. 415 and 557.7 vs. 50.7, a very conservative assumption), this resulted in a total dose of approximately 28.9 person-rem and a dollar value of \$724,850, again well below the anticipated cost savings.

The change to this sampling method does not mean that the project will not incorporate ALARA concepts as the sampling campaign advances or to mitigate doses as the design evolves and sampling information is accumulated, with that in mind, the following item has been discussed by the project for possible modification prior to initiating settler sampling:

Extension of the sampling T-bar (see figure 6) presently provides 2 feet on each side of the J-hook, it is assumed that this provides a total of 3 foot to the worker, if the T-bar was extended to 4 foot on each side such that it provided a total of 5 feet of distance it would significantly reduce the doses to workers from even the data book sludge values and would be appropriate as an ALARA feature for movement of higher dose rate samples (see KBC-40179_6 for data book dose rates, these are plotted on table 10 below)

Conclusion:

While dose rates for the unshielded settler sludge samples are anticipated to be higher than container sludge sampling, the collective dose is measurably lower. Controls that have been or that will be put in place for container sludge sampling will help further reduce collective doses, and by using the same sampling technique for settler sludge, operational lessons learned can be applied. Additionally, using the sampling process that operators have experience with could contribute to fewer unanticipated radiological events, which in themselves can be a significant contributor to workers collective dose.

The current STP project cost projections to design and construct underwater settler sludge sampling equipment is estimated to be \$1,977,000 (per table 9 above). This compares to a cost estimate using the container sludge sampling system of \$870,440 (a reduction of \$1,106,560) this additional cost cannot be justified for the sole purpose of personnel dose reduction. It is understood that there may be other operational considerations (they are not evaluated in this assessment) that may warrant underwater sampling of the settler sludge, but the ALARA consideration for dose should not be a deciding factor in the path forward for settler sludge sampling.

Figure 6
T-bar Assemble

Table 10

Data Book Values Dose Rates of 400 ml of Settler Sludge versus Distance (Worst Case Sludge)

MicroShield 7.02 DOE (7.02-0000)			
Date 3/16/2009	By [Signature]	Checked [Signature]	
Filename KBC40179_1.ms7	Run Date March 5, 2009	Run Time 10:10:33 AM	Duration 00:00:02
Project Info			
Case Title	Sample Bottle Unsh		
Description	Sample Bottle from 210/220 400ml		
Geometry	7 - Cylinder Volume - Side Shields		

Source Dimensions			
Height	2.195 cm (0.9 in)		
Radius	7.62 cm (3.0 in)		
Dose Points			
A	X	Y	Z
#1	10.638 cm (4.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#2	38.578 cm (1 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#3	108.1 cm (3 ft 6.6 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#4	312.898 cm (10 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
Shields			
Shield N	Dimension	Material	Density
Source	400.4 cm ³	Water	1.59
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	.478 cm	Water	1
Top Clad	.478 cm	Water	1

Source Input: Grouping Method - Linear Energy				
Number of Groups: 25				
Lower Energy Cutoff: 0.015				
Photons < 0.015: Excluded				
Library: Grove				
Nuclide	Ci	Bq	μCi/cm ³	Bq/cm ³
Am-241	2.7027e-002	1.0000e+009	6.7500e+001	2.4975e+006
Ba-137m	4.8484e-001	1.7939e+010	1.2109e+003	4.4803e+007
Co-60	4.4044e-004	1.6296e+007	1.1000e+000	4.0700e+004
Cs-134	1.0050e-003	3.7185e+007	2.5100e+000	9.2870e+004
Cs-137	5.1251e-001	1.8963e+010	1.2800e+003	4.7360e+007
Eu-154	3.7518e-003	1.3881e+008	9.3700e+000	3.4669e+005
Eu-155	1.1171e-003	4.1333e+007	2.7900e+000	1.0323e+005
Np-237	2.8869e-006	1.0681e+005	7.2100e-003	2.6677e+002
Pu-238	4.6446e-003	1.7185e+008	1.1600e+001	4.2920e+005
Pu-239	1.6496e-002	6.1037e+008	4.1200e+001	1.5244e+006
Pu-240	1.0010e-002	3.7037e+008	2.5000e+001	9.2500e+005
Pu-241	4.1642e-001	1.5407e+010	1.0400e+003	3.8480e+007
Pu-242	4.0440e-006	1.4963e+005	1.0100e-002	3.7370e+002
Sm-151	1.0130e-003	3.7481e+007	2.5300e+000	9.3610e+004
Sr-90	5.0450e-001	1.8667e+010	1.2600e+003	4.6620e+007
Tc-99	1.3173e-004	4.8741e+006	3.2900e-001	1.2173e+004
Y-90	5.0450e-001	1.8667e+010	1.2600e+003	4.6620e+007
Buildup: The material reference is Source				
Integration Parameters				
Radial				20
Circumferential				20
Y Direction (axial)				20
Results - Dose Point # 1 - (10.63752,1.1,0) cm				

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.043	1.826e+09	2.181e+04	7.426e+04	8.047e+01	2.740e+02
0.5923	5.491e+07	1.726e+04	2.832e+04	3.372e+01	5.531e+01
0.6618	1.617e+10	5.821e+06	9.223e+06	1.128e+04	1.788e+04
0.7924	4.274e+07	1.915e+04	2.880e+04	3.647e+01	5.484e+01
0.8759	1.775e+07	8.980e+03	1.317e+04	1.689e+01	2.477e+01
1.0017	3.912e+07	2.329e+04	3.314e+04	4.292e+01	6.106e+01
1.0416	5.689e+05	3.551e+02	5.008e+02	6.498e-01	9.165e-01
1.1185	1.429e+05	9.718e+01	1.349e+02	1.754e-01	2.435e-01
1.1509	1.339e+06	9.429e+02	1.300e+03	1.692e+00	2.333e+00
1.1732	1.630e+07	1.174e+04	1.612e+04	2.098e+01	2.881e+01
1.2456	1.429e+06	1.106e+03	1.499e+03	1.950e+00	2.644e+00
1.2745	4.927e+07	3.921e+04	5.288e+04	6.876e+01	9.274e+01
1.3325	1.630e+07	1.368e+04	1.828e+04	2.373e+01	3.171e+01
1.3652	1.130e+06	9.768e+02	1.299e+03	1.684e+00	2.240e+00
1.4944	9.017e+05	8.681e+02	1.134e+03	1.462e+00	1.910e+00
1.5952	3.991e+06	4.153e+03	5.361e+03	6.869e+00	8.868e+00
Totals	1.825e+10	5.984e+06	9.499e+06	1.162e+04	1.852e+04
Results - Dose Point # 2 - (38.57752,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.043	1.826e+09	8.677e+02	3.515e+03	3.202e+00	1.297e+01
0.5923	5.491e+07	8.139e+02	1.518e+03	1.590e+00	2.964e+00
0.6618	1.617e+10	2.763e+05	4.937e+05	5.357e+02	9.571e+02
0.7924	4.274e+07	9.193e+02	1.540e+03	1.751e+00	2.932e+00
0.8759	1.775e+07	4.337e+02	7.040e+02	8.156e-01	1.324e+00
1.0017	3.912e+07	1.134e+03	1.771e+03	2.089e+00	3.264e+00
1.0416	5.689e+05	1.733e+01	2.677e+01	3.171e-02	4.900e-02
1.1185	1.429e+05	4.762e+00	7.212e+00	8.596e-03	1.302e-02
1.1509	1.339e+06	4.628e+01	6.953e+01	8.304e-02	1.248e-01
1.1732	1.630e+07	5.768e+02	8.621e+02	1.031e+00	1.541e+00
1.2456	1.429e+06	5.454e+01	8.019e+01	9.617e-02	1.414e-01
1.2745	4.927e+07	1.936e+03	2.828e+03	3.395e+00	4.960e+00
1.3325	1.630e+07	6.771e+02	9.777e+02	1.175e+00	1.696e+00
1.3652	1.130e+06	4.842e+01	6.948e+01	8.349e-02	1.198e-01
1.4944	9.017e+05	4.324e+01	6.068e+01	7.282e-02	1.022e-01
1.5952	3.991e+06	2.076e+02	2.870e+02	3.434e-01	4.748e-01
Totals	1.825e+10	2.841e+05	5.080e+05	5.515e+02	9.898e+02
Results - Dose Point # 3 - (108.1,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.043	1.826e+09	1.001e+02	4.231e+02	3.693e-01	1.561e+00
0.5923	5.491e+07	9.801e+01	1.881e+02	1.914e-01	3.675e-01
0.6618	1.617e+10	3.333e+04	6.119e+04	6.461e+01	1.186e+02
0.7924	4.274e+07	1.112e+02	1.908e+02	2.117e-01	3.633e-01
0.8759	1.775e+07	5.252e+01	8.724e+01	9.877e-02	1.641e-01
1.0017	3.912e+07	1.376e+02	2.195e+02	2.535e-01	4.045e-01
1.0416	5.689e+05	2.103e+00	3.318e+00	3.849e-03	6.072e-03
1.1185	1.429e+05	5.787e-01	8.939e-01	1.045e-03	1.613e-03
1.1509	1.339e+06	5.626e+00	8.618e+00	1.010e-02	1.546e-02
1.1732	1.630e+07	7.014e+01	1.068e+02	1.253e-01	1.909e-01
1.2456	1.429e+06	6.638e+00	9.939e+00	1.170e-02	1.752e-02
1.2745	4.927e+07	2.357e+02	3.506e+02	4.133e-01	6.149e-01

1.3325	1.630e+07	8.247e+01	1.212e+02	1.431e-01	2.103e-01
1.3652	1.130e+06	5.899e+00	8.613e+00	1.017e-02	1.485e-02
1.4944	9.017e+05	5.275e+00	7.524e+00	8.883e-03	1.267e-02
1.5952	3.991e+06	2.534e+01	3.559e+01	4.192e-02	5.887e-02
Totals	1.825e+10	3.427e+04	6.296e+04	6.651e+01	1.226e+02
Results - Dose Point # 4 - (3.13e+02,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.043	1.826e+09	1.104e+01	4.903e+01	4.073e-02	1.809e-01
0.5923	5.491e+07	1.131e+01	2.224e+01	2.209e-02	4.343e-02
0.6618	1.617e+10	3.852e+03	7.232e+03	7.467e+00	1.402e+01
0.7924	4.274e+07	1.288e+01	2.254e+01	2.452e-02	4.293e-02
0.8759	1.775e+07	6.090e+00	1.031e+01	1.145e-02	1.939e-02
1.0017	3.912e+07	1.598e+01	2.594e+01	2.945e-02	4.780e-02
1.0416	5.689e+05	2.444e-01	3.921e-01	4.473e-04	7.175e-04
1.1185	1.429e+05	6.730e-02	1.056e-01	1.215e-04	1.907e-04
1.1509	1.339e+06	6.545e-01	1.018e+00	1.174e-03	1.827e-03
1.1732	1.630e+07	8.162e+00	1.263e+01	1.459e-02	2.256e-02
1.2456	1.429e+06	7.729e-01	1.175e+00	1.363e-03	2.071e-03
1.2745	4.927e+07	2.745e+01	4.143e+01	4.814e-02	7.266e-02
1.3325	1.630e+07	9.610e+00	1.432e+01	1.667e-02	2.485e-02
1.3652	1.130e+06	6.876e-01	1.018e+00	1.186e-03	1.755e-03
1.4944	9.017e+05	6.154e-01	8.893e-01	1.036e-03	1.498e-03
1.5952	3.991e+06	2.959e+00	4.207e+00	4.895e-03	6.959e-03
Totals	1.825e+10	3.960e+03	7.439e+03	7.685e+00	1.449e+01

MicroShield 7.02
DOE (7.02-0000)

Date 3/16/2009	By L	Checked RE
Filename KBC40179_2.ms7	Run Date March 5, 2009	Run Time 10:14:11 AM
Duration 00:00:02		
Project Info		
Case Title	Sample Bottle Unsh	
Description	Sample Bottle 240/250/260 400ml	
Geometry	7 - Cylinder Volume - Side Shields	

Source Dimensions			
Height	2.195 cm (0.9 in)		
Radius	7.62 cm (3.0 in)		
Dose Points			
A	X	Y	Z
#1	10.638 cm (4.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#2	38.578 cm (1 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#3	108.1 cm (3 ft 6.6 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#4	312.898 cm (10 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
Shields			
Shield N	Dimension	Material	Density
Source	400.4 cm ³	Water	1.43
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	.478 cm	Water	1

Source Input: Grouping Method - Linear Energy				
Number of Groups: 25				
Lower Energy Cutoff: 0.015				
Photons < 0.015: Excluded				
Library: Grove				
Nuclide	Ci	Bq	μCi/cm ³	Bq/cm ³
Am-241	7.7277e-003	2.8593e+008	1.9300e+001	7.1410e+005
Ba-137m	1.1591e-001	4.2885e+009	2.8948e+002	1.0711e+007
Co-60	3.9800e-004	1.4726e+007	9.9400e-001	3.6778e+004
Cs-134	3.0470e-005	1.1274e+006	7.6100e-002	2.8157e+003
Cs-137	1.2252e-001	4.5333e+009	3.0600e+002	1.1322e+007
Eu-154	1.1091e-003	4.1037e+007	2.7700e+000	1.0249e+005
Eu-155	5.7658e-004	2.1333e+007	1.4400e+000	5.3280e+004
Np-237	1.8018e-006	6.6667e+004	4.5000e-003	1.6650e+002
Pu-238	1.4174e-003	5.2444e+007	3.5400e+000	1.3098e+005
Pu-239	5.6056e-005	2.0741e+006	1.4000e-001	5.1800e+003
Pu-240	3.0711e-003	1.1363e+008	7.6700e+000	2.8379e+005
Pu-241	1.6537e-001	6.1185e+009	4.1300e+002	1.5281e+007
Pu-242	1.4815e-006	5.4815e+004	3.7000e-003	1.3690e+002
Sm-151	3.0470e-005	1.1274e+006	7.6100e-002	2.8157e+003
Sr-90	1.2132e-001	4.4889e+009	3.0300e+002	1.1211e+007
Tc-99	5.3654e-005	1.9852e+006	1.3400e-001	4.9580e+003
Y-90	1.2132e-001	4.4889e+009	3.0300e+002	1.1211e+007
Buildup: The material reference is Source				
Integration Parameters				
Radial				20
Circumferential				20
Y Direction (axial)				20
Results - Dose Point # 1 - (10.638,1.1,0) cm				

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.045	4.691e+08	6.461e+03	2.249e+04	2.146e+01	7.470e+01
0.5816	4.112e+06	1.324e+03	2.118e+03	2.589e+00	4.142e+00
0.6618	3.869e+09	1.456e+06	2.241e+06	2.822e+03	4.344e+03
0.7814	3.350e+06	1.539e+03	2.262e+03	2.936e+00	4.315e+00
0.8759	5.247e+06	2.765e+03	3.955e+03	5.200e+00	7.438e+00
1.0017	1.157e+07	7.159e+03	9.948e+03	1.319e+01	1.833e+01
1.046	6.954e+04	4.533e+01	6.241e+01	8.289e-02	1.141e-01
1.1185	4.224e+04	2.983e+01	4.049e+01	5.384e-02	7.308e-02
1.1372	2.184e+05	1.573e+02	2.127e+02	2.829e-01	3.827e-01
1.1732	1.473e+07	1.101e+04	1.479e+04	1.967e+01	2.643e+01
1.2456	4.224e+05	3.390e+02	4.500e+02	5.978e-01	7.934e-01
1.2745	1.457e+07	1.201e+04	1.587e+04	2.107e+01	2.783e+01
1.3325	1.473e+07	1.280e+04	1.676e+04	2.221e+01	2.909e+01
1.3652	3.427e+04	3.067e+01	3.997e+01	5.288e-02	6.892e-02
1.4944	2.666e+05	2.654e+02	3.402e+02	4.470e-01	5.729e-01
1.5952	1.180e+06	1.269e+03	1.608e+03	2.098e+00	2.660e+00
Totals	4.408e+09	1.513e+06	2.332e+06	2.934e+03	4.541e+03
Results - Dose Point # 2 - (38.578,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.045	4.691e+08	2.639e+02	1.108e+03	8.765e-01	3.680e+00
0.5816	4.112e+06	6.328e+01	1.143e+02	1.237e-01	2.235e-01
0.6618	3.869e+09	7.009e+04	1.207e+05	1.359e+02	2.340e+02
0.7814	3.350e+06	7.482e+01	1.217e+02	1.427e-01	2.321e-01
0.8759	5.247e+06	1.353e+02	2.127e+02	2.544e-01	4.000e-01
1.0017	1.157e+07	3.529e+02	5.349e+02	6.503e-01	9.857e-01
1.046	6.954e+04	2.240e+00	3.356e+00	4.095e-03	6.137e-03
1.1185	4.224e+04	1.479e+00	2.177e+00	2.670e-03	3.930e-03
1.1372	2.184e+05	7.806e+00	1.144e+01	1.404e-02	2.058e-02
1.1732	1.473e+07	5.472e+02	7.953e+02	9.779e-01	1.421e+00
1.2456	4.224e+05	1.691e+01	2.420e+01	2.981e-02	4.266e-02
1.2745	1.457e+07	5.999e+02	8.534e+02	1.052e+00	1.497e+00
1.3325	1.473e+07	6.408e+02	9.016e+02	1.112e+00	1.564e+00
1.3652	3.427e+04	1.537e+00	2.149e+00	2.650e-03	3.706e-03
1.4944	2.666e+05	1.336e+01	1.830e+01	2.250e-02	3.082e-02
1.5952	1.180e+06	6.408e+01	8.653e+01	1.060e-01	1.431e-01
Totals	4.408e+09	7.287e+04	1.255e+05	1.412e+02	2.443e+02
Results - Dose Point # 3 - (108.1,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.045	4.691e+08	3.060e+01	1.344e+02	1.016e-01	4.465e-01
0.5816	4.112e+06	7.639e+00	1.419e+01	1.494e-02	2.775e-02
0.6618	3.869e+09	8.477e+03	1.498e+04	1.643e+01	2.905e+01
0.7814	3.350e+06	9.070e+00	1.510e+01	1.730e-02	2.880e-02
0.8759	5.247e+06	1.643e+01	2.639e+01	3.089e-02	4.963e-02
1.0017	1.157e+07	4.292e+01	6.637e+01	7.909e-02	1.223e-01
1.046	6.954e+04	2.725e-01	4.164e-01	4.984e-04	7.615e-04
1.1185	4.224e+04	1.802e-01	2.701e-01	3.252e-04	4.876e-04
1.1372	2.184e+05	9.510e-01	1.419e+00	1.711e-03	2.553e-03
1.1732	1.473e+07	6.669e+01	9.869e+01	1.192e-01	1.764e-01
1.2456	4.224e+05	2.062e+00	3.003e+00	3.636e-03	5.294e-03
1.2745	1.457e+07	7.319e+01	1.059e+02	1.283e-01	1.857e-01

1.3325	1.473e+07	7.822e+01	1.119e+02	1.357e-01	1.941e-01
1.3652	3.427e+04	1.876e-01	2.667e-01	3.236e-04	4.600e-04
1.4944	2.666e+05	1.633e+00	2.271e+00	2.751e-03	3.825e-03
1.5952	1.180e+06	7.838e+00	1.074e+01	1.297e-02	1.776e-02
Totals	4.408e+09	8.815e+03	1.558e+04	1.708e+01	3.031e+01
Results - Dose Point # 4 - (312.898,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.045	4.691e+08	3.386e+00	1.567e+01	1.125e-02	5.203e-02
0.5816	4.112e+06	8.822e-01	1.679e+00	1.725e-03	3.282e-03
0.6618	3.869e+09	9.805e+02	1.772e+03	1.901e+00	3.435e+00
0.7814	3.350e+06	1.051e+00	1.785e+00	2.005e-03	3.405e-03
0.8759	5.247e+06	1.906e+00	3.120e+00	3.585e-03	5.867e-03
1.0017	1.157e+07	4.989e+00	7.847e+00	9.194e-03	1.446e-02
1.046	6.954e+04	3.170e-02	4.923e-02	5.796e-05	9.003e-05
1.1185	4.224e+04	2.097e-02	3.194e-02	3.785e-05	5.765e-05
1.1372	2.184e+05	1.107e-01	1.678e-01	1.992e-04	3.019e-04
1.1732	1.473e+07	7.766e+00	1.167e+01	1.388e-02	2.085e-02
1.2456	4.224e+05	2.403e-01	3.550e-01	4.237e-04	6.260e-04
1.2745	1.457e+07	8.531e+00	1.252e+01	1.496e-02	2.196e-02
1.3325	1.473e+07	9.122e+00	1.323e+01	1.583e-02	2.295e-02
1.3652	3.427e+04	2.189e-02	3.154e-02	3.775e-05	5.439e-05
1.4944	2.666e+05	1.907e-01	2.685e-01	3.212e-04	4.523e-04
1.5952	1.180e+06	9.158e-01	1.270e+00	1.515e-03	2.101e-03
Totals	4.408e+09	1.020e+03	1.842e+03	1.976e+00	3.584e+00

MicroShield 7.02 DOE (7.02-0000)				
Date	By	Checked		
3/16/2009	L	ea		
Filename	Run Date	Run Time	Duration	
KBC40179_3.ms7	March 5, 2009	10:16:44 AM	00:00:02	
Project Info				
Case Title	Sample Bottle Unsh			
Description	Sample Bottle Settler 400ml			
Geometry	7 - Cylinder Volume - Side Shields			
Source Dimensions				
Height	2.195 cm (0.9 in)			
Radius	7.62 cm (3.0 in)			
Dose Points				
A	X	Y	Z	
#1	10.638 cm (4.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)	
#2	38.578 cm (1 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)	
#3	108.1 cm (3 ft 6.6 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)	
#4	312.898 cm (10 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)	
Shields				
Shield N	Dimension	Material	Density	
Source	400.4 cm ³	Concrete	3	
Transition		Air	0.00122	
Air Gap		Air	0.00122	
Wall Clad	.478 cm	Water	1	

Source Input: Grouping Method - Linear Energy				
Number of Groups: 25				
Lower Energy Cutoff: 0.015				
Photons < 0.015: Excluded				
Library: Grove				
Nuclide	Ci	Bq	μCi/cm ³	Bq/cm ³
Am-241	1.9139e-001	7.0815e+009	4.7800e+002	1.7686e+007
Ba-137m	2.9583e+000	1.0946e+011	7.3883e+003	2.7337e+008
Co-60	3.1071e-004	1.1496e+007	7.7600e-001	2.8712e+004
Cs-134	1.1411e-003	4.2222e+007	2.8500e+000	1.0545e+005
Cs-137	3.1271e+000	1.1570e+011	7.8100e+003	2.8897e+008
Eu-154	1.3493e-002	4.9926e+008	3.3700e+001	1.2469e+006
Eu-155	4.7247e-003	1.7481e+008	1.1800e+001	4.3660e+005
Np-237	1.1451e-005	4.2370e+005	2.8600e-002	1.0582e+003
Pu-238	2.7227e-002	1.0074e+009	6.8000e+001	2.5160e+006
Pu-239	1.1491e-001	4.2519e+009	2.8700e+002	1.0619e+007
Pu-240	6.9269e-002	2.5630e+009	1.7300e+002	6.4010e+006
Pu-241	2.3704e+000	8.7704e+010	5.9200e+003	2.1904e+008
Pu-242	2.5065e-005	9.2741e+005	6.2600e-002	2.3162e+003
Sm-151	1.1411e-003	4.2222e+007	2.8500e+000	1.0545e+005
Sr-90	3.4995e+000	1.2948e+011	8.7400e+003	3.2338e+008
Tc-99	8.4484e-004	3.1259e+007	2.1100e+000	7.8070e+004
Y-90	3.4995e+000	1.2948e+011	8.7400e+003	3.2338e+008

Buildup: The material reference is Source	
Integration Parameters	
Radial	20
Circumferential	20
Y Direction (axial)	20

Results - Dose Point # 1 - (10.638,1.1,0) cm
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Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	4.190e+04	6.121e+04	1.652e+02	2.414e+02
0.5875	8.505e+07	2.005e+04	3.587e+04	3.918e+01	7.010e+01
0.6617	9.861e+10	2.708e+07	4.681e+07	5.249e+04	9.075e+04
0.7873	6.758e+07	2.320e+04	3.827e+04	4.420e+01	7.293e+01
0.8759	6.383e+07	2.512e+04	4.034e+04	4.723e+01	7.587e+01
1.0017	1.407e+08	6.576e+04	1.022e+05	1.212e+02	1.883e+02
1.0441	1.131e+06	5.574e+02	8.576e+02	1.020e+00	1.569e+00
1.1185	5.139e+05	2.766e+02	4.184e+02	4.992e-01	7.553e-01
1.1421	3.170e+06	1.752e+03	2.638e+03	3.149e+00	4.740e+00
1.1732	1.150e+07	6.575e+03	9.835e+03	1.175e+01	1.758e+01
1.2456	5.139e+06	3.173e+03	4.679e+03	5.594e+00	8.249e+00
1.2745	1.772e+08	1.126e+05	1.652e+05	1.975e+02	2.898e+02
1.3325	1.150e+07	7.733e+03	1.123e+04	1.342e+01	1.948e+01
1.3652	1.284e+06	8.903e+02	1.286e+03	1.535e+00	2.218e+00
1.4944	3.243e+06	2.522e+03	3.574e+03	4.248e+00	6.019e+00
1.5952	1.435e+07	1.212e+04	1.696e+04	2.005e+01	2.805e+01
Totals	1.104e+11	2.740e+07	4.730e+07	5.317e+04	9.177e+04
Results - Dose Point # 2 - (38.578,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	1.358e+03	2.024e+03	5.354e+00	7.981e+00
0.5875	8.505e+07	8.667e+02	1.781e+03	1.694e+00	3.480e+00
0.6617	9.861e+10	1.182e+06	2.332e+06	2.291e+03	4.522e+03
0.7873	6.758e+07	1.026e+03	1.917e+03	1.956e+00	3.653e+00
0.8759	6.383e+07	1.121e+03	2.027e+03	2.108e+00	3.813e+00
1.0017	1.407e+08	2.967e+03	5.156e+03	5.468e+00	9.502e+00
1.0441	1.131e+06	2.524e+01	4.332e+01	4.616e-02	7.925e-02
1.1185	5.139e+05	1.259e+01	2.118e+01	2.273e-02	3.824e-02
1.1421	3.170e+06	7.990e+01	1.336e+02	1.436e-01	2.401e-01
1.1732	1.150e+07	3.005e+02	4.986e+02	5.370e-01	8.910e-01
1.2456	5.139e+06	1.457e+02	2.376e+02	2.569e-01	4.190e-01
1.2745	1.772e+08	5.182e+03	8.398e+03	9.089e+00	1.473e+01
1.3325	1.150e+07	3.570e+02	5.715e+02	6.194e-01	9.915e-01
1.3652	1.284e+06	4.119e+01	6.550e+01	7.102e-02	1.129e-01
1.4944	3.243e+06	1.175e+02	1.825e+02	1.979e-01	3.074e-01
1.5952	1.435e+07	5.675e+02	8.677e+02	9.387e-01	1.435e+00
Totals	1.104e+11	1.196e+06	2.356e+06	2.319e+03	4.569e+03
Results - Dose Point # 3 - (108.1,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	1.509e+02	2.269e+02	5.949e-01	8.946e-01
0.5875	8.505e+07	1.027e+02	2.172e+02	2.006e-01	4.244e-01
0.6617	9.861e+10	1.403e+05	2.847e+05	2.719e+02	5.520e+02
0.7873	6.758e+07	1.222e+02	2.344e+02	2.329e-01	4.466e-01
0.8759	6.383e+07	1.338e+02	2.480e+02	2.515e-01	4.664e-01
1.0017	1.407e+08	3.549e+02	6.314e+02	6.539e-01	1.163e+00
1.0441	1.131e+06	3.020e+00	5.306e+00	5.525e-03	9.706e-03
1.1185	5.139e+05	1.509e+00	2.596e+00	2.724e-03	4.686e-03
1.1421	3.170e+06	9.579e+00	1.637e+01	1.722e-02	2.943e-02
1.1732	1.150e+07	3.604e+01	6.112e+01	6.441e-02	1.092e-01
1.2456	5.139e+06	1.749e+01	2.914e+01	3.084e-02	5.138e-02
1.2745	1.772e+08	6.225e+02	1.030e+03	1.092e+00	1.806e+00

1.3325	1.150e+07	4.292e+01	7.012e+01	7.446e-02	1.217e-01
1.3652	1.284e+06	4.953e+00	8.037e+00	8.541e-03	1.386e-02
1.4944	3.243e+06	1.415e+01	2.241e+01	2.383e-02	3.775e-02
1.5952	1.435e+07	6.843e+01	1.066e+02	1.132e-01	1.763e-01
Totals	1.104e+11	1.420e+05	2.876e+05	2.753e+02	5.577e+02
Results - Dose Point # 4 - (312.898,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	1.647e+01	2.517e+01	6.496e-02	9.925e-02
0.5875	8.505e+07	1.178e+01	2.546e+01	2.302e-02	4.975e-02
0.6617	9.861e+10	1.612e+04	3.339e+04	3.125e+01	6.473e+01
0.7873	6.758e+07	1.408e+01	2.750e+01	2.683e-02	5.241e-02
0.8759	6.383e+07	1.543e+01	2.912e+01	2.902e-02	5.476e-02
1.0017	1.407e+08	4.101e+01	7.417e+01	7.557e-02	1.367e-01
1.0441	1.131e+06	3.492e-01	6.235e-01	6.388e-04	1.140e-03
1.1185	5.139e+05	1.746e-01	3.051e-01	3.152e-04	5.507e-04
1.1421	3.170e+06	1.109e+00	1.925e+00	1.993e-03	3.459e-03
1.1732	1.150e+07	4.174e+00	7.185e+00	7.459e-03	1.284e-02
1.2456	5.139e+06	2.027e+00	3.427e+00	3.574e-03	6.042e-03
1.2745	1.772e+08	7.216e+01	1.211e+02	1.265e-01	2.124e-01
1.3325	1.150e+07	4.978e+00	8.247e+00	8.636e-03	1.431e-02
1.3652	1.284e+06	5.746e-01	9.454e-01	9.909e-04	1.630e-03
1.4944	3.243e+06	1.644e+00	2.637e+00	2.768e-03	4.442e-03
1.5952	1.435e+07	7.953e+00	1.255e+01	1.316e-02	2.075e-02
Totals	1.104e+11	1.631e+04	3.373e+04	3.164e+01	6.540e+01

MicroShield 7.02
DOE (7.02-0000)

Date 3/16/2009	By L	Checked DE
Filename KBC40179_4.ms7	Run Date March 5, 2009	Run Time 2:23:22 PM
Duration 00:00:02		
Project Info		
Case Title	Settler Sludge Tank	
Description	Settler Tanks 54% Full of Sludge, Max Dose DRF	
Geometry	7 - Cylinder Volume - Side Shields	

Source Dimensions			
Height		487.68 cm (16 ft)	
Radius		25.4 cm (10.0 in)	
Dose Points			
A	X	Y	Z
#1	28.575 cm (11.3 in)	243.84 cm (8 ft)	0.0 cm (0.0 in)
#2	31.115 cm (1 ft 0.2 in)	243.84 cm (8 ft)	0.0 cm (0.0 in)
#3	56.515 cm (1 ft 10.3 in)	243.84 cm (8 ft)	0.0 cm (0.0 in)
Shields			
Shield N	Dimension	Material	Density
Source	9.88e+05 cm³	Concrete	3
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	.635 cm	Iron	7.86

Source Input: Grouping Method - Linear Energy					
Number of Groups: 25					
Lower Energy Cutoff: 0.015					
Photons < 0.015: Excluded					
Library: Grove					
Nuclide	Ci	Bq	μCi/cm³	Bq/cm³	
Am-241	2.5502e+002	9.4357e+012	2.5800e+002	9.5460e+006	
Ba-137m	3.9366e+003	1.4566e+014	3.9827e+003	1.4736e+008	
Co-60	4.1416e-001	1.5324e+010	4.1900e-001	1.5503e+004	
Cs-134	1.5222e+000	5.6322e+010	1.5400e+000	5.6980e+004	
Cs-137	4.1614e+003	1.5397e+014	4.2100e+003	1.5577e+008	
Eu-154	1.8187e+001	6.7293e+011	1.8400e+001	6.8080e+005	
Eu-155	6.3260e+000	2.3406e+011	6.4000e+000	2.3680e+005	
Np-237	1.5222e-002	5.6322e+008	1.5400e-002	5.6980e+002	
Pu-238	3.6276e+001	1.3422e+012	3.6700e+001	1.3579e+006	
Pu-239	1.5321e+002	5.6687e+012	1.5500e+002	5.7350e+006	
Pu-240	9.1925e+001	3.4012e+012	9.3000e+001	3.4410e+006	
Pu-241	3.1630e+003	1.1703e+014	3.2000e+003	1.1840e+008	
Pu-242	3.3409e-002	1.2361e+009	3.3800e-002	1.2506e+003	
Sm-151	1.4332e+000	5.3030e+010	1.4500e+000	5.3650e+004	
Sr-90	4.6655e+003	1.7262e+014	4.7200e+003	1.7464e+008	
Tc-99	1.1268e+000	4.1693e+010	1.1400e+000	4.2180e+004	
Y-90	4.6655e+003	1.7262e+014	4.7200e+003	1.7464e+008	
Buildup: The material reference is Source					
Integration Parameters					
Radial				20	
Circumferential				20	
Y Direction (axial)				20	
Results - Dose Point # 1 - (28.575,243.84,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup

0.0419	1.492e+13	1.208e-04	4.623e-04	4.754e-07	1.819e-06
0.5874	1.139e+11	4.857e+04	1.608e+05	9.492e+01	3.143e+02
0.6617	1.312e+14	6.858e+07	2.153e+08	1.329e+05	4.173e+05
0.7873	9.054e+10	6.369e+04	1.857e+05	1.214e+02	3.538e+02
0.8759	8.603e+10	7.266e+04	2.027e+05	1.366e+02	3.812e+02
1.0017	1.897e+11	2.017e+05	5.330e+05	3.717e+02	9.823e+02
1.0441	1.519e+09	1.734e+03	4.509e+03	3.173e+00	8.248e+00
1.1185	6.927e+08	8.906e+02	2.253e+03	1.608e+00	4.067e+00
1.1421	4.262e+09	5.680e+03	1.425e+04	1.021e+01	2.562e+01
1.1732	1.532e+10	2.139e+04	5.312e+04	3.822e+01	9.492e+01
1.2456	6.927e+09	1.071e+04	2.601e+04	1.889e+01	4.586e+01
1.2745	2.389e+11	3.843e+05	9.249e+05	6.739e+02	1.622e+03
1.3325	1.532e+10	2.661e+04	6.299e+04	4.616e+01	1.093e+02
1.3652	1.712e+09	3.098e+03	7.272e+03	5.343e+00	1.254e+01
1.4944	4.371e+09	9.227e+03	2.098e+04	1.554e+01	3.534e+01
1.5952	1.935e+10	4.561e+04	1.015e+05	7.545e+01	1.679e+02
Totals	1.469e+14	6.947e+07	2.176e+08	1.346e+05	4.215e+05

Results - Dose Point # 2 - (31.115,243.84,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.492e+13	1.207e-03	4.374e-03	4.749e-06	1.721e-05
0.5874	1.139e+11	4.141e+04	1.387e+05	8.092e+01	2.710e+02
0.6617	1.312e+14	5.852e+07	1.858e+08	1.134e+05	3.603e+05
0.7873	9.054e+10	5.443e+04	1.605e+05	1.037e+02	3.058e+02
0.8759	8.603e+10	6.215e+04	1.754e+05	1.169e+02	3.298e+02
1.0017	1.897e+11	1.727e+05	4.616e+05	3.183e+02	8.506e+02
1.0441	1.519e+09	1.486e+03	3.906e+03	2.719e+00	7.144e+00
1.1185	6.927e+08	7.636e+02	1.953e+03	1.378e+00	3.525e+00
1.1421	4.262e+09	4.871e+03	1.235e+04	8.755e+00	2.220e+01
1.1732	1.532e+10	1.835e+04	4.604e+04	3.279e+01	8.228e+01
1.2456	6.927e+09	9.198e+03	2.256e+04	1.622e+01	3.977e+01
1.2745	2.389e+11	3.300e+05	8.022e+05	5.787e+02	1.407e+03
1.3325	1.532e+10	2.286e+04	5.465e+04	3.965e+01	9.482e+01
1.3652	1.712e+09	2.662e+03	6.310e+03	4.591e+00	1.088e+01
1.4944	4.371e+09	7.936e+03	1.822e+04	1.337e+01	3.068e+01
1.5952	1.935e+10	3.926e+04	8.818e+04	6.494e+01	1.459e+02
Totals	1.469e+14	5.928e+07	1.878e+08	1.148e+05	3.639e+05

Results - Dose Point # 3 - (56.515,243.84,0) cm

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.492e+13	1.285e-03	4.504e-03	5.056e-06	1.772e-05
0.5874	1.139e+11	2.024e+04	6.844e+04	3.956e+01	1.337e+02
0.6617	1.312e+14	2.864e+07	9.170e+07	5.552e+04	1.778e+05
0.7873	9.054e+10	2.667e+04	7.918e+04	5.083e+01	1.509e+02
0.8759	8.603e+10	3.048e+04	8.651e+04	5.732e+01	1.627e+02
1.0017	1.897e+11	8.479e+04	2.277e+05	1.563e+02	4.196e+02
1.0441	1.519e+09	7.297e+02	1.926e+03	1.335e+00	3.524e+00
1.1185	6.927e+08	3.751e+02	9.631e+02	6.770e-01	1.739e+00
1.1421	4.262e+09	2.393e+03	6.094e+03	4.301e+00	1.095e+01
1.1732	1.532e+10	9.014e+03	2.271e+04	1.611e+01	4.059e+01
1.2456	6.927e+09	4.520e+03	1.113e+04	7.970e+00	1.962e+01
1.2745	2.389e+11	1.622e+05	3.957e+05	2.844e+02	6.939e+02
1.3325	1.532e+10	1.124e+04	2.696e+04	1.949e+01	4.677e+01
1.3652	1.712e+09	1.309e+03	3.113e+03	2.257e+00	5.367e+00
1.4944	4.371e+09	3.903e+03	8.986e+03	6.574e+00	1.513e+01

1.5952	1.935e+10	1.931e+04	4.350e+04	3.195e+01	7.195e+01
Totals	1.469e+14	2.901e+07	9.268e+07	5.620e+04	1.795e+05

MicroShield 7.02
DOE (7.02-0000)

Date	By	Checked	
3/16/2009	L	JE	
Filename	Run Date	Run Time	Duration
KBC40179_5.ms7	March 5, 2009	2:26:13 PM	00:00:02
Project Info			
Case Title	Sample Bottle Shield		
Description	Sample Bottle Settler 400ml in cart shield (1.4in Pb)		
Geometry	7 - Cylinder Volume - Side Shields		

Source Dimensions			
Height	2.195 cm (0.9 in)		
Radius	7.62 cm (3.0 in)		
Dose Points			
A	X	Y	Z
#1	14.194 cm (5.6 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#2	42.164 cm (1 ft 4.6 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#3	111.654 cm (3 ft 8.0 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#4	316.382 cm (10 ft 4.6 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
Shields			
Shield N	Dimension	Material	Density
Source	400.4 cm ³	Concrete	3
Shield 1	3.556 cm	Lead	11.34
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	.478 cm	Water	1
Top Clad	.478 cm	Water	1

Source Input: Grouping Method - Standard Indices				
Number of Groups: 25				
Lower Energy Cutoff: 0.015				
Photons < 0.015: Excluded				
Library: Grove				
Nuclide	Ci	Bq	μCi/cm ³	Bq/cm ³
Am-241	1.9139e-001	7.0815e+009	4.7800e+002	1.7686e+007
Ba-137m	2.9583e+000	1.0946e+011	7.3883e+003	2.7337e+008
Co-60	3.1071e-004	1.1496e+007	7.7600e-001	2.8712e+004
Cs-134	1.1411e-003	4.2222e+007	2.8500e+000	1.0545e+005
Cs-137	3.1271e+000	1.1570e+011	7.8100e+003	2.8897e+008
Eu-154	1.3493e-002	4.9926e+008	3.3700e+001	1.2469e+006
Eu-155	4.7247e-003	1.7481e+008	1.1800e+001	4.3660e+005
Np-237	1.1451e-005	4.2370e+005	2.8600e-002	1.0582e+003
Pu-238	2.7227e-002	1.0074e+009	6.8000e+001	2.5160e+006
Pu-239	1.1491e-001	4.2519e+009	2.8700e+002	1.0619e+007
Pu-240	6.9269e-002	2.5630e+009	1.7300e+002	6.4010e+006
Pu-241	2.3704e+000	8.7704e+010	5.9200e+003	2.1904e+008
Pu-242	2.5065e-005	9.2741e+005	6.2600e-002	2.3162e+003
Sm-151	1.1411e-003	4.2222e+007	2.8500e+000	1.0545e+005
Sr-90	3.4995e+000	1.2948e+011	8.7400e+003	3.2338e+008
Tc-99	8.4484e-004	3.1259e+007	2.1100e+000	7.8070e+004
Y-90	3.4995e+000	1.2948e+011	8.7400e+003	3.2338e+008
Buildup: The material reference is Shield 1				
Integration Parameters				
Radial				20
Circumferential				20
Y Direction (axial)				20

Results - Dose Point # 1 - (14.194,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	1.248e+04	0.000e+00	1.015e-27	0.000e+00	3.517e-29
0.03	6.625e+09	0.000e+00	8.309e-22	0.000e+00	8.234e-24
0.04	1.655e+09	3.462e-235	2.845e-22	1.531e-237	1.258e-24
0.05	3.746e+07	3.858e-130	8.302e-24	1.028e-132	2.212e-26
0.06	2.558e+09	8.768e-78	7.126e-22	1.741e-80	1.415e-24
0.08	5.434e+07	2.071e-36	2.263e-23	3.277e-39	3.580e-26
0.1	2.402e+08	2.585e-92	3.967e-06	3.955e-95	6.070e-09
0.15	7.255e+03	4.346e-36	1.379e-25	7.157e-39	2.271e-28
0.2	3.410e+07	6.217e-15	9.339e-15	1.097e-17	1.648e-17
0.3	1.495e+04	6.109e-08	9.431e-08	1.159e-10	1.789e-10
0.4	3.562e+06	1.719e-02	3.011e-02	3.350e-05	5.867e-05
0.5	1.697e+06	1.796e-01	3.405e-01	3.526e-04	6.683e-04
0.6	9.858e+10	5.611e+04	1.106e+05	1.095e+02	2.159e+02
0.8	2.344e+08	8.187e+02	1.701e+03	1.557e+00	3.235e+00
1.0	1.663e+08	1.589e+03	3.355e+03	2.929e+00	6.184e+00
1.5	2.076e+08	7.274e+03	1.464e+04	1.224e+01	2.463e+01
Totals	1.104e+11	6.579e+04	1.303e+05	1.263e+02	2.499e+02
Results - Dose Point # 2 - (42.164,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	1.248e+04	0.000e+00	9.948e-29	0.000e+00	3.446e-30
0.03	6.625e+09	0.000e+00	8.140e-23	0.000e+00	8.068e-25
0.04	1.655e+09	5.231e-236	2.787e-23	2.314e-238	1.233e-25
0.05	3.746e+07	5.266e-131	8.134e-25	1.403e-133	2.167e-27
0.06	2.558e+09	1.039e-78	6.982e-23	2.063e-81	1.387e-25
0.08	5.434e+07	1.963e-37	2.217e-24	3.107e-40	3.508e-27
0.1	2.402e+08	3.236e-93	3.887e-07	4.951e-96	5.947e-10
0.15	7.255e+03	4.137e-37	1.351e-26	6.812e-40	2.225e-29
0.2	3.410e+07	5.442e-16	8.176e-16	9.605e-19	1.443e-18
0.3	1.495e+04	5.138e-09	7.938e-09	9.747e-12	1.506e-11
0.4	3.562e+06	1.443e-03	2.533e-03	2.811e-06	4.935e-06
0.5	1.697e+06	1.514e-02	2.883e-02	2.973e-05	5.659e-05
0.6	9.858e+10	4.760e+03	9.439e+03	9.290e+00	1.842e+01
0.8	2.344e+08	7.027e+01	1.473e+02	1.337e-01	2.803e-01
1.0	1.663e+08	1.378e+02	2.942e+02	2.539e-01	5.423e-01
1.5	2.076e+08	6.428e+02	1.313e+03	1.081e+00	2.209e+00
Totals	1.104e+11	5.611e+03	1.119e+04	1.076e+01	2.146e+01
Results - Dose Point # 3 - (111.654,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	1.248e+04	0.000e+00	1.399e-29	0.000e+00	4.845e-31
0.03	6.625e+09	0.000e+00	1.145e-23	0.000e+00	1.134e-25
0.04	1.655e+09	7.028e-237	3.920e-24	3.108e-239	1.734e-26
0.05	3.746e+07	6.957e-132	1.144e-25	1.853e-134	3.047e-28
0.06	2.558e+09	1.345e-79	9.818e-24	2.671e-82	1.950e-26
0.08	5.434e+07	2.533e-38	3.117e-25	4.009e-41	4.933e-28
0.1	2.402e+08	4.270e-94	5.466e-08	6.532e-97	8.362e-11
0.15	7.255e+03	5.402e-38	1.900e-27	8.895e-41	3.129e-30
0.2	3.410e+07	7.109e-17	1.068e-16	1.255e-19	1.885e-19
0.3	1.495e+04	6.750e-10	1.043e-09	1.281e-12	1.979e-12
0.4	3.562e+06	1.906e-04	3.350e-04	3.714e-07	6.527e-07

0.5	1.697e+06	2.011e-03	3.834e-03	3.947e-06	7.526e-06
0.6	9.858e+10	6.344e+02	1.261e+03	1.238e+00	2.462e+00
0.8	2.344e+08	9.421e+00	1.982e+01	1.792e-02	3.771e-02
1.0	1.663e+08	1.855e+01	3.979e+01	3.420e-02	7.334e-02
1.5	2.076e+08	8.719e+01	1.791e+02	1.467e-01	3.013e-01
Totals	1.104e+11	7.496e+02	1.500e+03	1.437e+00	2.874e+00
Results - Dose Point # 4 - (316.382,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.02	1.248e+04	0.000e+00	1.739e-30	0.000e+00	6.023e-32
0.03	6.625e+09	0.000e+00	1.423e-24	0.000e+00	1.410e-26
0.04	1.655e+09	8.020e-238	4.872e-25	3.547e-240	2.155e-27
0.05	3.746e+07	7.978e-133	1.422e-26	2.125e-135	3.787e-29
0.06	2.558e+09	1.545e-80	1.220e-24	3.068e-83	2.424e-27
0.08	5.434e+07	2.929e-39	3.874e-26	4.635e-42	6.131e-29
0.1	2.402e+08	4.964e-95	6.794e-09	7.594e-98	1.039e-11
0.15	7.255e+03	6.312e-39	2.362e-28	1.039e-41	3.889e-31
0.2	3.410e+07	8.341e-18	1.253e-17	1.472e-20	2.212e-20
0.3	1.495e+04	7.974e-11	1.233e-10	1.513e-13	2.338e-13
0.4	3.562e+06	2.263e-05	3.981e-05	4.409e-08	7.757e-08
0.5	1.697e+06	2.396e-04	4.577e-04	4.704e-07	8.983e-07
0.6	9.858e+10	7.585e+01	1.511e+02	1.480e-01	2.949e-01
0.8	2.344e+08	1.132e+00	2.387e+00	2.152e-03	4.541e-03
1.0	1.663e+08	2.236e+00	4.810e+00	4.121e-03	8.867e-03
1.5	2.076e+08	1.057e+01	2.179e+01	1.778e-02	3.666e-02
Totals	1.104e+11	8.978e+01	1.801e+02	1.721e-01	3.450e-01

MicroShield 7.02
DOE (7.02-0000)

Date 3/16/2009	By K	Checked JE
Filename KBC40179_6.ms7	Run Date March 5, 2009	Run Time 2:33:06 PM
Duration 00:00:03		
Project Info		
Case Title	Settler Sample Unsh	
Description	Sample Bottle Settler 400ml at Distances up to 10ft	
Geometry	7 - Cylinder Volume - Side Shields	

Source Dimensions			
Height	2.195 cm (0.9 in)		
Radius	7.62 cm (3.0 in)		
Dose Points			
A	X	Y	Z
#1	38.583 cm (1 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#2	69.063 cm (2 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#3	99.543 cm (3 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#4	160.503 cm (5 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#5	251.943 cm (8 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
#6	312.903 cm (10 ft 3.2 in)	1.1 cm (0.4 in)	0.0 cm (0.0 in)
Shields			
Shield N	Dimension	Material	Density
Source	400.4 cm ³	Concrete	3
Transition		Air	0.00122
Air Gap		Air	0.00122
Wall Clad	.478 cm	Water	1
Top Clad	.478 cm	Water	1

Source Input: Grouping Method - Linear Energy				
Number of Groups: 25				
Lower Energy Cutoff: 0.015				
Photons < 0.015: Excluded				
Library: Grove				
Nuclide	CI	Bq	μCi/cm ³	Bq/cm ³
Am-241	1.9139e-001	7.0815e+009	4.7800e+002	1.7686e+007
Ba-137m	2.9583e+000	1.0946e+011	7.3883e+003	2.7337e+008
Co-60	3.1071e-004	1.1496e+007	7.7600e-001	2.8712e+004
Cs-134	1.1411e-003	4.2222e+007	2.8500e+000	1.0545e+005
Cs-137	3.1271e+000	1.1570e+011	7.8100e+003	2.8897e+008
Eu-154	1.3493e-002	4.9926e+008	3.3700e+001	1.2469e+006
Eu-155	4.7247e-003	1.7481e+008	1.1800e+001	4.3660e+005
Np-237	1.1451e-005	4.2370e+005	2.8600e-002	1.0582e+003
Pu-238	2.7227e-002	1.0074e+009	6.8000e+001	2.5160e+006
Pu-239	1.1491e-001	4.2519e+009	2.8700e+002	1.0619e+007
Pu-240	6.9269e-002	2.5630e+009	1.7300e+002	6.4010e+006
Pu-241	2.3704e+000	8.7704e+010	5.9200e+003	2.1904e+008
Pu-242	2.5065e-005	9.2741e+005	6.2600e-002	2.3162e+003
Sm-151	1.1411e-003	4.2222e+007	2.8500e+000	1.0545e+005
Sr-90	3.4995e+000	1.2948e+011	8.7400e+003	3.2338e+008
Tc-99	8.4484e-004	3.1259e+007	2.1100e+000	7.8070e+004
Y-90	3.4995e+000	1.2948e+011	8.7400e+003	3.2338e+008
Buildup: The material reference is Source				
Integration Parameters				
Radial				20
Circumferential				20

Y Direction (axial)					20
Results - Dose Point # 1 - (38.5826,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	1.357e+03	2.024e+03	5.352e+00	7.979e+00
0.5875	8.505e+07	8.664e+02	1.780e+03	1.693e+00	3.479e+00
0.6617	9.861e+10	1.181e+06	2.332e+06	2.290e+03	4.521e+03
0.7873	6.758e+07	1.026e+03	1.917e+03	1.956e+00	3.653e+00
0.8759	6.383e+07	1.121e+03	2.027e+03	2.108e+00	3.812e+00
1.0017	1.407e+08	2.966e+03	5.155e+03	5.466e+00	9.500e+00
1.0441	1.131e+06	2.523e+01	4.331e+01	4.615e-02	7.923e-02
1.1185	5.139e+05	1.259e+01	2.118e+01	2.272e-02	3.823e-02
1.1421	3.170e+06	7.988e+01	1.336e+02	1.436e-01	2.401e-01
1.1732	1.150e+07	3.004e+02	4.985e+02	5.369e-01	8.908e-01
1.2456	5.139e+06	1.457e+02	2.376e+02	2.568e-01	4.189e-01
1.2745	1.772e+08	5.181e+03	8.396e+03	9.086e+00	1.472e+01
1.3325	1.150e+07	3.569e+02	5.714e+02	6.193e-01	9.913e-01
1.3652	1.284e+06	4.118e+01	6.548e+01	7.101e-02	1.129e-01
1.4944	3.243e+06	1.175e+02	1.825e+02	1.978e-01	3.073e-01
1.5952	1.435e+07	5.673e+02	8.675e+02	9.385e-01	1.435e+00
Totals	1.104e+11	1.195e+06	2.356e+06	2.319e+03	4.568e+03
Results - Dose Point # 2 - (69.0626,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	3.862e+02	5.782e+02	1.523e+00	2.280e+00
0.5875	8.505e+07	2.572e+02	5.387e+02	5.026e-01	1.053e+00
0.6617	9.861e+10	3.512e+05	7.061e+05	6.808e+02	1.369e+03
0.7873	6.758e+07	3.057e+02	5.809e+02	5.825e-01	1.107e+00
0.8759	6.383e+07	3.343e+02	6.145e+02	6.286e-01	1.156e+00
1.0017	1.407e+08	8.861e+02	1.564e+03	1.633e+00	2.882e+00
1.0441	1.131e+06	7.540e+00	1.314e+01	1.379e-02	2.404e-02
1.1185	5.139e+05	3.765e+00	6.429e+00	6.797e-03	1.160e-02
1.1421	3.170e+06	2.390e+01	4.055e+01	4.296e-02	7.288e-02
1.1732	1.150e+07	8.992e+01	1.514e+02	1.607e-01	2.705e-01
1.2456	5.139e+06	4.362e+01	7.215e+01	7.692e-02	1.272e-01
1.2745	1.772e+08	1.552e+03	2.550e+03	2.722e+00	4.472e+00
1.3325	1.150e+07	1.070e+02	1.736e+02	1.856e-01	3.012e-01
1.3652	1.284e+06	1.234e+01	1.990e+01	2.129e-02	3.431e-02
1.4944	3.243e+06	3.525e+01	5.547e+01	5.937e-02	9.342e-02
1.5952	1.435e+07	1.704e+02	2.638e+02	2.818e-01	4.363e-01
Totals	1.104e+11	3.554e+05	7.133e+05	6.892e+02	1.383e+03
Results - Dose Point # 3 - (99.5426,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	1.792e+02	2.692e+02	7.066e-01	1.062e+00
0.5875	8.505e+07	1.215e+02	2.566e+02	2.374e-01	5.014e-01
0.6617	9.861e+10	1.660e+05	3.364e+05	3.218e+02	6.522e+02
0.7873	6.758e+07	1.446e+02	2.769e+02	2.756e-01	5.276e-01
0.8759	6.383e+07	1.582e+02	2.930e+02	2.976e-01	5.510e-01
1.0017	1.407e+08	4.197e+02	7.458e+02	7.735e-01	1.374e+00
1.0441	1.131e+06	3.573e+00	6.268e+00	6.535e-03	1.147e-02
1.1185	5.139e+05	1.785e+00	3.066e+00	3.221e-03	5.535e-03
1.1421	3.170e+06	1.133e+01	1.934e+01	2.036e-02	3.476e-02
1.1732	1.150e+07	4.263e+01	7.220e+01	7.618e-02	1.290e-01

1.2456	5.139e+06	2.069e+01	3.442e+01	3.648e-02	6.069e-02
1.2745	1.772e+08	7.361e+02	1.217e+03	1.291e+00	2.134e+00
1.3325	1.150e+07	5.075e+01	8.282e+01	8.805e-02	1.437e-01
1.3652	1.284e+06	5.857e+00	9.493e+00	1.010e-02	1.637e-02
1.4944	3.243e+06	1.673e+01	2.647e+01	2.818e-02	4.458e-02
1.5952	1.435e+07	8.090e+01	1.259e+02	1.338e-01	2.082e-01
Totals	1.104e+11	1.680e+05	3.398e+05	3.258e+02	6.590e+02
Results - Dose Point # 4 - (160.5026,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	6.631e+01	1.002e+02	2.615e-01	3.950e-01
0.5875	8.505e+07	4.588e+01	9.778e+01	8.965e-02	1.911e-01
0.6617	9.861e+10	6.271e+04	1.282e+05	1.216e+02	2.486e+02
0.7873	6.758e+07	5.469e+01	1.056e+02	1.042e-01	2.012e-01
0.8759	6.383e+07	5.988e+01	1.117e+02	1.126e-01	2.101e-01
1.0017	1.407e+08	1.590e+02	2.845e+02	2.929e-01	5.243e-01
1.0441	1.131e+06	1.353e+00	2.391e+00	2.476e-03	4.374e-03
1.1185	5.139e+05	6.763e-01	1.170e+00	1.221e-03	2.112e-03
1.1421	3.170e+06	4.294e+00	7.381e+00	7.717e-03	1.327e-02
1.1732	1.150e+07	1.616e+01	2.755e+01	2.888e-02	4.923e-02
1.2456	5.139e+06	7.844e+00	1.314e+01	1.383e-02	2.316e-02
1.2745	1.772e+08	2.792e+02	4.644e+02	4.896e-01	8.144e-01
1.3325	1.150e+07	1.925e+01	3.161e+01	3.340e-02	5.485e-02
1.3652	1.284e+06	2.222e+00	3.624e+00	3.831e-03	6.249e-03
1.4944	3.243e+06	6.351e+00	1.011e+01	1.070e-02	1.702e-02
1.5952	1.435e+07	3.072e+01	4.807e+01	5.081e-02	7.952e-02
Totals	1.104e+11	6.347e+04	1.295e+05	1.231e+02	2.512e+02
Results - Dose Point # 5 - (251.9426,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	2.594e+01	3.946e+01	1.023e-01	1.556e-01
0.5875	8.505e+07	1.832e+01	3.940e+01	3.580e-02	7.700e-02
0.6617	9.861e+10	2.506e+04	5.168e+04	4.859e+01	1.002e+02
0.7873	6.758e+07	2.188e+01	4.256e+01	4.169e-02	8.110e-02
0.8759	6.383e+07	2.397e+01	4.505e+01	4.507e-02	8.472e-02
1.0017	1.407e+08	6.368e+01	1.147e+02	1.173e-01	2.115e-01
1.0441	1.131e+06	5.422e-01	9.645e-01	9.919e-04	1.764e-03
1.1185	5.139e+05	2.711e-01	4.720e-01	4.893e-04	8.519e-04
1.1421	3.170e+06	1.721e+00	2.977e+00	3.093e-03	5.351e-03
1.1732	1.150e+07	6.478e+00	1.111e+01	1.158e-02	1.986e-02
1.2456	5.139e+06	3.146e+00	5.300e+00	5.547e-03	9.345e-03
1.2745	1.772e+08	1.120e+02	1.874e+02	1.964e-01	3.286e-01
1.3325	1.150e+07	7.723e+00	1.276e+01	1.340e-02	2.213e-02
1.3652	1.284e+06	8.915e-01	1.462e+00	1.537e-03	2.522e-03
1.4944	3.243e+06	2.549e+00	4.079e+00	4.294e-03	6.869e-03
1.5952	1.435e+07	1.233e+01	1.940e+01	2.040e-02	3.209e-02
Totals	1.104e+11	2.536e+04	5.221e+04	4.919e+01	1.012e+02
Results - Dose Point # 6 - (312.9026,1.1,0) cm					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0419	1.120e+10	1.647e+01	2.517e+01	6.496e-02	9.925e-02
0.5875	8.505e+07	1.178e+01	2.546e+01	2.302e-02	4.974e-02
0.6617	9.861e+10	1.612e+04	3.339e+04	3.125e+01	6.473e+01

0.7873	6.758e+07	1.408e+01	2.750e+01	2.683e-02	5.241e-02
0.8759	6.383e+07	1.543e+01	2.912e+01	2.901e-02	5.476e-02
1.0017	1.407e+08	4.101e+01	7.417e+01	7.556e-02	1.367e-01
1.0441	1.131e+06	3.492e-01	6.234e-01	6.388e-04	1.140e-03
1.1185	5.139e+05	1.746e-01	3.051e-01	3.152e-04	5.507e-04
1.1421	3.170e+06	1.109e+00	1.925e+00	1.993e-03	3.459e-03
1.1732	1.150e+07	4.174e+00	7.185e+00	7.459e-03	1.284e-02
1.2456	5.139e+06	2.027e+00	3.427e+00	3.574e-03	6.042e-03
1.2745	1.772e+08	7.215e+01	1.211e+02	1.265e-01	2.124e-01
1.3325	1.150e+07	4.977e+00	8.247e+00	8.636e-03	1.431e-02
1.3652	1.284e+06	5.746e-01	9.454e-01	9.909e-04	1.630e-03
1.4944	3.243e+06	1.644e+00	2.637e+00	2.768e-03	4.441e-03
1.5952	1.435e+07	7.953e+00	1.255e+01	1.316e-02	2.075e-02
Totals	1.104e+11	1.631e+04	3.373e+04	3.163e+01	6.540e+01