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June 23, 2021
GO2-21-084

10 CFR 20.2002

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: **COLUMBIA GENERATING STATION, DOCKET NO. 50-397
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION RELATED
TO ON-SITE COOLING SYSTEM SEDIMENT DISPOSAL**

References:
1. Letter from S.A. Vance (Energy Northwest) to NRC, "On-Site Cooling System Sediment Disposal," dated December 21, 2020 (ADAMS Accession Number ML20356A172).

2. Email from M. Chawla (NRC) to Richard Garcia (Energy Northwest), "FINAL - Request for Additional Information - Columbia Generating Station - On-Site Cooling System Sediment Disposal Approval Request - EPID L-2020-LLL-0031," dated April 30, 2021.

Dear Sir or Madam:

By Reference 1, Energy Northwest submitted a request to dispose of sediments from the Circulating Water system cooling towers and Standby Service Water system spray ponds at Columbia Generating Station in accordance with 10 CFR 20.2002. By Reference 2, the U.S. Nuclear Regulatory Commission requested additional information related to the Energy Northwest submittal. The enclosure to this letter contains the requested information.

No new regulatory commitments are being made by this letter or the enclosure. If there are any questions or if additional information is needed, please contact Mr. R. Wynegar, Regulatory Compliance Supervisor, at 509-377-8362.

I declare under penalty of perjury that the foregoing is true and correct.

Executed this 23rd day of June, 2021.

Respectfully,

Recoverable Signature

X Vance, Scott A.

Final Approver

Signed by: Vance, Scott A.

Scott A. Vance
Vice President, Corporate Governance and General Counsel

Enclosure: As stated

cc: NRC RIV Regional Administrator
NRC NRR Project Manager
NRC Senior Resident Inspector
CD Sonoda – BPA
A Kidder – EFSEC
E Fordham – WDOH
R Brice – WDOH
L Albin – WDOH

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

NRC REQUEST No. HCR-1:

Energy Northwest's 10 CFR 20.2002 submittal identifies that sediment disposal cell expansion was completed in November 2020. Is the disposal area located in a previously disturbed area or considered an archaeologically sensitive area?

ENERGY NORTHWEST RESPONSE TO RAI HCR-1:

The sediment disposal area is located within a previously disturbed area. The entire sediment disposal area, including the new cell added in November 2020, is located within an inactive construction era borrow pit. The sediment disposal area is not considered an archaeologically sensitive area. The only "Culturally Sensitive Zone" at Columbia Generating Station is located approximately 3 miles to the east along the Columbia river.

NRC REQUEST No. HCR-2:

Did Energy Northwest contact or consult with the State Historic Preservation Officer or Federally- or State-recognized tribes regarding the November 2020 disposal cell expansion and any associated ground disturbance? If so, provide a discussion of the consultation(s) conducted.

ENERGY NORTHWEST RESPONSE TO RAI HCR-2:

Energy Northwest did not contact or consult with the State Historic Preservation Officer or Federally/State-recognized tribes regarding the November 2020 disposal cell expansion and associated ground disturbance. Energy Northwest followed its established Cultural Resource Protection Program procedure, GBP-ENV-19, to determine that consultation was not appropriate. Because the sediment disposal cell area is located in an inactive borrow pit and extensive evaluation of the area was prepared prior to construction of CGS, new consultation was not necessary.

NRC REQUEST No. HCR-3:

Did Energy Northwest follow the site's cultural resource protection procedure prior to conducting any ground disturbance of the disposal area? If so, describe the steps taken in accordance with the procedure prior to and when conducting ground disturbing activities of the disposal area.

ENERGY NORTHWEST RESPONSE TO RAI HCR-3:

Energy Northwest followed its Cultural Resource Protection Program procedure, GBP-ENV-19, prior to and when conducting the ground disturbance in the sediment disposal area. Energy Northwest staff utilized GBP-ENV-19 to verify the planned ground disturbance activity was located within a previously disturbed area and not within a culturally sensitive zone. GBP-ENV-19 provides a cultural resources protection program flow chart along with maps of past disturbed areas, undisturbed areas, and a culturally sensitive zone along the Columbia river. These tools were used by Energy Northwest staff to validate the ground disturbance activity could proceed without additional review or consultation. GBP-ENV-19 outlines how Energy Northwest addresses discovery or inadvertent disturbance of archaeological material or human remains. No archaeological or human remains were discovered during the November 2020 ground disturbance activity.

NRC REQUEST No. HCR-4:

Did Energy Northwest conduct an archaeological survey of the disposal area prior to conducting ground disturbance? If so, provide a discussion of the survey findings.

ENERGY NORTHWEST RESPONSE TO RAI HCR-4:

Energy Northwest did not conduct an archaeological survey of the sediment disposal area prior to conducting ground disturbance in November 2020. The November 2020 expansion is located adjacent to the existing sediment disposal cells on previously disturbed ground. As described in HCR-1, the entire sediment disposal area, including the November 2020 expansion, is located within an inactive construction era borrow pit.

NRC REQUEST No. SHH-1:

Provide specific details describing the different types of workers involved with the activities that occur within the sediment disposal area (i.e., are the workers involved with the disposal actions the same workers involved with the monitoring activities?).

ENERGY NORTHWEST RESPONSE TO RAI SHH-1:

There are 4 (four) types of workers involved with the activities that occur within the sediment disposal area;

- Energy Northwest Environmental Services Laboratory personnel that collect environmental samples.
- Energy Northwest site support contractor staff that work to collect sediment from cooling towers and spray ponds and place the sediment in the active disposal cells.
- Energy Northwest Health Physics Technicians that provide dosimetry and a frisker if personnel need to enter the Radiologically Controlled Area (RCA) that

surrounds the disposal cells.
- Offsite contractor laborers that work to collect sediment from cooling towers and spray ponds and place the sediment in the active disposal cells.

NRC REQUEST No. SHH-2:

Confirm whether all workers involved with activities occurring within the sediment disposal area qualify as radiation workers under the facility's radiation protection plan, are members of the public, or a combination of both. If multiple groups are involved, document how each of their doses are calculated.

ENERGY NORTHWEST RESPONSE TO RAI SHH-2:

The workers involved with sediment disposal are a combination of Energy Northwest radiation workers and members of the public contracted to operate pumper trucks. Any worker entering the RCA surrounding the disposal area must have dosimetry and be logged onto a Radiation Work Permit as required by Energy Northwest's radiation protection procedures. The 10 CFR 20 dose limit for a Member of the Public is applicable to the workers that are not qualified radiation workers whether they enter the RCA or not.

The majority of work for sediment disposal does not necessitate entering the RCA since a hose is used to transfer sediment and water from the pumper truck, which is parked outside the RCA, to the disposal cell inside the RCA. The personnel routinely entering the RCA are radiation workers from the Energy Northwest Environmental Services Laboratory that collect a dry sediment sample several weeks after each disposal operation. The dose to work groups is determined using environmental thermoluminescent dosimeter (TLD) results and bounding calculations. See the Radiation Protection (RP) Calculation 21-01 Rev 001 in Attachment 1.

NRC REQUEST No. SHH-3:

Provide an assessment of the impacts, including specific doses when available, to members of the public involved with the disposal actions and other operating activities (e.g., monitoring activities) associated with the activities occurring within the Sediment Disposal Area. Include any dose modeling data and results or other references used to evaluate these scenarios.

ENERGY NORTHWEST RESPONSE TO RAI SHH-3:

The impacts to members of the public involved with the disposal activities has been assessed by examining the environmental TLD results as reported in each Annual Radiological Environmental Operating Report. The TLD station 119B is an appropriate

indicator since it measures exposure and is located at the RCA Boundary that surrounds the disposal cells. A negative bias is present between TLD station 119B and the control station 119Ctrl in Table 3 of the support information to Energy Northwest's request for disposal per 10 CFR 20.2002. This negative bias is discussed more in the response to request SHH-6.

To assess the impact for this request, we can use another TLD control (TLD Station 9) that is located 28.35 miles from Columbia Generating Station (CGS) in the West-Southwest sector. A table summarizing the past five years of data for TLD station 9 and 119B is included here.

Year	**TLD Station 9**	**TLD Station 119B**	
	Milli-Roentgen (mR) per standard quarter (mean value)	Milli-Roentgen (mR) per standard quarter (mean value)	Δ
2016	19.78	21.99	2.21
2017	18.60	20.30	1.70
2018	18.98	21.34	2.36
2019	19.18	21.66	2.48
2020	19.35	22.58	3.23

This data shows that the TLD 119B is measuring exposure above that measured by control station 9. This exposure to 119B is attributed to both CGS and the sediment disposal cell. The background corrected standard quarter measurements are on the order of 2-3 mR per standard quarter, or 8-12 mR per year.

A review of recent sediment disposal activities indicated that laborers are only scheduled for 72 hours of work per sediment disposal activity. There are often 2 or 3 disposal activities per year. This provides reasonable assurance that the impacts during sediment disposal actions are within the disposal area dose limit cited in section 2.5.2 of the 10 CFR 20.2002 disposal request, and are below the thresholds that require monitoring per Energy Northwest procedure GEN-RPP-06, Dosimetry Program Description. It should be noted that the response to request SHH-2 above discusses the posted requirements for entry into the RCA at the sediment disposal cells.

NRC REQUEST No. SHH-4:

Clarify the total area of the sediment disposal area and the volumes of sediment that have previously been disposed of and have yet to be disposed in the sediment disposal area. Is the 3600 ft^2 (120 ft X 300 ft) fenced area discussed in the State Environmental Policy Act (SEPA) Environmental Checklist included with Enclosure Attachment 3, the sediment disposal area being considered in this alternate disposal request? If not, provide the area of the sediment disposal area and a reference to these dimensions.

Also, based on the information provided in Sections 1.2 and 5.5.2, clarify if the 2850 cubic yards of material includes the 1400 cubic yards of material that has yet to be disposed and if the total volume of material in the sediment disposal area at the time of closure is 2850 cubic yards or 4250 cubic yards (2850 cubic yards + 1400 cubic yards).

ENERGY NORTHWEST RESPONSE TO RAI SHH-4:

The total area of the sediment disposal area is approximately 48,000 ft^2. This includes the 36,000 ft^2 (120 ft X 300 ft) currently used sediment disposal area described in the State Environmental Policy Act (SEPA) Environmental Checklist included with Enclosure Attachment 3 and the 12,064 ft^2 (116 ft X 104 ft) for the new sediment disposal cell added in November 2020. See Attachment 2 for an As-Built Facilities and Commercial Engineering drawing of the November 2020 sediment disposal cell. As stated in Section 5.5.2, the assumed total volume of sediment to be disposed was 2,850 cubic yards (yd^3) over 30 years based on the original 36,000 ft^2 area. This was calculated in 1995 based on an estimated yearly volume of 60 yd^3 per year for the cooling towers and 35 yd^3 per year for the spray pond sediments. An analysis of the last ten years provides a more accurate yearly volume of 198 yd^3 as mentioned in Section 1.2. We now anticipate approximately 200 yd^3 per year for the remaining life of the plant. This sediment will be placed in the current disposal area which should have space for another 200 yd^3 and the November 2020 sediment disposal cell which should have room for another 1260 yd^3 as shown in the Attachment 2 As-Built Facilities and Commercial Engineering drawing. The total estimated volume in the existing sediment cells at the time of closure will be approximately 4,310 yd^3 (2,850 yd^3 in existing cells + 200 yd^3 to be added to active cells + 1,260 yd^3 to be added to the November 2020 sediment cell).

NRC REQUEST No. SHH-5:

Explain why Section 5.5.2, Dose Projection Assumptions, only considers two areas when there are more than two disposal cells. By using separate volumes, does this indicate that the sediments from the cooling towers and the spray ponds remain separate when being placed in the disposal cells (i.e., specific disposal cells for each sediment) or are they mixed within a single disposal cell? If specific cells are used for each sediment, how many and what are the dimensions of the specific disposal cells? If the sediments are mixed, explain the significance of using a depth of 1.2 m for spray pond sediments and 2 m for cooling tower sediments when performing the dose calculations.

ENERGY NORTHWEST RESPONSE TO RAI SHH-5:

The two areas considered in Section 5.5.2 are the sources from which the sediment comes, cooling towers and spray ponds. The estimated volume accumulated from each source is estimated in section 5.5.2. The spray pond volume is approximately 40% less

than the cooling tower volume, so the total volume in a disposal cell would have 40% less spray pond sediment than cooling tower sediment. Reducing 2 meters by 40% equals 1.2 meters. The sediments disposed of in a given year from both sources will go into the same active disposal cell, but at different times. The sediments are not actively mixed at the time of disposal to be homogeneous, and some striation of the dried sediment in the active disposal cell will occur. The history of sampling as reported in the Annual Radiological Environmental Operating Report shows the radionuclides detected and the concentrations are similar for both cooling tower and spray pond sediment. Therefore, the sediment from both sources is all considered one volume with a depth of 2 meters for calculation purposes and setting disposal limits.

The total number of disposal cells has increased. Energy Northwest completed Radiation Protection Calculation 21-01 (see Attachment 1) to evaluate expanding the number of disposal cells beyond the original calculation that considered radiation exposure from one cylindrical cell with a volume of 1,800 cubic yards. The new calculation showed that when the volume of sediment doubles to approximately 3,600 cubic yards, or 2,800 cubic meters, the dose rate to a constant receptor location increased by less than 5%. This new calculation used the maximum measured concentration of radionuclides found in Table 2 of the 10 CFR 20.2002 disposal request and did not consider radioactive decay that would occur during the time it takes to fill a cell. This assures that increasing the number of disposal cells will not significantly increase the dose to the occupational worker assumed for setting disposal concentration limits.

NRC REQUEST No. SHH-6:

Confirm the process used to establish annual doses based on the measured direct radiation values reported in Table 3, “Measurements of direct radiation at the disposal area using TLD Station 119B and TLD Station 119Ctrl” and their location relative to the sediment disposal area. What role do the background measurements play and how are net negative values addressed for both the TLD measurements and the radionuclide concentrations measured in the sediment samples? How do these doses compare with the dose values calculated using the individual radionuclide concentrations measured in the sediment samples collected during each disposal and summarized in Table 2 of Section 3.2, “Analysis of Sediment,” of the enclosure?

ENERGY NORTHWEST RESPONSE TO RAI SHH-6:

The process to establish annual doses based on environmental TLD results requires exchanging and reading the TLDs quarterly. The exact dates a TLD is placed and removed from the field is not exactly 91.25 days, so the TLD measurements are normalized to a standard quarter based on the number of days it was in the field. The quarterly TLD results for a given monitoring station and year were averaged and the mean was reported in Table 3. TLD 119B is about 1 m above the ground at the disposal

area RCA boundary, and is 0.31 miles from CGS in the South sector. TLD 119Ctrl is located at 0.28 miles from CGS in the South-Southeast sector, approximately 200 yards East of the sediment disposal area.

TLD station 119Ctrl was deployed as a control to measure background with contributions from CGS. Then the measurements from 119B could be subtracted by 119Ctrl to show only exposure from the sediment disposal cell. A negative bias between 119Ctrl and 119B has been present for many years even though both TLDs are approximately the same distance from CGS. The bias is likely caused by obstructions, or the lack of obstructions, between the TLDs and CGS (see Attachment 3 images). The response to request SHH-3 looks at TLD measurements from another control that is far from CGS. Energy Northwest intends to move TLD 119Ctrl to an area with similar obstructions as 119B. Energy Northwest also intends to move TLD 119B farther East on the RCA boundary since the currently active disposal cell is farther East.

The radionuclides of interest in the sediment are often not positively identified by the analysis method. The a-posteriori Minimum Detectable Activity (MDA) calculated for the sediment samples is reported in the Annual Radiological Environmental Operating Report in the “Cooling System Sediment Disposal Area” section as a less than value. The total activity reported includes the less than value multiplied by the disposed sediment mass. Table 2 in Energy Northwest’s request for disposal per 10 CFR 20.2002 summarizes the reported sampling results since 2010.

RP Calculation 21-01 was completed to calculate the expected exposure and dose rate resulting from the measured concentrations in the disposed sediment. The annual exposure that TLD 119B would be expected to receive given the assumptions in the calculation is 19 mR/yr, or 4.75 mR/quarter. There are some conservative assumptions written into the RP Calculation about the maximum measured sediment concentration and the time since disposing of sediment in the disposal cell. Combining this response with Energy Northwest’s response to SHH-3, demonstrates that the expected exposure from measured sediment concentrations is within a factor of two from the range listed in response to SHH-3 (2-3 mR/quarter).

NRC REQUEST No. SHH-7:

Clarify the process used to calculate the quarterly average mean value for the TLD measurement (i.e., the average of 3 months of measurements, the average of 12 months of measurements divided by 4, or some other method).

ENERGY NORTHWEST RESPONSE TO RAI SHH-7:

TLDs are deployed and exchanged on a quarterly basis. The mean value is an average of quarterly TLD results for a calendar year.

NRC REQUEST No. SHH-8:

Without consideration for the TLD control location (TLD Station 119Ctrl), how do the doses associated with the TLD measurements compare with the doses calculated using the radionuclide concentrations measured in the pre-disposal samples?

ENERGY NORTHWEST RESPONSE TO RAI SHH-8:

RP Calculation 21-01 was completed to calculate the expected exposure and dose rate resulting from the measured concentrations in the disposed sediment. The annual exposure that TLD 119B would be expected to receive given the assumptions in the calculation is 19 mR/yr, or 4.75 mR/quarter. Some conservative assumptions were made based on maximum sediment concentrations summarized in Table 2, and the time of soil disposal. This shows that calculated dose using measured radionuclide concentrations is within a factor of two of the TLD measurements discussed in SHH-3.

NRC REQUEST No. SHH-9:

Considering up-to-date site characteristics for the sediment disposal area and the cumulative impacts from the addition of sediments and radionuclides, provide up-to-date doses to individuals working within the sediment disposal area as well as for current and future reasonably foreseeable land-use scenarios.

ENERGY NORTHWEST RESPONSE TO RAI SHH-9:

Work conducted at the sediment disposal cells is limited to sediment disposal activities, and the subsequent sampling of the sediments. Work orders put together to perform these disposal activities allocate the following personnel for the job: two (2) Energy Northwest laborers working fifty (50) hours each, and three (3) contracted vendors working 72 hours each. Discussion with Energy Northwest personnel performing sampling activities following disposal activities confirmed that the time spent at the disposal cells for sample collection is less than one hour.

The total exposure rate for the sediment disposal cells as measured via environmental TLD 119B in 2020 was 90.3 mR/year. Background subtraction from this TLD using the nearby control 119Ctrl, measured in 2020 to be 92.1 mR/year, yields a small negative exposure rate at the sediment disposal area, possibly due to the control TLD having clearer line of site to the reactor building (as described in SHH-6). Therefore, in order to provide a more conservative estimate of the exposure rate at the sediment disposal cell, the control TLD located 28 miles WSW from CGS at station 9 (ST-9) will be used instead for the background subtraction of 119B in this analysis. In 2020 the exposure rate for ST-9 was 77.6 mR/year, resulting in a measured exposure rate of 12.7 mR/year in excess of background at the sediment disposal cell area as measured by TLD 119B.

Using this exposure rate of 12.7 mrem/year we can estimate that the dose to the Energy Northwest laborers working for 50 hours and the contracted vendors working 72 hours on a job at the sediment disposal cell will receive approximately 7.25E-02 and 1.04E-01 mrem respectively.

As CGS resides on land leased from the Department of Energy (DOE), future uses of the land comprising the sediment disposal cells following CGS decommissioning can reasonably be assumed to be a continuation of activities by the DOE. This would preclude the land being used for farming or residential purposes. The potentially maximally exposed member of the public in this scenario would be a DOE worker. Using the previously determined 12.7 mR/year exposure rate above background at the sediment disposal cell, and a 2000 hour/year work schedule, this worker would be expected to receive approximately 2.90E0 mrem/year based on the current disposal cell characteristics.

In the cases described above, doses to current and future individuals based on the up to date characteristics of the sediment disposal cells are expected to be less than the bounding 15 mrem/year used to calculate the maximum isotopic concentrations allowable in sediments being disposed of in the disposal cells per Energy Northwest's submission.

GO2-21-084 Enclosure, Attachment 1:

RP Calculation 21-01 Rev 001

DIC 1572.3

CALCULATION NO. 21-01 Rev 001	DATE ASSIGNED 5/27/2021	PAGE 1 OF 31
TITLE 10 CFR 20.2002 Application RAI Supporting Calculation		
REQUESTED BY Brad Barfuss E&RP	RETENTION ☒ LIFETIME ☐ NONPERMANENT	

Revision 001, Revised per management request to more clearly state the dose per year (8760 hours) and the dose a worker may expect based on limited hours in a work year (2000 hrs). Also included the hours scheduled each cleaning (72 hours), with historically up to 3 cleaning events scheduled each year.

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COMPLETED BY Andrew Jensen	Andrew Jensen	DATE 6/15/21
REVIEWED BY Trevor Omoto	TSOmoto	DATE 6/16/21
APPROVED BY Sam Nappi	Sam Nappi	DATE 6/16/21

Purpose

The purpose of this calculation is to support ENs response to the NRC's Request for Additional Information relative to EN's application per 10 CFR 20.2002 (letter # GO2-20-104). The main body of the application is supported by RP Calculation 94-03 (reference 1).

This calculation will evaluate two scenarios;

1. The expected annual dose rate measured by environmental TLDs given the maximum concentrations of radioactivity measured in the discarded sediment
2. The dose rate to a worker that would result from increasing the number of disposal cells. This will use the highest measured concentrations of radionuclides in the sediment since 2005.

Assumptions

1. Assumptions as listed in reference 1, with the following additions/changes.
2. The highest measured Co-60 concentration was 2.72 E 3 pCi/kg in 2014.
3. The highest measured Cs-137 concentration was 3.64 E 2 pCi/kg in 2011.
4. The highest measured Cs-134 concentration was 1.23 E 2 pCi/kg in 2011.
5. The concentrations of Zn-65 and Mn-54 have been below the Minimum Detectable Activity as reported in the Annual Radiological Environmental Operating Report.
6. The actual volume of individual disposal cells does not exceed 1400 m^3.
7. An equation to decay the radionuclides is not used. This is very conservative since it is expected to take 7 years to fill a cell to a depth of 2m.
8. Version 9.05 of MicroShield will be used, and the doses will be calculated using ICRP 51.

Scenario 1 Assumptions

1. The disposal cell will be modeled as a rectangle instead of a circle as this reflects the actual geometry of the disposal cell.
2. The rectangle volume will be 2800 m^3 to model two active cells side-by-side. The rectangle dimensions are 28 m long, 50 m wide, with a depth of 2 m.

Scenario 2 Assumptions

1. The disposal cell will be modeled as a cylinder with a worker in the center to calculate a conservative Effective Dose Equivalent (EDE).
2. Two cylinders will be modeled to show how the Exposure rate and EDE will change if the disposal cell area is expanded. One cylinder with a volume of 1400 m^3 (approximately 1800 cubic yards as in Reference 1), and one with a volume of 2800 m^3.

Method of Calculation

Version 9.05 of the MicroShield software is used to calculate Exposure Rate (μR/hr) and Effective Dose Equivalent rate (μrem/hr) using the dose factors from ICRP 51 for the scenarios identified in the purpose. The rates are multiplied by either 2000 hours for a work year or 8760 for a calendar year. An equation to decrease exposure and EDE for decay time was not used to be conservative.

The environmental TLD dose point is set at one meter above and one meter from the edge of the source in scenario 1. However, the environmental TLD distance may change if the TLD is moved when a new disposal cell becomes active. The historical environmental TLD measured results will be tabulated for the years 2018-2020 and included in the calculation for scenario 1. TLD Station 119B is the indicator TLD at the disposal cell area which is located 0.31 miles in the South Sector from Columbia Generating Station (CGS). Since this close location may be exposed to radiation/skyshine from CGS, a control TLD (station 119C) was deployed East of the disposal cell at 0.28 miles in the South-Southeast sector from CGS. TLD 119C is intended to measure the background including CGS contributions, and then TLD 119B measurements could be subtracted by TLD 119C measurements to get a representation of the exposure just from the disposal cell. Another control TLD (TLD Station 9) is positioned 28.35 miles in the West-Southwest sector from CGS to measure background with no added contribution from CGS.

The worker dose point in scenario 2 will be set at the center of the cylinder and one meter above the source as was done in Reference 1.

Calculations

Scenario 1

The results for calculated exposure to a TLD dose point are shown in Table 1 below. See Attachment 1 for the Microshield report used to obtain Table 1 results. The calculated value at TLD dose point used the following equation;

Exposure (mR) = Exposure Rate (μR/hr) * 8760 hr/yr / 1000 μR/mR

Table 1. Calculation Results for Measured Concentrations at Time of Disposal

Nuclide	Max Concentration (pCi/kg)	Density (g/cm^3)	Max Concentration (μCi/cm^3)	Exposure Rate (uR/hr)	EDE Rate (urem/hr)	Exposure at TLD dose point (mR)
Mn-54	*<MDA	1.5		2.1E+00	1.4E+00	1.9E+01
Co-60	2.7E+03	1.5	4.1E-06			
Zn-65	*<MDA	1.5				
Cs-134	1.2E+02	1.5	1.8E-07			
Cs-137	3.6E+02	1.5	5.5E-07			

* The Minimum Detectable Activity (MDA) is an a-posteriori value reported in the Annual Radiological Environmental Operating Report for each sample

The TLD results for TLD stations 9, 119B and 119C are shown in Table 2 below. These values were recorded from the Annual Radiological Environmental Operating Reports from 2018, 2019 and 2020. The 3-year quarterly average and standard deviations were calculated using the excel AVERAGE and STDEV functions respectively.

Table 2. Environmental TLD Measurements

TLD Exposure Time	Station 119B	Station 119Ctrl	Control Station 9
2020 Q1 (mR)	21.7	22.7	19.4
2020 Q2 (mR)	21.7	22.9	19.4
2020 Q3 (mR)	23.9	24.2	19.4
2020 Q4 (mR)	23.0	22.4	19.4
2019 Q1 (mR)	21.3	21.2	18.6
2019 Q2 (mR)	20.4	21.1	18.9
2019 Q3 (mR)	21.2	22.5	19.6
2019 Q4 (mR)	23.8	23.8	19.7
2018 Q1 (mR)	21.2	22.6	19.7
2018 Q2 (mR)	21.6	23.2	18.5
2018 Q3 (mR)	20.9	22.8	19.1
2018 Q4 (mR)	21.7	22.8	18.7
3 yr Quarterly Average	21.9	22.7	19.2
3 yr Quarterly Std Deviation	1.11	0.89	0.43

Scenario 2

The calculated EDE during a 2,000 hr working year was modeled for 2 different volume sources with the maximum concentrations measured since 2005. The results for a single disposal cell are in Table 3 below, and the results for two active disposal cells (doubled the volume) are in Table 4. See Attachment 2 for the Microshield report used to obtain Table 3 results. See Attachment 3 for the Microshield report used to obtain Table 4 results.

The equation used to calculate the Annual EDE (mrem/work-yr) is as follows;

Annual EDE (mrem/work-yr) = EDE Rate * 2000 hr/yr / 1000 µrem/mrem

Table 3. Cylinder Geometry with Measured Concentrations

Nuclide	Max Concentration (µCi/cm^3)	Exposure Rate at Max Conc. (uR/hr)	EDE Rate at Max Conc. (urem/hr)	Annual EDE (mrem/work-yr)
Mn-54	*<MDA	7.62E+00	4.97E+00	9.94E+00
Co-60	4.08E-06			
Zn-65	*<MDA			
Cs-134	1.85E-07			
Cs-137	5.46E-07			

* The Minimum Detectable Activity (MDA) is an a-posteriori value reported in the Annual Radiological Environmental Operating Report for each sample

Table 4. Cylinder Geometry with 2x Volume and Measured Concentrations

Nuclide	Max Concentration (µCi/cm^3)	Exposure Rate at Max Conc. (uR/hr)	EDE Rate at Max Conc. (urem/hr)	Annual EDE (mrem/work-yr)
Mn-54	*<MDA	7.76E+00	5.07E+00	1.01E+01
Co-60	4.08E-06			
Zn-65	*<MDA			
Cs-134	1.85E-07			
Cs-137	5.46E-07			

* The Minimum Detectable Activity (MDA) is an a-posteriori value reported in the Annual Radiological Environmental Operating Report for each sample

Conclusion

Scenario 1

The annual exposure that an environmental TLD would expect to receive from measured concentrations of sediment was calculated to be 19 mR/year (8760 hours/yr), 4.75 mR/standard quarter. This number is conservative since it is expected to take 7 years to fill one disposal cell, and that would result in some decay time for the previously disposed sediments. The environmental TLD results were reviewed to correlate this calculated value. The TLD results make it obvious that both 119B and 119C are influenced by CGS when compared to the control station 9. That is why 119C was deployed, however, 119C was placed in a location that appears to be picking up more direct radiation exposure than what the indicator 119B is picking up at the disposal cells.

If the TLD indicator 119B reading is subtracted by the control station 9 reading, then it results in approximately 2.5 mR/quarter that is accumulated at the disposal cell. It is unclear how much of the 2.5 mR/quarter is from skyshine. Nonetheless, it provides a good correlation for calculated and measured exposure rates within a factor of two. It also provides reasonable assurance that the negative bias created by increased TLD 119C results are not masking an exposure issue per 10 CFR 20 regulations, or the disposal permit from Washington's Energy Facility Site Evaluation Council (EFSEC) Resolution 299.

Scenario 2

The EDE per work year (2000 hrs) was calculated to be 9.90 mrem for a single disposal cell of 1400 m^3 and 10.1 mrem when the disposal cell volume is doubled. The dose increase was small because increasing the cylindrical radius from 15 to 21 meters decreases the dose received per unit volume in the area from 15 m to 21 m since there is more distance and more material to shield the dose point. Therefore, the dose in mrem only increased a few percent when the source volume was doubled. There is also an element of time that it would take to fill 2 disposal cells that wasn't included in the calculation. The radioactive decay occurring while disposal cells fill will result in even less of an increase to the dose when adding disposal cells (see figure 1 in Reference 1).

A history of disposal activities shows that workers are scheduled for 72 hours to clean the cooling towers. This typically occurs 2 or 3 times each year and occasionally take less than the scheduled time. The assumption that a worker is at the disposal cell for 2,000 hours per year is conservative. An appropriate EDE estimate based on worker hours would reduce 10 mrem by a factor of 11% (216/2000 = 11%). Resulting in an estimated EDE of 1.1 mrem.

This provides reasonable assurance that even after adding many disposal cells during the operating life of Columbia Generating Station, the dose to a single receptor (as identified in Reference 1) will not be significantly increased to exceed the limits established in Washington's EFSEC Resolution 299.

References

1. RP Calculation 94-3, Annual Radiation Dose from Cooling Tower Sediment (CTS) Disposal, DIC 1572.3
2. 10 CFR 20 – Standards for Protection Against Radiation
3. EFSEC Resolution 299, Columbia Generating Station Cooling System Sediment Disposal
4. SWP-RPP-01, Radiation Protection Program, Revision 16.001
5. Annual Radiological Environmental Operating Report for the Columbia Generating Station
6. MicroShield User's Manual

Attachments

1. Microshield Summary Rectangular Volume
2. Microshield Summary Cylinder Volume
3. Microshield Summary Cylinder 2x Volume

ATTACHMENT 1

MicroShield 9.05
Energy Northwest (9.05-0000)

Date	By	Checked

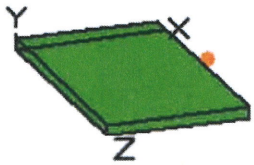
Filename	Run Date	Run Time	Duration
2800 Cube with Measured Activity.msd	June 9, 2021	7:43:07 PM	00:00:00

Project Info

Case Title	Disposal Cell Study
Description	Disposal Cell Dose with Measured Activity
Geometry	13 - Rectangular Volume

Source Dimensions

Length	2.8e+3 cm (91 ft 10.4 in)
Width	5.0e+3 cm (164 ft 0.5 in)
Height	200.0 cm (6 ft 6.7 in)



Dose Points

A	X	Y	Z
#1	2.9e+3 cm (95 ft 1.7 in)	300.0 cm (9 ft 10.1 in)	2.5e+3 cm (82 ft 0.3 in)

Shields

Shield N	Dimension	Material	Density
Source	2800.0 m³	Concrete	1.5
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input: Grouping Method - Actual Photon Energies
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ba-137m	1.4568e-003	5.3903e+007	5.2030e-007	1.9251e-002
Co-60	1.1480e-002	4.2476e+008	4.1000e-006	1.5170e-001
Cs-134	5.0400e-004	1.8648e+007	1.8000e-007	6.6600e-003
Cs-137	1.5400e-003	5.6980e+007	5.5000e-007	2.0350e-002

Buildup: The material reference is Source
Integration Parameters

X Direction	10
Y Direction	20
Z Direction	20

Results

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	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.0045	5.596e+05	2.995e-14	3.263e-14	2.053e-14	2.237e-14	1.792e-14	1.953e-14	1.792e-16	1.953e-16
0.0045	1.666e+04	8.918e-16	9.717e-16	6.113e-16	6.661e-16	5.336e-16	5.815e-16	5.336e-18	5.815e-18
0.0318	1.116e+06	3.128e-07	4.349e-07	2.606e-09	3.622e-09	2.275e-09	3.162e-09	2.275e-11	3.162e-11
0.0318	3.998e+04	1.121e-08	1.558e-08	9.334e-11	1.298e-10	8.148e-11	1.133e-10	8.148e-13	1.133e-12
0.0322	7.376e+04	2.246e-08	3.144e-08	1.807e-10	2.530e-10	1.578e-10	2.209e-10	1.578e-12	2.209e-12
0.0322	2.059e+06	6.269e-07	8.776e-07	5.045e-09	7.063e-09	4.404e-09	6.166e-09	4.404e-11	6.166e-11

0.0364	7.493e+05	4.896e-07	7.426e-07	2.782e-09	4.219e-09	2.429e-09	3.683e-09	2.429e-11	3.683e-11
0.0364	2.684e+04	1.754e-08	2.660e-08	9.966e-11	1.512e-10	8.701e-11	1.320e-10	8.701e-13	1.320e-12
0.2769	6.601e+03	4.244e-07	1.356e-06	7.961e-10	2.544e-09	6.950e-10	2.221e-09	6.950e-12	2.221e-11
0.4753	2.723e+05	3.845e-05	1.067e-04	7.545e-08	2.094e-07	6.587e-08	1.828e-07	6.587e-10	1.828e-09
0.5632	1.563e+06	2.838e-04	7.503e-04	5.557e-07	1.469e-06	4.852e-07	1.282e-06	4.852e-09	1.282e-08
0.5693	2.877e+06	5.311e-04	1.399e-03	1.039e-06	2.739e-06	9.073e-07	2.391e-06	9.073e-09	2.391e-08
0.6047	1.820e+07	3.676e-03	9.520e-03	7.171e-06	1.857e-05	6.261e-06	1.622e-05	6.261e-08	1.622e-07
0.6616	4.850e+07	1.121e-02	2.833e-02	2.174e-05	5.492e-05	1.898e-05	4.794e-05	1.898e-07	4.794e-07
0.6938	6.929e+04	1.721e-05	4.293e-05	3.322e-08	8.288e-08	2.900e-08	7.235e-08	2.900e-10	7.235e-10
0.7958	1.593e+07	4.872e-03	1.173e-02	9.273e-06	2.233e-05	8.095e-06	1.950e-05	8.095e-08	1.950e-07
0.8019	1.628e+06	5.039e-04	1.211e-03	9.581e-07	2.303e-06	8.364e-07	2.011e-06	8.364e-09	2.011e-08
1.0386	1.865e+05	8.605e-05	1.944e-04	1.576e-07	3.559e-07	1.376e-07	3.107e-07	1.376e-09	3.107e-09
1.1679	3.357e+05	1.862e-04	4.093e-04	3.331e-07	7.322e-07	2.908e-07	6.392e-07	2.908e-09	6.392e-09
1.1732	4.248e+08	2.373e-01	5.211e-01	4.241e-04	9.313e-04	3.702e-04	8.130e-04	3.702e-06	8.130e-06
1.3325	4.248e+08	2.903e-01	6.199e-01	5.037e-04	1.075e-03	4.397e-04	9.388e-04	4.397e-06	9.388e-06
1.3652	5.669e+05	4.027e-04	8.554e-04	6.944e-07	1.475e-06	6.062e-07	1.288e-06	6.062e-09	1.288e-08
Totals	**9.443e+08**	**5.494e-01**	**1.196e+00**	**9.698e-04**	**2.112e-03**	**8.466e-04**	**1.844e-03**	**8.466e-06**	**1.844e-05**

Dose Equivalent Report

Program	MicroShield, Grove Software, Inc.
Version	9.05
Organization	Energy Northwest
Serial #	9.05-0000
Date / Time	This case was run on Wednesday, June 9, 2021 at 7:43:07 PM
Filename	S:\Radiation Protection\Radiological Support\RP Calculations\Word versions\RP Calc 21-01\2800 Cube with Measured Activity.msd
Case Title	Disposal Cell Study
Description	Disposal Cell Dose with Measured Activity
Geometry	13 - Rectangular Volume
Sensitivity	No

Results

Nominal Case	
Dose Point #1	**(29, 3, 25) m**
Variable	**Not Applicable**

Results (Summed over energies)	**Units**	**Without Buildup**	**With Buildup**
Photon Fluence Rate (flux)	Photons/cm²/sec	4.521e-001	9.895e-001
Photon Energy Fluence Rate	MeV/cm²/sec	5.494e-001	1.196e+000
Exposure and Dose Rates			
Exposure Rate in Air	mR/hr	9.698e-004	2.112e-003
Absorbed Dose Rate in Air	mGy/hr	8.466e-006	1.844e-005
Absorbed Dose Rate in Air	mrad/hr	8.466e-004	1.844e-003
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
Parallel Geometry	mSv/hr	9.631e-006	2.098e-005
Opposed Geometry	mSv/hr	8.264e-006	1.799e-005
Rotational Geometry	mSv/hr	8.264e-006	1.799e-005
Isotropic Geometry	mSv/hr	7.377e-006	1.606e-005

Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
Parallel Geometry	mSv/hr	1.025e-005	2.234e-005
Opposed Geometry	mSv/hr	9.865e-006	2.149e-005
Rotational Geometry	mSv/hr	9.865e-006	2.149e-005
Isotropic Geometry	mSv/hr	7.821e-006	1.703e-005

Effective Dose Equivalent Rate (ICRP 51 - 1987)			
Anterior/Posterior Geometry	mSv/hr	8.665e-006	1.887e-005
Posterior/Anterior Geometry	mSv/hr	7.965e-006	1.734e-005
Lateral Geometry	mSv/hr	6.312e-006	1.374e-005
Rotational Geometry	mSv/hr	7.169e-006	1.561e-005
Isotropic Geometry	mSv/hr	6.332e-006	1.378e-005

Nominal Case

Dose Point #1 **(29, 3, 25) m**

Variable **Not Applicable**

Results (Summed over energies)	**Units**	**Without Buildup**	**With Buildup**
Bladder Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	9.058e-006	1.973e-005
Postero-anterior Geometry	mSv/hr	6.689e-006	1.456e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	5.474e-006	1.191e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	6.899e-006	1.502e-005
Isotropic Geometry	mSv/hr	5.939e-006	1.292e-005
Bone (Red Marrow) Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	6.775e-006	1.475e-005
Postero-anterior Geometry	mSv/hr	8.211e-006	1.788e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	5.969e-006	1.299e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	6.913e-006	1.505e-005
Isotropic Geometry	mSv/hr	6.102e-006	1.328e-005

Bone (Surface) Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	7.373e-006	1.605e-005
Postero-anterior Geometry	mSv/hr	7.819e-006	1.703e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	4.524e-006	1.005e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	7.061e-006	1.538e-005
Isotropic Geometry	mSv/hr	6.269e-006	1.365e-005

Breast - Female Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	9.436e-006	2.055e-005
Postero-anterior Geometry	mSv/hr	6.885e-006	1.498e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	7.019e-006	1.528e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	7.454e-006	1.623e-005
Isotropic Geometry	mSv/hr	7.089e-006	1.543e-005

Colon Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	8.478e-006	1.847e-005
Postero-anterior Geometry	mSv/hr	7.415e-006	1.614e-005
Left Lateral Geometry	mSv/hr	5.393e-006	1.173e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	5.393e-006	1.173e-005
Rotational Geometry	mSv/hr	6.865e-006	1.494e-005
Isotropic Geometry	mSv/hr	5.767e-006	1.255e-005

Gonads - Female Ovaries Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	7.792e-006	1.697e-005
Postero-anterior Geometry	mSv/hr	7.675e-006	1.672e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	4.883e-006	1.063e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	6.794e-006	1.479e-005
Isotropic Geometry	mSv/hr	5.786e-006	1.259e-005

Antero-posterior Geometry	mSv/hr	9.804e-006	2.136e-005
Postero-anterior Geometry	mSv/hr	6.750e-006	1.469e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	5.626e-006	1.223e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	6.873e-006	1.496e-005
Isotropic Geometry	mSv/hr	6.517e-006	1.419e-005

Gonads Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	8.863e-006	1.930e-005
Postero-anterior Geometry	mSv/hr	7.321e-006	1.594e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	5.159e-006	1.122e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	6.828e-006	1.486e-005
Isotropic Geometry	mSv/hr	1.312e-004	3.292e-004

Liver Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	8.471e-006	1.845e-005
Postero-anterior Geometry	mSv/hr	7.554e-006	1.645e-005
Left Lateral Geometry	mSv/hr	3.673e-006	7.984e-006
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	7.439e-006	1.620e-005
Rotational Geometry	mSv/hr	7.055e-006	1.536e-005
Isotropic Geometry	mSv/hr	6.152e-006	1.339e-005

Oesophagus Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	7.134e-006	1.553e-005
Postero-anterior Geometry	mSv/hr	7.668e-006	1.670e-005
Left Lateral Geometry	mSv/hr	6.648e-006	1.447e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	6.130e-006	1.334e-005
Rotational Geometry	mSv/hr	7.036e-006	1.532e-005
Isotropic Geometry	mSv/hr	6.049e-006	1.316e-005

Antero-posterior Geometry	mSv/hr	7.744e-006	1.686e-005
Postero-anterior Geometry	mSv/hr	7.745e-006	1.687e-005
Left Lateral Geometry	mSv/hr	5.993e-006	1.304e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	5.496e-006	1.196e-005
Rotational Geometry	mSv/hr	7.003e-006	1.525e-005
Isotropic Geometry	mSv/hr	6.092e-006	1.326e-005

Skin Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	8.257e-006	1.798e-005
Postero-anterior Geometry	mSv/hr	8.245e-006	1.795e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	7.171e-006	1.561e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	7.815e-006	1.702e-005
Isotropic Geometry	mSv/hr	7.342e-006	1.598e-005

Stomach Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	8.974e-006	1.955e-005
Postero-anterior Geometry	mSv/hr	6.716e-006	1.703e-005
Left Lateral Geometry	mSv/hr	7.479e-006	1.628e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	3.783e-006	8.224e-006
Rotational Geometry	mSv/hr	7.037e-006	1.532e-005
Isotropic Geometry	mSv/hr	6.065e-006	1.320e-005

Thyroid Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	1.034e-005	2.252e-005
Postero-anterior Geometry	mSv/hr	6.124e-006	1.333e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	9.193e-006	2.002e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	8.794e-006	1.915e-005
Isotropic Geometry	mSv/hr	6.675e-006	1.453e-005

Effective Dose (ICRP 74 - 1997)

	mSv/hr	8.455e-006	1.841e-005
Postero-anterior Geometry	mSv/hr	7.499e-006	1.633e-005
Left Lateral Geometry	mSv/hr	6.017e-006	1.310e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	5.700e-006	1.240e-005
Rotational Geometry	mSv/hr	7.131e-006	1.553e-005
Isotropic Geometry	mSv/hr	6.220e-006	1.354e-005

Eye Lens Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	9.248e-006	2.015e-005
Postero-anterior Geometry	mSv/hr	4.508e-006	9.801e-006
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	8.491e-006	1.849e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	8.491e-006	1.849e-005
Isotropic Geometry	mSv/hr	7.753e-006	1.688e-005

Thymus Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	9.453e-006	2.060e-005
Postero-anterior Geometry	mSv/hr	5.060e-006	1.101e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	6.127e-006	1.333e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	6.127e-006	1.333e-005
Isotropic Geometry	mSv/hr	7.076e-006	1.541e-005

Uterus Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	7.914e-006	1.724e-005
Postero-anterior Geometry	mSv/hr	7.247e-006	1.578e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	5.017e-006	1.091e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	5.017e-006	1.091e-005
Isotropic Geometry	mSv/hr	6.585e-006	1.434e-005

END

ATTACHMENT 2

MicroShield 9.05
Energy Northwest (9.05-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
CircleDisposal Cell Dose with Measured Activity.msd	June 14, 2021	4:12:20 PM	00:00:00

Project Info

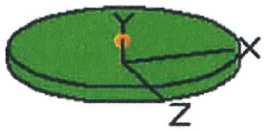
Case Title	Disposal Cell Study
Description	Disposal Cell Dose w/ Measured Activity
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions

Height	200.0 cm (6 ft 6.7 in)
Radius	1.5e+3 cm (49 ft 2.6 in)

Dose Points

A	X	Y	Z
#1	0.0 cm (0 in)	300.0 cm (9 ft 10.1 in)	0.0 cm (0 in)



Shields

Shield N	Dimension	Material	Density
Source	1413.717 m³	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Actual Photon Energies
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ba-137m	7.3021e-004	2.7018e+007	5.1652e-007	1.9111e-002
Co-60	5.7962e-003	2.1446e+008	4.1000e-006	1.5170e-001
Cs-134	2.5447e-004	9.4154e+006	1.8000e-007	6.6600e-003
Cs-137	7.7754e-004	2.8769e+007	5.5000e-007	2.0350e-002

Buildup: The material reference is Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.0045	2.805e+05	1.672e-11	1.799e-11	1.146e-11	1.233e-11	1.001e-11	1.076e-11	1.001e-13	1.076e-13
0.0045	8.414e+03	5.017e-13	5.397e-13	3.439e-13	3.699e-13	3.002e-13	3.229e-13	3.002e-15	3.229e-15
0.0318	5.593e+05	2.405e-06	3.207e-06	2.003e-08	2.671e-08	1.749e-08	2.332e-08	1.749e-10	2.332e-10
0.0318	2.018e+04	8.677e-08	1.157e-07	7.228e-10	9.639e-10	6.310e-10	8.415e-10	6.310e-12	8.415e-12
0.0322	3.724e+04	1.708e-07	2.292e-07	1.374e-09	1.845e-09	1.200e-09	1.610e-09	1.200e-11	1.610e-11
0.0322	1.032e+06	4.732e-06	6.352e-06	3.809e-08	5.112e-08	3.325e-08	4.463e-08	3.325e-10	4.463e-10
0.0364	3.755e+05	3.162e-06	4.569e-06	1.796e-08	2.596e-08	1.568e-08	2.266e-08	1.568e-10	2.266e-10
0.0364	1.355e+04	1.141e-07	1.649e-07	6.483e-10	9.369e-10	5.659e-10	8.179e-10	5.659e-12	8.179e-12

0.2769	3.333e+03	1.769e-06	5.208e-06	3.318e-09	9.769e-09	2.897e-09	8.528e-09	2.897e-11	8.528e-11
0.4753	1.375e+05	1.564e-04	4.046e-04	3.068e-07	7.939e-07	2.679e-07	6.931e-07	2.679e-09	6.931e-09
0.5632	7.890e+05	1.145e-03	2.829e-03	2.243e-06	5.540e-06	1.958e-06	4.836e-06	1.958e-08	4.836e-08
0.5693	1.453e+06	2.142e-03	5.275e-03	4.192e-06	1.032e-05	3.660e-06	9.013e-06	3.660e-08	9.013e-08
0.6047	9.189e+06	1.479e-02	3.580e-02	2.885e-05	6.986e-05	2.518e-05	6.098e-05	2.518e-07	6.098e-07
0.6616	2.431e+07	4.459e-02	1.054e-01	8.645e-05	2.043e-04	7.547e-05	1.783e-04	7.547e-07	1.783e-06
0.6938	3.498e+04	6.878e-05	1.605e-04	1.328e-07	3.099e-07	1.159e-07	2.705e-07	1.159e-09	2.705e-09
0.7958	8.041e+06	1.934e-02	4.357e-02	3.682e-05	8.292e-05	3.214e-05	7.239e-05	3.214e-07	7.239e-07
0.8019	8.220e+05	2.000e-03	4.496e-03	3.803e-06	8.549e-06	3.320e-06	7.463e-06	3.320e-08	7.463e-08
1.0386	9.415e+04	3.369e-04	7.101e-04	6.169e-07	1.300e-06	5.385e-07	1.135e-06	5.385e-09	1.135e-08
1.1679	1.695e+05	7.240e-04	1.482e-03	1.295e-06	2.651e-06	1.131e-06	2.315e-06	1.131e-08	2.315e-08
1.1732	2.145e+08	9.224e-01	1.887e+00	1.648e-03	3.371e-03	1.439e-03	2.943e-03	1.439e-05	2.943e-05
1.3325	2.145e+08	1.119e+00	2.220e+00	1.942e-03	3.852e-03	1.695e-03	3.363e-03	1.695e-05	3.363e-05
1.3652	2.862e+05	1.550e-03	3.058e-03	2.673e-06	5.273e-06	2.333e-06	4.603e-06	2.333e-08	4.603e-08
Totals	**4.766e+08**	**2.128e+00**	**4.310e+00**	**3.758e-03**	**7.615e-03**	**3.280e-03**	**6.648e-03**	**3.280e-05**	**6.648e-05**

Dose Equivalent Report

Program	MicroShield, Grove Software, Inc.
Version	9.05
Organization	Energy Northwest
Serial #	9.05-0000
Date / Time	This case was run on Monday, June 14, 2021 at 4:12:20 PM
Filename	S:\Radiation Protection\Radiological Support\RP Calculations\Word versions\RP Calc 21-01\CircleDisposal Cell Dose with Measured Activity.msd
Case Title	Disposal Cell Study
Description	Disposal Cell Dose w/ Measured Activity
Geometry	8 - Cylinder Volume - End Shields
Sensitivity	No

Results

Nominal Case

Dose Point #1	**(0, 3, 0) m**
Variable	**Not Applicable**

Results (Summed over energies)	**Units**	**Without Buildup**	**With Buildup**
Photon Fluence Rate (flux)	Photons/cm²/sec	1.753e+000	3.573e+000
Photon Energy Fluence Rate	MeV/cm²/sec	2.128e+000	4.310e+000
Exposure and Dose Rates			
Exposure Rate in Air	mR/hr	3.758e-003	7.615e-003
Absorbed Dose Rate in Air	mGy/hr	3.280e-005	6.648e-005
Absorbed Dose Rate in Air	mrad/hr	3.280e-003	6.648e-003
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
Parallel Geometry	mSv/hr	3.732e-005	7.566e-005
Opposed Geometry	mSv/hr	3.202e-005	6.487e-005
Rotational Geometry	mSv/hr	3.202e-005	6.487e-005
Isotropic Geometry	mSv/hr	2.858e-005	5.790e-005

Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
Parallel Geometry	mSv/hr	3.973e-005	8.056e-005
Opposed Geometry	mSv/hr	3.822e-005	7.748e-005
Rotational Geometry	mSv/hr	3.822e-005	7.748e-005
Isotropic Geometry	mSv/hr	3.030e-005	6.140e-005

Effective Dose Equivalent Rate (ICRP 51 - 1987)			
Anterior/Posterior Geometry	mSv/hr	3.357e-005	6.806e-005
Posterior/Anterior Geometry	mSv/hr	3.086e-005	6.253e-005
Lateral Geometry	mSv/hr	2.445e-005	4.952e-005
Rotational Geometry	mSv/hr	2.778e-005	5.628e-005
Isotropic Geometry	mSv/hr	2.453e-005	4.969e-005

Nominal Case

Dose Point #1 **(0, 3, 0) m**

Variable **Not Applicable**

Results (Summed over energies)	**Units**	**Without Buildup**	**With Buildup**
Bladder Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.510e-005	7.116e-005
Postero-anterior Geometry	mSv/hr	2.591e-005	5.249e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.121e-005	4.293e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.673e-005	5.415e-005
Isotropic Geometry	mSv/hr	2.301e-005	4.659e-005
Bone (Red Marrow) Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	2.625e-005	5.317e-005
Postero-anterior Geometry	mSv/hr	3.182e-005	6.449e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.313e-005	4.684e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.678e-005	5.427e-005
Isotropic Geometry	mSv/hr	2.364e-005	4.788e-005

Bone (Surface) Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	2.857e-005	5.789e-005
Postero-anterior Geometry	mSv/hr	3.030e-005	6.141e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	1.760e-005	3.643e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.736e-005	5.544e-005
Isotropic Geometry	mSv/hr	2.429e-005	4.921e-005

Breast - Female Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.656e-005	7.412e-005
Postero-anterior Geometry	mSv/hr	2.667e-005	5.402e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.719e-005	5.509e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.888e-005	5.851e-005
Isotropic Geometry	mSv/hr	2.747e-005	5.565e-005

Colon Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.285e-005	6.659e-005
Postero-anterior Geometry	mSv/hr	2.873e-005	5.821e-005
Left Lateral Geometry	mSv/hr	2.089e-005	4.230e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.089e-005	4.230e-005
Rotational Geometry	mSv/hr	2.660e-005	5.388e-005
Isotropic Geometry	mSv/hr	2.234e-005	4.525e-005

Gonads - Female Ovaries Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.019e-005	6.119e-005
Postero-anterior Geometry	mSv/hr	2.974e-005	6.027e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	1.892e-005	3.831e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.632e-005	5.334e-005
Isotropic Geometry	mSv/hr	2.242e-005	4.540e-005

Antero-posterior Geometry	mSv/hr	3.799e-005	7.703e-005
Postero-anterior Geometry	mSv/hr	2.615e-005	5.297e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.179e-005	4.408e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.663e-005	5.395e-005
Isotropic Geometry	mSv/hr	2.525e-005	5.115e-005

Gonads Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.434e-005	6.961e-005
Postero-anterior Geometry	mSv/hr	2.836e-005	5.747e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	1.998e-005	4.046e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.645e-005	5.360e-005
Isotropic Geometry	mSv/hr	5.226e-004	1.226e-003

Liver Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.282e-005	6.653e-005
Postero-anterior Geometry	mSv/hr	2.927e-005	5.931e-005
Left Lateral Geometry	mSv/hr	1.423e-005	2.877e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.882e-005	5.840e-005
Rotational Geometry	mSv/hr	2.733e-005	5.538e-005
Isotropic Geometry	mSv/hr	2.383e-005	4.828e-005

Oesophagus Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	2.764e-005	5.601e-005
Postero-anterior Geometry	mSv/hr	2.971e-005	6.021e-005
Left Lateral Geometry	mSv/hr	2.575e-005	5.216e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.375e-005	4.809e-005
Rotational Geometry	mSv/hr	2.726e-005	5.522e-005
Isotropic Geometry	mSv/hr	2.343e-005	4.746e-005

Antero-posterior Geometry	mSv/hr	3.001e-005	6.081e-005
Postero-anterior Geometry	mSv/hr	3.001e-005	6.082e-005
Left Lateral Geometry	mSv/hr	2.322e-005	4.702e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.129e-005	4.311e-005
Rotational Geometry	mSv/hr	2.713e-005	5.497e-005
Isotropic Geometry	mSv/hr	2.360e-005	4.780e-005

Skin Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.199e-005	6.483e-005
Postero-anterior Geometry	mSv/hr	3.195e-005	6.474e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.778e-005	5.628e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	3.028e-005	6.135e-005
Isotropic Geometry	mSv/hr	2.844e-005	5.763e-005

Stomach Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.477e-005	7.050e-005
Postero-anterior Geometry	mSv/hr	2.602e-005	6.141e-005
Left Lateral Geometry	mSv/hr	2.898e-005	5.871e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	1.465e-005	2.964e-005
Rotational Geometry	mSv/hr	2.726e-005	5.524e-005
Isotropic Geometry	mSv/hr	2.349e-005	4.759e-005

Thyroid Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	4.006e-005	8.123e-005
Postero-anterior Geometry	mSv/hr	2.373e-005	4.804e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	3.562e-005	7.218e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	3.407e-005	6.904e-005
Isotropic Geometry	mSv/hr	2.586e-005	5.239e-005

Effective Dose (ICRP 74 - 1997)

	mSv/hr	3.276e-005	6.640e-005
Postero-anterior Geometry	mSv/hr	2.906e-005	5.888e-005
Left Lateral Geometry	mSv/hr	2.331e-005	4.721e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.208e-005	4.471e-005
Rotational Geometry	mSv/hr	2.763e-005	5.598e-005
Isotropic Geometry	mSv/hr	2.410e-005	4.881e-005
Eye Lens Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.584e-005	7.267e-005
Postero-anterior Geometry	mSv/hr	1.746e-005	3.532e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	3.290e-005	6.668e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	3.290e-005	6.668e-005
Isotropic Geometry	mSv/hr	3.004e-005	6.087e-005
Thymus Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.663e-005	7.428e-005
Postero-anterior Geometry	mSv/hr	1.960e-005	3.969e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.374e-005	4.807e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.374e-005	4.807e-005
Isotropic Geometry	mSv/hr	2.741e-005	5.556e-005
Uterus Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.066e-005	6.215e-005
Postero-anterior Geometry	mSv/hr	2.808e-005	5.690e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	1.943e-005	3.933e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	1.943e-005	3.933e-005
Isotropic Geometry	mSv/hr	2.551e-005	5.169e-005

END

ATTACHMENT 3

MicroShield 9.05
Energy Northwest (9.05-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
2x VolumeCircle with Measured Activity.msd	June 14, 2021	4:17:39 PM	00:00:00

Project Info

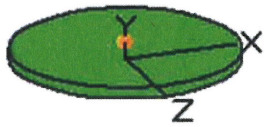
Case Title	Disposal Cell Study
Description	Disposal Cell Dose w/ Measured Activity
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions

Height	200.0 cm (6 ft 6.7 in)
Radius	2.1e+3 cm (69 ft 2.7 in)

Dose Points

A	X	Y	Z
#1	0.0 cm (0 in)	300.0 cm (9 ft 10.1 in)	0.0 cm (0 in)



Shields

Shield N	Dimension	Material	Density
Source	2797.337 m³	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Actual Photon Energies
Library: Grove

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ba-137m	1.4449e-003	5.3460e+007	5.1652e-007	1.9111e-002
Co-60	1.1469e-002	4.2436e+008	4.1000e-006	1.5170e-001
Cs-134	5.0352e-004	1.8630e+007	1.8000e-007	6.6600e-003
Cs-137	1.5385e-003	5.6926e+007	5.5000e-007	2.0350e-002

Buildup: The material reference is Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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	Absorbed Dose Rate mrad/hr No Buildup	Absorbed Dose Rate mrad/hr With Buildup	Absorbed Dose Rate mGy/hr No Buildup	Absorbed Dose Rate mGy/hr With Buildup
0.0045	5.550e+05	1.672e-11	1.798e-11	1.146e-11	1.233e-11	1.000e-11	1.076e-11	1.000e-13	1.076e-13
0.0045	1.665e+04	5.015e-13	5.395e-13	3.438e-13	3.698e-13	3.001e-13	3.228e-13	3.001e-15	3.228e-15
0.0318	1.107e+06	2.309e-06	3.077e-06	1.924e-08	2.563e-08	1.679e-08	2.237e-08	1.679e-10	2.237e-10
0.0318	3.994e+04	8.333e-08	1.110e-07	6.941e-10	9.248e-10	6.060e-10	8.074e-10	6.060e-12	8.074e-12
0.0322	7.369e+04	1.640e-07	2.199e-07	1.320e-09	1.770e-09	1.152e-09	1.545e-09	1.152e-11	1.545e-11
0.0322	2.042e+06	4.544e-06	6.093e-06	3.657e-08	4.904e-08	3.192e-08	4.281e-08	3.192e-10	4.281e-10
0.0364	7.431e+05	3.036e-06	4.387e-06	1.725e-08	2.493e-08	1.506e-08	2.176e-08	1.506e-10	2.176e-10
0.0364	2.682e+04	1.096e-07	1.583e-07	6.225e-10	8.996e-10	5.435e-10	7.853e-10	5.435e-12	7.853e-12

0.2769	6.595e+03	1.798e-06	5.307e-06	3.372e-09	9.956e-09	2.944e-09	8.691e-09	2.944e-11	8.691e-11
0.4753	2.720e+05	1.591e-04	4.123e-04	3.122e-07	8.089e-07	2.725e-07	7.062e-07	2.725e-09	7.062e-09
0.5632	1.561e+06	1.166e-03	2.883e-03	2.282e-06	5.646e-06	1.993e-06	4.929e-06	1.993e-08	4.929e-08
0.5693	2.875e+06	2.180e-03	5.376e-03	4.267e-06	1.052e-05	3.725e-06	9.185e-06	3.725e-08	9.185e-08
0.6047	1.818e+07	1.505e-02	3.649e-02	2.936e-05	7.119e-05	2.563e-05	6.215e-05	2.563e-07	6.215e-07
0.6616	4.810e+07	4.539e-02	1.074e-01	8.799e-05	2.082e-04	7.682e-05	1.818e-04	7.682e-07	1.818e-06
0.6938	6.922e+04	7.001e-05	1.636e-04	1.352e-07	3.158e-07	1.180e-07	2.757e-07	1.180e-09	2.757e-09
0.7958	1.591e+07	1.969e-02	4.441e-02	3.748e-05	8.453e-05	3.272e-05	7.379e-05	3.272e-07	7.379e-07
0.8019	1.626e+06	2.036e-03	4.583e-03	3.872e-06	8.714e-06	3.380e-06	7.607e-06	3.380e-08	7.607e-08
1.0386	1.863e+05	3.431e-04	7.239e-04	6.282e-07	1.325e-06	5.484e-07	1.157e-06	5.484e-09	1.157e-08
1.1679	3.353e+05	7.373e-04	1.511e-03	1.319e-06	2.703e-06	1.151e-06	2.359e-06	1.151e-08	2.359e-08
1.1732	4.244e+08	9.395e-01	1.923e+00	1.679e-03	3.436e-03	1.466e-03	3.000e-03	1.466e-05	3.000e-05
1.3325	4.244e+08	1.140e+00	2.263e+00	1.978e-03	3.926e-03	1.727e-03	3.428e-03	1.727e-05	3.428e-05
1.3652	5.664e+05	1.579e-03	3.116e-03	2.722e-06	5.374e-06	2.377e-06	4.691e-06	2.377e-08	4.691e-08
Totals	**9.430e+08**	**2.168e+00**	**4.393e+00**	**3.827e-03**	**7.762e-03**	**3.341e-03**	**6.776e-03**	**3.341e-05**	**6.776e-05**

Dose Equivalent Report

Program	MicroShield, Grove Software, Inc.
Version	9.05
Organization	Energy Northwest
Serial #	9.05-0000
Date / Time	This case was run on Monday, June 14, 2021 at 4:17:39 PM
Filename	S:\Radiation Protection\Radiological Support\RP Calculations\Word versions\RP Calc 21-01\2x VolumeCircle with Measured Activity.msd
Case Title	Disposal Cell Study
Description	Disposal Cell Dose w/ Measured Activity
Geometry	8 - Cylinder Volume - End Shields
Sensitivity	No

Results

Nominal Case

Dose Point #1	**(0, 3, 0) m**
Variable	**Not Applicable**

Results (Summed over energies)	**Units**	**Without Buildup**	**With Buildup**
Photon Fluence Rate (flux)	Photons/cm²/sec	1.786e+000	3.642e+000
Photon Energy Fluence Rate	MeV/cm²/sec	2.168e+000	4.393e+000
Exposure and Dose Rates			
Exposure Rate in Air	mR/hr	3.827e-003	7.762e-003
Absorbed Dose Rate in Air	mGy/hr	3.341e-005	6.776e-005
Absorbed Dose Rate in Air	mrad/hr	3.341e-003	6.776e-003
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
Parallel Geometry	mSv/hr	3.801e-005	7.711e-005
Opposed Geometry	mSv/hr	3.261e-005	6.612e-005
Rotational Geometry	mSv/hr	3.261e-005	6.612e-005
Isotropic Geometry	mSv/hr	2.911e-005	5.902e-005

Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
Parallel Geometry	mSv/hr	4.047e-005	8.211e-005
Opposed Geometry	mSv/hr	3.893e-005	7.898e-005
Rotational Geometry	mSv/hr	3.893e-005	7.898e-005
Isotropic Geometry	mSv/hr	3.086e-005	6.258e-005

Effective Dose Equivalent Rate (ICRP 51 - 1987)			
Anterior/Posterior Geometry	mSv/hr	3.420e-005	6.937e-005
Posterior/Anterior Geometry	mSv/hr	3.143e-005	6.374e-005
Lateral Geometry	mSv/hr	2.491e-005	5.048e-005
Rotational Geometry	mSv/hr	2.829e-005	5.736e-005
Isotropic Geometry	mSv/hr	2.499e-005	5.065e-005

Nominal Case

Dose Point #1 **(0, 3, 0) m**

Variable **Not Applicable**

Results (Summed over energies)	**Units**	**Without Buildup**	**With Buildup**
Bladder Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.575e-005	7.253e-005
Postero-anterior Geometry	mSv/hr	2.639e-005	5.350e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.160e-005	4.376e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.722e-005	5.519e-005
Isotropic Geometry	mSv/hr	2.343e-005	4.749e-005
Bone (Red Marrow) Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	2.673e-005	5.420e-005
Postero-anterior Geometry	mSv/hr	3.241e-005	6.574e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.355e-005	4.774e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.728e-005	5.531e-005
Isotropic Geometry	mSv/hr	2.408e-005	4.881e-005

Bone (Surface) Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	2.910e-005	5.900e-005
Postero-anterior Geometry	mSv/hr	3.086e-005	6.259e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	1.792e-005	3.713e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.787e-005	5.651e-005
Isotropic Geometry	mSv/hr	2.474e-005	5.016e-005

Breast - Female Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.724e-005	7.555e-005
Postero-anterior Geometry	mSv/hr	2.717e-005	5.506e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.770e-005	5.615e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.941e-005	5.964e-005
Isotropic Geometry	mSv/hr	2.797e-005	5.672e-005

Colon Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.346e-005	6.788e-005
Postero-anterior Geometry	mSv/hr	2.926e-005	5.934e-005
Left Lateral Geometry	mSv/hr	2.128e-005	4.312e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.128e-005	4.312e-005
Rotational Geometry	mSv/hr	2.709e-005	5.492e-005
Isotropic Geometry	mSv/hr	2.276e-005	4.612e-005

Gonads - Female Ovaries Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.075e-005	6.237e-005
Postero-anterior Geometry	mSv/hr	3.029e-005	6.143e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	1.927e-005	3.905e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.681e-005	5.437e-005
Isotropic Geometry	mSv/hr	2.283e-005	4.628e-005

Antero-posterior Geometry	mSv/hr	3.869e-005	7.852e-005
Postero-anterior Geometry	mSv/hr	2.663e-005	5.399e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.219e-005	4.493e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.712e-005	5.499e-005
Isotropic Geometry	mSv/hr	2.572e-005	5.214e-005

Gonads Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.498e-005	7.095e-005
Postero-anterior Geometry	mSv/hr	2.889e-005	5.858e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.035e-005	4.124e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.694e-005	5.463e-005
Isotropic Geometry	mSv/hr	5.319e-004	1.249e-003

Liver Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.343e-005	6.781e-005
Postero-anterior Geometry	mSv/hr	2.981e-005	6.045e-005
Left Lateral Geometry	mSv/hr	1.449e-005	2.933e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.936e-005	5.952e-005
Rotational Geometry	mSv/hr	2.784e-005	5.645e-005
Isotropic Geometry	mSv/hr	2.428e-005	4.921e-005

Oesophagus Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	2.815e-005	5.709e-005
Postero-anterior Geometry	mSv/hr	3.026e-005	6.137e-005
Left Lateral Geometry	mSv/hr	2.623e-005	5.317e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.419e-005	4.902e-005
Rotational Geometry	mSv/hr	2.777e-005	5.629e-005
Isotropic Geometry	mSv/hr	2.387e-005	4.838e-005

Antero-posterior Geometry	mSv/hr	3.056e-005	6.198e-005
Postero-anterior Geometry	mSv/hr	3.056e-005	6.199e-005
Left Lateral Geometry	mSv/hr	2.365e-005	4.792e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.169e-005	4.394e-005
Rotational Geometry	mSv/hr	2.763e-005	5.603e-005
Isotropic Geometry	mSv/hr	2.404e-005	4.872e-005

Skin Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.258e-005	6.608e-005
Postero-anterior Geometry	mSv/hr	3.254e-005	6.599e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.830e-005	5.737e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	3.084e-005	6.254e-005
Isotropic Geometry	mSv/hr	2.897e-005	5.874e-005

Stomach Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	3.542e-005	7.186e-005
Postero-anterior Geometry	mSv/hr	2.650e-005	6.259e-005
Left Lateral Geometry	mSv/hr	2.951e-005	5.984e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	1.492e-005	3.021e-005
Rotational Geometry	mSv/hr	2.777e-005	5.630e-005
Isotropic Geometry	mSv/hr	2.393e-005	4.850e-005

Thyroid Absorbed Dose (ICRP 74 - 1997)

Antero-posterior Geometry	mSv/hr	4.080e-005	8.279e-005
Postero-anterior Geometry	mSv/hr	2.417e-005	4.897e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	3.628e-005	7.357e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	3.470e-005	7.037e-005
Isotropic Geometry	mSv/hr	2.634e-005	5.340e-005

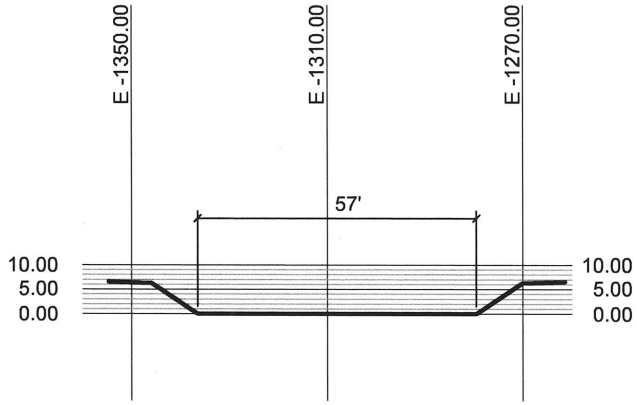
Effective Dose (ICRP 74 - 1997)

	mSv/hr	3.337e-005	6.768e-005
Postero-anterior Geometry	mSv/hr	2.959e-005	6.001e-005
Left Lateral Geometry	mSv/hr	2.374e-005	4.812e-005
Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Right Lateral Geometry	mSv/hr	2.249e-005	4.558e-005
Rotational Geometry	mSv/hr	2.814e-005	5.706e-005
Isotropic Geometry	mSv/hr	2.454e-005	4.975e-005
Eye Lens Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.650e-005	7.407e-005
Postero-anterior Geometry	mSv/hr	1.779e-005	3.600e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	3.351e-005	6.796e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	3.351e-005	6.796e-005
Isotropic Geometry	mSv/hr	3.060e-005	6.205e-005
Thymus Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.731e-005	7.571e-005
Postero-anterior Geometry	mSv/hr	1.997e-005	4.046e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	2.418e-005	4.899e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	2.418e-005	4.899e-005
Isotropic Geometry	mSv/hr	2.792e-005	5.663e-005
Uterus Absorbed Dose (ICRP 74 - 1997)			
Antero-posterior Geometry	mSv/hr	3.123e-005	6.335e-005
Postero-anterior Geometry	mSv/hr	2.860e-005	5.800e-005
Left Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Lateral Geometry	mSv/hr	1.979e-005	4.009e-005
Right Lateral Geometry	mSv/hr	0.000e+000	0.000e+000
Rotational Geometry	mSv/hr	1.979e-005	4.009e-005
Isotropic Geometry	mSv/hr	2.598e-005	5.268e-005

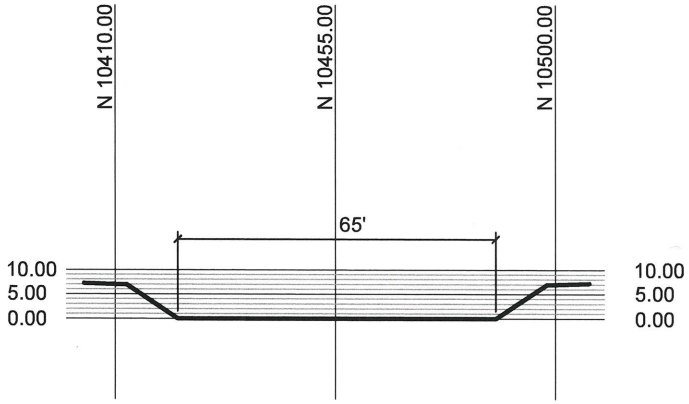
END

GO2-21-084 Enclosure, Attachment 2:

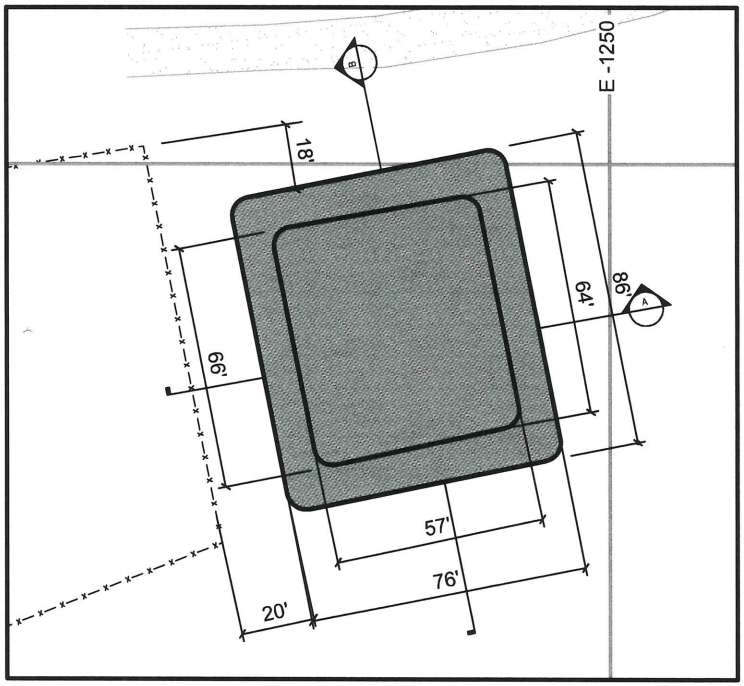
As-Built Facilities and Commercial Engineering Drawing of November 2020 Sediment Disposal Cell



A EAST-WEST PROFILE
SCALE : 1/2" = 1'-0"



B NORTH-SOUTH PROFILE
SCALE : 1/2" = 1'-0"



1 SITE PLAN - SEDIMENT CELL
SCALE : 3/8"=1'-0"

GENERAL NOTES:

SEDIMENT CELL VOLUME = 34000 C.F., 1260 C.Y.

AS-BUILT

JUNE 01, 2021

REV	DATE	DESCRIPTION	DWN	CHK	ENGR

ENERGY NORTHWEST

FACILITIES & COMMERCIAL ENGINEERING

SIGNATURE		DATE
APPROVED	RH	26 MAY 2021
DESIGN	RH	19 MAY 2021
CHECKED	APP	26 MAY 2021
DRAWN	AMC	19 MAY 2021
SCALE AS NOTED		
OLD FILE/DRAWING NO.		-

COLUMBIA GENERATING STATION

SEDIMENT CELLS REBUILD

CIVIL - PROFILES

CAD FILE NO.	SHEET NO.	REV.
02SCC101	C101	0

GO2-21-084 Enclosure, Attachment 3:

Line of Site Images for TLD Stations 119B and 119Ctrl

Figure 1 Line of site image from TLD Station 119B to Columbia Generating Station

Figure 2 Line of site image from TLD Station 119Ctrl to Columbia Generating Station