MALCOLM PIRNIE

Technical Memorandum

Date: October 14, 2008

Revised: March 30, 2009

To: Jon Erickson, Colorado Department of Public Health and Environment

From: Jason Kerstiens, DEN

Re: Results of residuals sampling at CORADS Systems

Project No.: 5322-009

Samples were collected from three water systems that have treatment for radionuclides in Colorado to better understand the concentration of radionuclides in the treatment processes and residuals and the associated radiation exposure. All three water systems are participating in the Colorado Radionuclide Abatement and Disposal Strategy (CO-RADS) project. The following systems were sampled:

- Redhill Forest (RHF) on June 4, 2008
- Blue Mountain Water District (Blue Mountain) on June 24, 2008
- May Valley on June 26, 2008

Samples of treated streams, waste streams, and resin/media were collected by employees of the Colorado Department of Public Health and Environment (CDPHE) Radiation Materials Unit of the Hazardous Materials and Waste Management Division. Radiation exposure rates were also measured around each treatment facility. Laboratory testing was performed by the Laboratory Services Division of CDPHE. Malcolm Pirnie is preparing this memorandum to report the results of the sampling and analysis.

Redhill Forest

The sampling locations at RHF are illustrated in Figure 1.

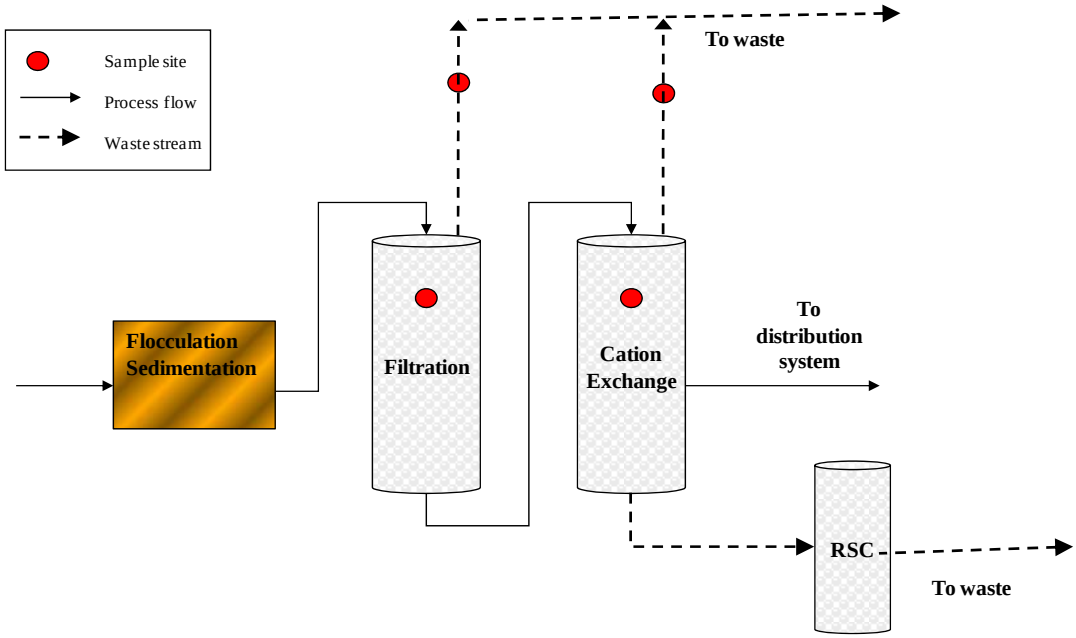

Figure 1 – Redhill Forest Sampling Location Schematic

Table 1 describes the sampling locations at RHF.

Table 1 – Redhill Forest Sampling Location Descriptions

Sample Name	Description/Other Info
Filter Media Pre-backwash 1	Antracite iron filtration media, composite sample from multiple sites across the media taken just prior to filter backwash after treating approximately 35,000 gallons.
Filter Media Pre-backwash 2	Anthracite iron filtration media, sample taken from a corner of the filtration bed that gave the highest gamma exposure readings, just prior to filter backwash.
Spent Filter Backwash Water	Backwash waste water, single grab taken during the early phase of the backwash cycle
Filter Media Post-Backwash	Composite sample of anthracite media approximately 1 hour after backwash
Ion Exchange Resin Pre-regeneration	Composite sample of the cation exchange resin prior to regeneration
Ion Exchange Backwash Water	Single grab of backwash waste water taken during the early phase of the backwash cycle.
Ion Exchange Regeneration Water	Single grab of ion exchange regeneration waste water, taken during the early phase of the regeneration process. Rinse water was not sampled since it mixes with regenerated waste in a tank prior to sampling location.

Results of the radionuclide analyses performed at RHF are summarized in Table 2.

Table 2 – Analytical Results for Radionuclides at RHF

Analyte	Media and Resin (pCi/g)						Liquid Residuals (pCi/L)		
	Filter Media Pre Backwash 1	Filter Media Pre Backwash 2	Filter Media Post Backwash		Ion Exchange Resin Pre-regeneration	Ion Exchange Resin post regeneration	Spent Filter Backwash Water	Ion Exchange Backwash	Ion Exchange Regeneration Water
Gross Alpha 900.0	2360	2150	2020	1102	366	333	325	160	
Gross Alpha 00-02									2250
Gross Beta 900.0	1020	910	930	290	337	293	174	97	
Lead 212 901.1	35	36	36		18	11			
Lead 214 901.1	229	226	220		142	67			
Potassium 40 901.1	11	10	15.3		BDL	1.6			
Radium 228 901.1	33.5	33.9	33.6		16.7	7.4			
Radium 228 904.0			58				902	6.2	99.3
Radium 223 901.1	6.7	7.1	8		9	BDL			
Radium 226 901.1	266	261	260		181	44.7			
Radium 226 903.0			514				162	73	118
Uranium 235	2.1	2.5	2.3		3.6	BDL			
Uranium 238	41	42	40		32	10			
Uranium, tot 200.8 (mg/L)			23				0.035	0.017	BDL

Blank cells indicate analysis was not performed
BDL = Below Detection Limit for analysis
EPA 901.1 is a gamma spectroscopy method
EPA 200.8, EPA 900, EPA 903.0, EPA 904.0 are standard drinking water methods, if used for solid samples, digestion was performed to prepare sample
EPA 0-02 is a co-precipitation method

Table 3 shows the analytical results from the water quality sampling conducted at RHF.

Table 3 – Water Quality Results from RHF

Analyte	Units	Liquid Residuals		
		Spent Filter Backwash Water	Ion Exchange Backwash	Ion Exchange Regeneration Water
Alkalinity, Total	mg/L	60	52	30
Aluminum, Total	mg/L	28	11	BDL
Arsenic, Total	mg/L	0.007	0.011	0.007
Barium, Total	mg/L	0.042	0.02	0.89
Beryllium, Total	mg/L	BDL	BDL	BDL
Cadmium, Total	mg/L	BDL	BDL	BDL
Calcium (Carbonate)	mg/L	120	78	7400
Chromium, Total	mg/L	BDL	BDL	BDL
Copper, Total	mg/L	BDL	0.014	0.012
Iron, Total	mg/L	34	22	2.9
Lead, Total	mg/L	0.001	0.011	0.003
Magnesium, Total	mg/L	11	9.8	680
Manganese, Total	mg/L	8	3.4	1.3
Molybdenum, Total	mg/L	BDL	BDL	BDL
Nickel, Total	mg/L	BDL	BDL	0.39
Nitrate-N	mg/L	BDL	BDL	0.95
pH	-	6.9	7	6.3
Potassium, Total	mg/L	2.7	5	150
Selenium, Total	mg/L	BDL	BDL	0.002
Silicon, Total	mg/L	7.4	5.3	3
Silver, Total	mg/L	BDL	BDL	0.036
Sodium, Total	mg/L	33	59	11400
Solids, Dissolved	mg/L	300	290	40000
Sulfate	mg/L	160	160	190
Thallium, Total	mg/L	0.006	0.004	0.019
Turbidity	NTU	100	64	7.9
Uranium, Total	mg/L	0.035	0.017	BDL
Zinc, Total	mg/L	1.2	0.68	13
Total Organic Carbon (TOC)	mg/L	1.6	1.1	0.9

Exposure rates (over background) in µrem/hr measured in the facility are illustrated and summarized in Figure 2. Measured values were adjusted for the background radiation rate of 10 µrem/hr

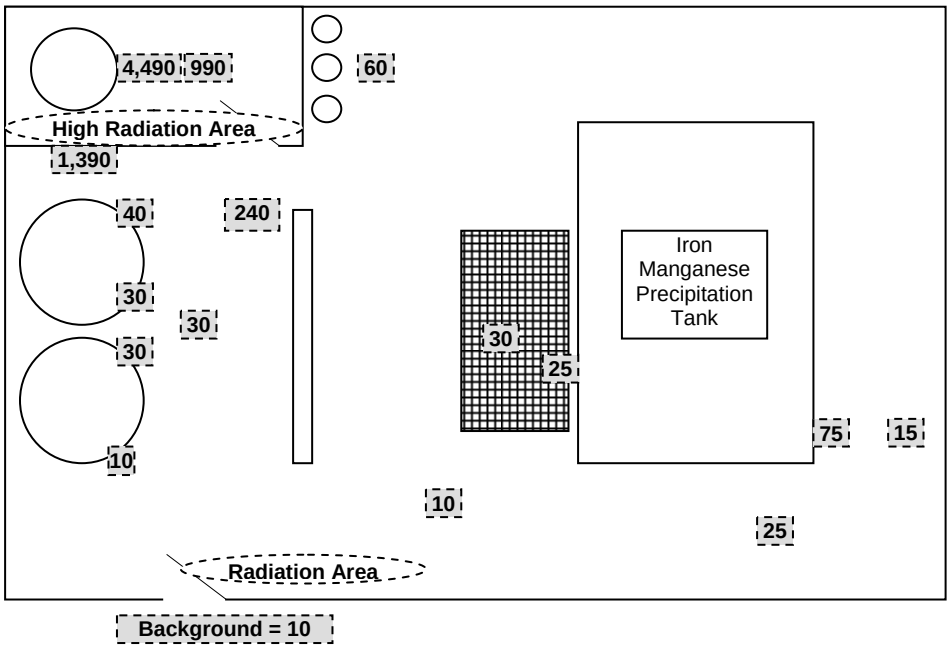

Figure 2 – Radiation Exposure rates (µrem/hr over Background) in the RHF Treatment Facility

Blue Mountain

The Sampling locations at Blue Mountain are illustrated in Figure 3.

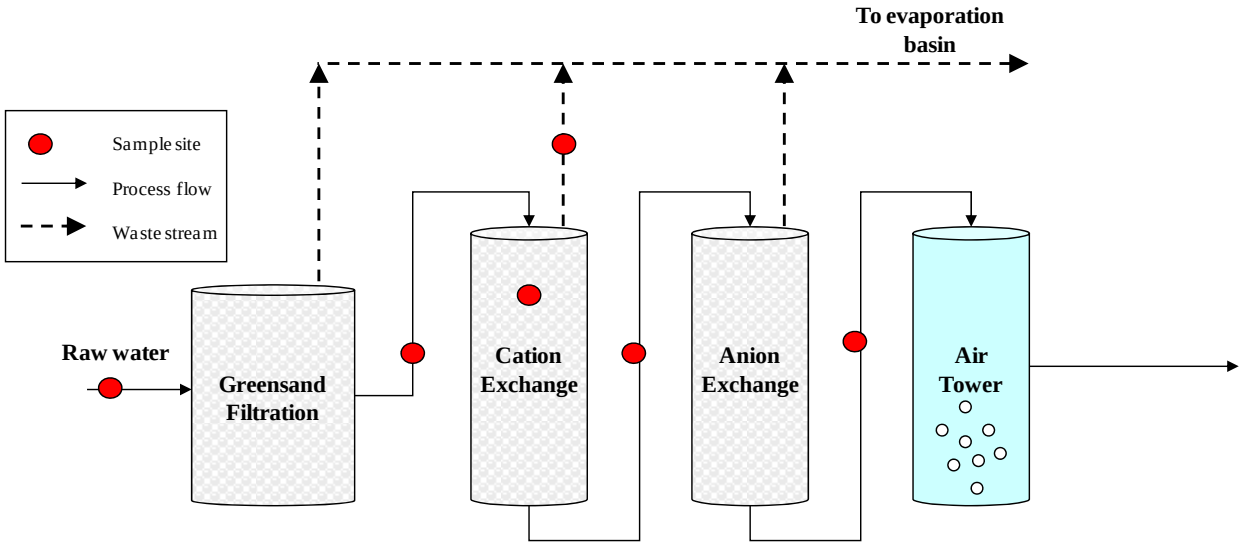

Figure 3 – Blue Mountain Sampling Locations

Table 4 describes the sampling locations at Blue Mountain.

Table 4 – Blue Mountain Sampling Location Descriptions

Sample Name	Description/Other Info
Ion Exchange Resin Pre-regeneration	Composite sample of the cation exchange media just prior to regeneration
Ion Exchange Backwash Water	Time average composite of backwash waste water from the ion exchange process – BW volume 800 gal
Ion Exchange Regeneration Water	Time/volume average composite of ion exchange regeneration waste water – Regen volume 800 gal
Ion Exchange Rinse Water	Time/volume average composite of fast and slow rinse waste water – Rinse volume 800 gal slow, 500 gal fast rinse
Ion Exchange Resin Post-regeneration	Composite sample of the cation exchange media just after the regeneration/rinse process
Blank	Duplicate of IX Media Post Regen
Raw	Raw water sample
Greensand Effluent	Water sample taken after greensand treatment
Cation Exchange Effluent	Water sample taken after cation exchange treatment
Anion Exchange Effluent	Water sample taken after anion exchange treatment

Results of radionuclide analyses performed at Blue Mountain are summarized in Table 5.

Table 5 – Analytical Results for Radionuclides at Blue Mountain

Analyte	Resin Samples (pCi/g)			Liquid Samples (pCi/L)						
	Ion Exchange Resin Pre-Regeneration	Ion Exchange Resin Post Regeneration	Ion Exchange Post Regeneration (Duplicate)	Raw Water	Greensand Effluent	Cation Exchange Effluent	Anion Exchange Effluent	Ion Exchange Backwash Water	Ion Exchange Regeneration Water	Ion Exchange Rinse Water
Gross Alpha 900.0	219	152	240	21	26	3	4	2490		
Gross Alpha 00-02									2254	249
Gross Beta 900.0	135	127	147	8	5	6	BDL	1040		
Lead 212 901.1	2.7	2.4	2.3	BDL	BDL	BDL	BDL		BDL	
Lead 214 901.1	143	85	119	BDL	BDL	BDL	BDL		223	
Potassium 40 901.1	BDL	BDL	BDL	25.9	BDL	BDL	BDL		BDL	
Radium 228 901.1	3.6	2.9	2.6	BDL	BDL	BDL	BDL		26	
Radium 228 904.0				1.1	BDL	BDL	BDL	20.8	7.5	BDL
Radium 226 901.1	125	115	104	BDL	66	BDL	BDL		1500	
Radium 226 903.0				6.7	0.5	5.3	0.1	218	8.3	114
Thorium 228 3084-89				BDL	1.24	0.02	0.754	5.19	12.46	0.216
Thorium 230 3084-89				BDL	BDL	BDL	BDL	2.01	0.11	0.112
Thorium 232 3084-89				BDL	BDL	BDL	BDL	BDL	BDL	BDL
Uranium, tot 200.8 (mg/L)				0.032	0.037	0.02	BDL	0.76	0.36	0.11
Uranium 235 901.1	BDL	BDL	BDL							
Uranium 238 901.1	4.8	2	3.5							

Actinium 228 is a surrogate for Radium 228
Blank cells indicate the analysis was not conducted
EPA 901.1 is a gamma spectroscopy method
EPA 200.8, EPA 900, EPA 903.0, EPA 904.0 are standard drinking water methods, if used for solid samples, digestion was performed to prepare sample
EPA 0-02 is a co-precipitation method
ASTM 3084-89 is standard thorium speciation method
BDL = Below Detection Limit for analysis

Table 6 presents the results of the water quality analysis conducted at Blue Mountain.

Table 6 – Water Quality Results at Blue Mountain

Analyte	Units	Raw Water	Greensand Effluent	Cation Exchange Effluent	Anion Exchange Effluent	Ion Exchange Backwash Water	Ion Exchange Regeneration Water	Ion Exchange Rinse Water
Alkalinity, Total	mg/L	170	160	170	170	160	120	190
Aluminum, total	mg/L	BDL	BDL	BDL	BDL	0.33	BDL	BDL
Arsenic, total	mg/L	0.001	BDL	BDL	BDL	BDL	0.007	0.002
Barium, total	mg/L	0.11	0.11	BDL	0.009	0.91	15	1.2
Beryllium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium, total	mg/L	BDL	BDL	BDL	BDL	BDL	0.002	BDL
Calcium (Carbonate)	mg/L	110	100	1	4.3	120	13000	950
Chromium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper, total	mg/L	BDL	0.005	0.006	0.012	0.16	0.009	BDL
Iron, total	mg/L	1.5	BDL	0.022	BDL	29	3.9	0.38
Lead, total	mg/L	BDL	BDL	BDL	0.003	BDL	BDL	BDL
Magnesium, total	mg/L	16	15	0.065	0.15	15	910	47
Manganese, total	mg/L	0.14	0.27	BDL	BDL	9.5	3.8	0.02
Molybdenum, total	mg/L	BDL	BDL	BDL	BDL	BDL	0.083	BDL
Nickel, total	mg/L	BDL	BDL	BDL	BDL	0.11	0.044	BDL
N-Nitrate/Nitrite	mg/L	BDL	BDL	0.11	BDL	BDL	BDL	BDL
pH	-	7.4	7.4	7.4	7.6	7.9	7	7.9
Potassium, total	mg/L	2.8	2.6	0.21	0.21	3.1	23	3.3
Selenium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Silicon, total	mg/L	5.1	5.1	5.4	5.7	6.9	4.1	2.6
Silver, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sodium, total	mg/L	4	4	84	76	5.4	4900	1500
Solids, Dissolved	mg/L	180	310	210	230	190	28600	5510
Strontium, total	mg/L	0.28	0.26	BDL	BDL	0.25	25	1.9
Sulfate	mg/L	17	17	18	19	17	6	25
Turbidity	NTU	16	0.09	0.22	0.18	109	14	3.3
Uranium, total	mg/L	0.021	0.022	0.001	BDL	0.033	0.035	0.043
Zinc, total	mg/L	0.032	0.037	0.02	BDL	0.76	0.36	0.11
Total Organic Carbon	mg/L	BDL	BDL	BDL	BDL	0.5	BDL	0.6

Radiation exposure rates (over background) measured around the cation exchange vessels at Blue Mountain are shown in Figure 4. Measured values were adjusted for the background radiation rate of 15 µrem/hr.

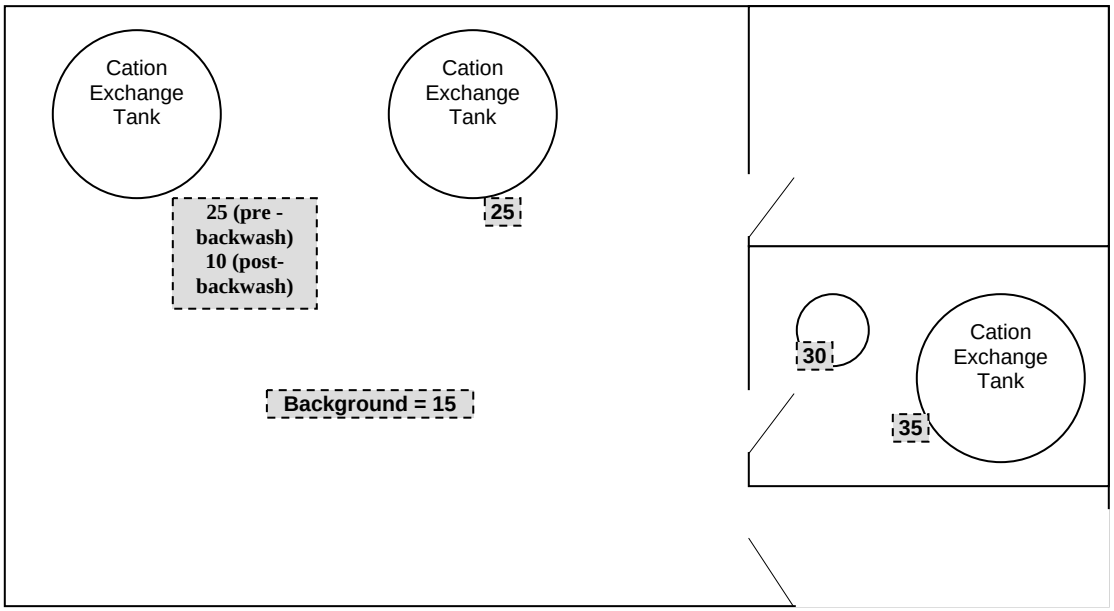

Figure 4 – Radiation Exposure Rates (µrem/hr Above Background) Measured Around the Cation Exchange Vessels at Blue Mountain

May Valley

Samples at May Valley were collected at two of their well house treatment facilities, Bunker Well and Ullom Well. The sampling locations at May Valley are illustrated in Figure 5.

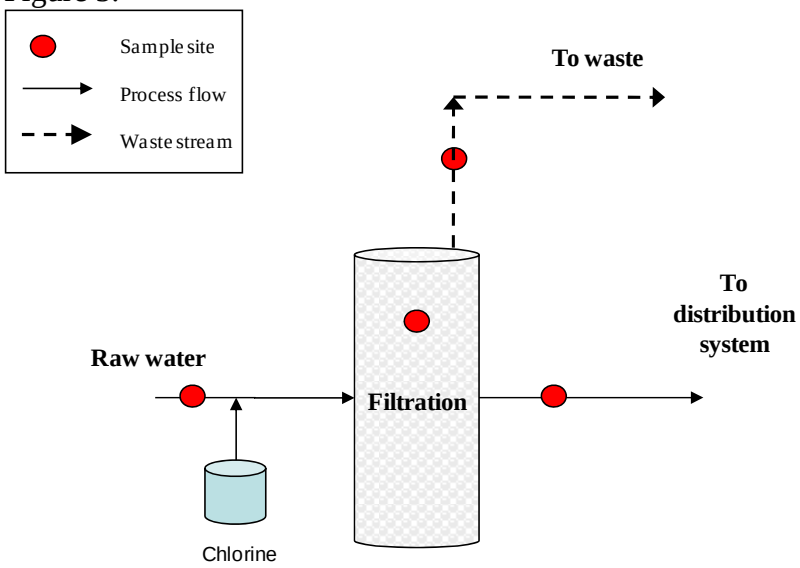

Figure 5 – Sample Locations at Bunker Well and Ullom Well at May Valley

Table 7 describes the sampling locations at the Bunker Well and Ullom Well at May Valley.

Table 7 – May Valley Sample Location Descriptions (Bunker Well and Ullom Well)

Sample Name	Description/Other Info
Filtration Media Pre-backwash	Half of media sample from each filter at the site
Filtration Media Post-backwash	Taken from first tank only
Raw Water	Grab
Filter Effluent	Grab
Spent Filter Backwash	Time/volume averaged composite

Table 8 summarizes the results of the radionuclide analyses performed on samples collected at May Valley.

Table 8 – Radionuclide Analyses at May Valley (Bunker Well and Ullom Well)

Analyte	Filter Media (pCi/g)				Liquid Samples (pCi/L)					
	Filter Media Pre-Backwash (Bunker)	Filter Media Post Backwash (Bunker)	Filter Media Pre Backwash (Ullom)	Filter Media Post Backwash (Ullom)	Raw Water (Ullom)	Raw Water (Bunker)	Finished Water (Ullom)	Finished Water (Bunker)	Spent Filter Backwash (Ullom)	Spent Filter Backwash (Bunker)
Gross Alpha 900	2237	1839	8403	6892						
Gross Alpha 00-02					17	42	33	64	560	405
Gross Beta 900	969	930	3900	4079						
Lead 212 901.1	196	124	433	447	1.9	BDL	BDL	4.8	117	106
Lead 214 901.1	317	131	NR	590						
Potassium 40 901.1	25	20.4	50	55.7						
Radium 228 901.1	264	179	540	550	9.4	15.8	9.2	13.5	252	252
Radium 228 904.0	830	570	2210	1560	6	9.8	4.7	9	306	110.3
Radium 226 901.1	210	141	515	513	BDL	BDL	BDL	42.6	391	369
Radium 226 903.0	320	180	654	838	7.7	15.7	10.3	11.3	280	231
Thorium 228 3084-89					0.26	1.74	0.51	0.30	77.25	20.55
Thorium 230 3084-89					BDL	0.05	BDL	BDL	BDL	BDL
Thorium 232 3084-89					BDL	BDL	BDL	BDL	BDL	BDL
Uranium, Tot. 200.8 (mg/L)					BDL	BDL	BDL	BDL	BDL	BDL
Uranium 234 901.1	2.4	2.2	3.2	2.8						
Uranium 235 901.1	BDL	BDL	BDL	2.1						
Uranium 238 901.1	148	97	300	312						

Actinium 228 is a surrogate for Radium 228
Blank cells indicate the analysis was not conducted
EPA 901.1 is a gamma spectroscopy method
EPA 200.8, EPA 900, EPA 903.0, EPA 904.0 are standard drinking water methods, if used for solid samples, digestion was performed to prepare sample
EPA 0-02 is a co-precipitation method
ASTM 3084-89 is standard thorium speciation method
BDL = Below Detection Limit for analysis

Table 9 presents the water quality analyses conducted on samples collected at May Valley.

Table 9 – May Valley Water Quality Results (Ullom Well and Bunker Well)

Analyte	Units	Raw Water (Ullom)	Raw Water (Bunker)	Finished Water (Ullom)	Finished Water (Bunker)	Spent Filter Backwash (Ullom)	Spent Filter Backwash (Bunker)
Alkalinity, Total	mg/L	240	430	400	400	400	420
Aluminum, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Barium, total	mg/L	0.009	0.007	0.008	0.007	0.06	0.045
Beryllium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Calcium (Carbonate)	mg/L	180	200	150	200	170	220
Chromium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Copper, total	mg/L	0.012	BDL	0.014	0.009	1.6	0.9
Iron, total	mg/L	0.21	0.26	0.057	0.12	69	66
Lead, total	mg/L	BDL	BDL	0.002	BDL	BDL	BDL
Magnesium, total	mg/L	30	36	22	35	22	36
Manganese, total	mg/L	0.017	0.15	0.007	0.011	7.4	6.6
Molybdenum, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Nickel, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
N-Nitrate/Nitrite	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
pH	-	7.5	7.3	7.6	7.7	7.7	7.6
Potassium, total	mg/L	13	17	13	16	14	17
Selenium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Silicon, total	mg/L	5	4.4	4.5	4.2	8.7	8.6
Silver, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Sodium, total	mg/L	610	600	650	620	650	700
Solids, Dissolved	mg/L	1990	2110	1750	1960	1990	2070
Strontium, total	mg/L	1.8	1.4	1.4	1.4	1.8	1.7
Sulfate	mg/L	1100	1100	1000	1100	1000	970
Turbidity	NTU	5.1	14	0.04	0.32	52	46
Uranium, total	mg/L	BDL	BDL	BDL	BDL	BDL	BDL
Zinc, total	mg/L	0.048	0.048	0.05	0.04	0.25	0.14
Total Organic Carbon	mg/L	0.9	0.7	0.6	0.6	1	0.8

Radiation exposure rates (over background) measured around the filter vessels at May Valley (Ullom Well and Bunker Well) are shown in Figure 6. Measured values were adjusted for the background radiation rate of 15 µrem/hr.

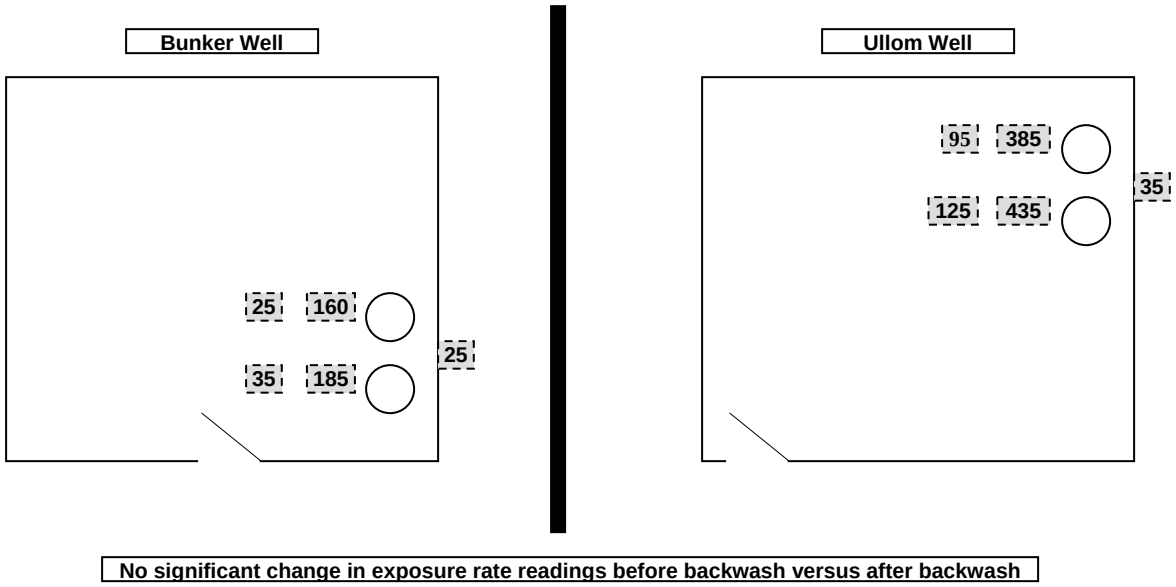

Figure 6 – Radiation Exposure Rates (µrem/hr over background) Measured Around the Iron Filters at May Valley