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Via Email: [DFrydenlund@denisonmines.com](mailto:DFrydenlund@denisonmines.com)



### Re: Modelling of Radon Emissions from Denison La Sal Mine

Dear Dave,

In March this year, we provided Denison with a report on doses from radon released from Denison's La Sal underground uranium mines (SENES 2010). The EPA's regulations at 40 CFR 61.23(a) provide that compliance with this emission standard shall be determined and the effective dose equivalent calculated by the U.S. Environmental Protection Agency ("EPA") computer code COMPLY-R. In addition; however, 40 CFR 61.23(b) provides that owners or operators may demonstrate compliance with this emission standard through the use of computer models that are equivalent to COMPLY-R, provided that the model has received prior approval from EPA headquarters.

The purpose of the March 2010 report was to evaluate the suitability of COMPLY-R for calculating doses to members of the public in the vicinity of the Mine and compare to an alternate approach using a more sophisticated EPA - approved regulatory model, AERMOD, for the air dispersion component of the assessment, calculating the doses to members of the public using the more appropriate of the two models.

For reasons given in the March 2010 report, we concluded that COMPLY-R is not a suitable model for calculating doses in the vicinity of the Mine, due to the complex features associated with the Mine, and that AERMOD provides much more reliable estimates of such doses. Overall, we concluded that COMPLY-R should be considered a conservative model for predicting doses in simple situations, such as for a mine with one vent in flat terrain and with relatively constant emission rates. Moreover, we concluded that COMPLY-R will generally

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overstate doses for mines that have numerous vents and numerous receptors, particularly where the vents and receptors are distributed over a broad area if used with the most simple COMPLY-R application.. If the application of COMPLY-R in those circumstances shows the highest dose to a member of the public being lower than the 10 mrem/y standard, then that should be considered to be a very conservative evaluation. However, if the application of COMPLY-R shows that the highest dose to a member of the public exceeds the 10 mrem/y standard, the dose estimate is likely to be overstated and a more refined model should be employed.

In addition to simply running COMPLY-R as if the terrain was flat, which it most certainly is not near the La Sal mine, we also ran COMPLY-R in March 2010 for a select set of receptors where the modelled vent stack heights were increased by the difference in terrain elevation to account for the fact that certain receptors are located at a lower elevation than the vents which provides the same result as increasing stack height. (The effect of differences in heights of vents is intrinsic to the meteorological model embedded in COMPLY-R as described in Appendix G and hence, adjustment for different heights is necessarily contemplated by the users guide.) Taking into account the difference in elevation As anticipated, this partial move to a more realistic dispersion scenario resulted in somewhat lower doses for those receptors. Finally, as previously indicated, we ran the EPA's air dispersion model AERMOD to estimate radon concentrations at receptors and then used those concentrations with the COMPLY-R dose calculation protocol to estimate doses.

As a result of the Notice of Violation ("NOV"), docket No. CAA-08-2010-0016 dated August 17, 2010 relating to Denison's underground uranium mines near La Sal, Utah, Denison requested that SENES model the doses from radon emissions from the La Sal Mines in order that dose estimates can be provided to the EPA on a monthly basis, starting with results for September 2010. This report summarizes the results of the modelling done in support of the request by Denison. It should be noted that two sets of results are provided. The first results are from the application of COMPLY-R using multiple runs to calculate doses at each individual location and taking (roughly) into account terrain effects as previously described in our March 2010 report. The second analysis was performed using the AERMOD model as previously described in our March 2010 report. An exemplar COMPLY-R run is provided in Appendix A.

The methods and results of our analysis can be described as follows:

## **1.0 Models and Model Inputs**

### **1.1 Models**

COMPLY R is the EPA's reference model for assessing the dose from radon from mine upcasts.

As noted earlier in this report, the EPA's regulatory air dispersion code AERMOD was also used to estimate atmospheric dispersion. AERMOD is a steady state Gaussian plume dispersion model that can be used to assess pollutant concentrations from a wide variety of complex industrial settings including multiple stacks, fugitive emissions, and building wake effects. The

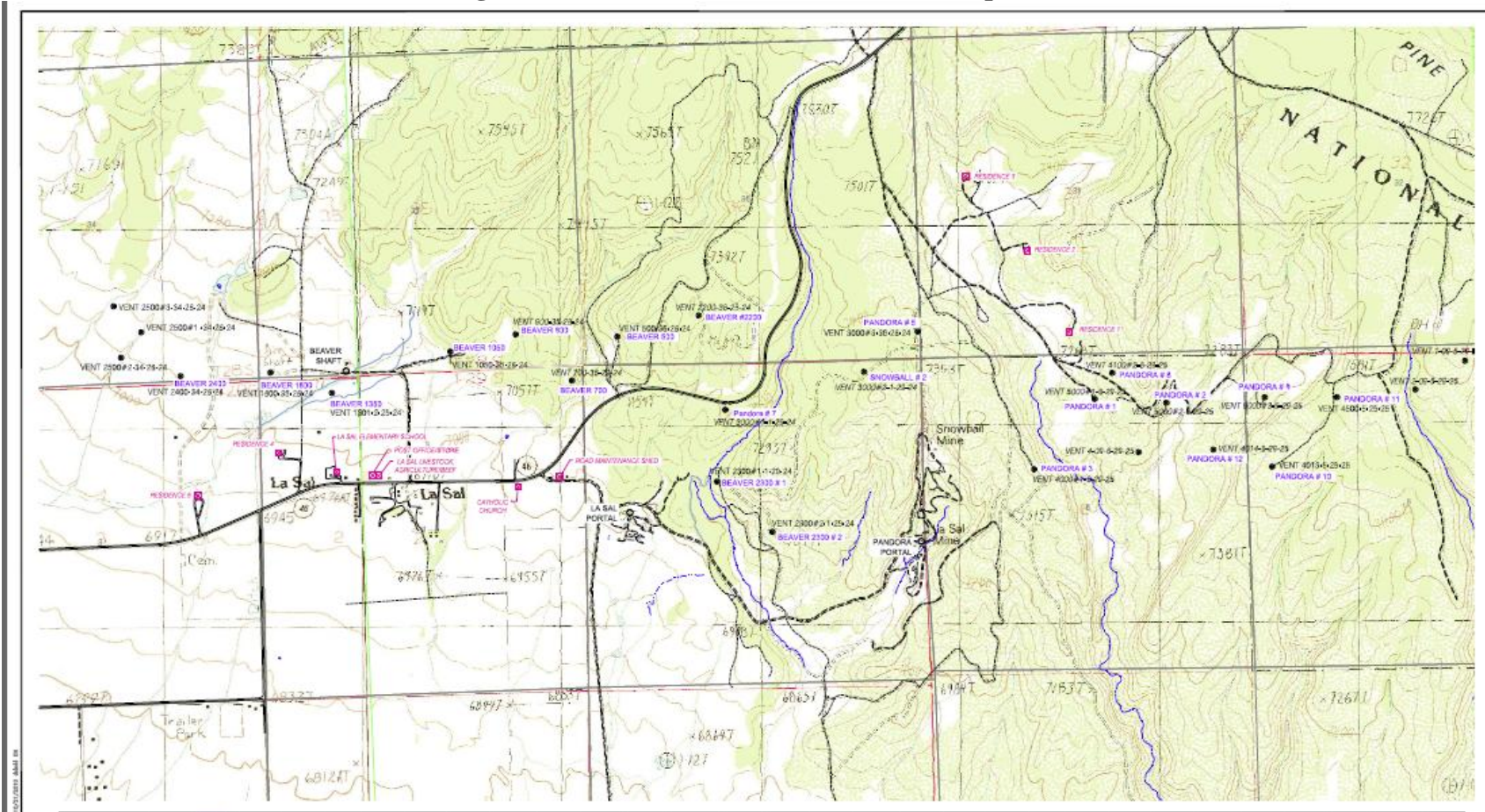
AERMOD Modelling System consists of two pre-processors (AERMET version 06341 and AERMAP version 09040) and the dispersion model AERMOD. The AERMOD Model is the regulatory model currently recommended by the EPA for simulating short-term air quality impacts from industrial complexes.

## 1.2 Model Inputs

### Sources and Receptors

The surface features and locations of mine vents and receptors are shown on Figure 1.

Figure 1 Locations of Sources and Receptors



Note: Locations from Utah State Planes, NAD83, South Zone.



The characteristics of the various mine vents are summarized in Table 1, distances between sources and receptors are shown in Table 2 and monthly radon emissions in Table 3. The radon emissions provided in Table 3 represent the current best estimate of radon emissions and take into account estimates of radon releases from all venting stacks whether mechanically vented or not. The locations of the various vents have been resurveyed using a high quality GPS system and the receptor locations have been confirmed. Two additional residence locations have been added relative to the March 30 report.

#### Meteorological Data

The EPA data set for Grand Junction Airport, CO (for the period 1987-1991) was considered to be representative of the Mine vicinity and was used for the modelling in this Report [EPA 2009 (<http://www.epa.gov/scram001/>) available on the SCRAM Web page]. This location has been accepted by the State of Utah Department of Environmental Quality, Division of Air Quality (“UDAQ”) for purposes of modelling in connection with the issuance of a State Air Approval Order for the Mine.



Table 1 Summary of Stack Characteristics and Radon Emissions

Source No.	Source name	Easting	Northing	Elevations (m)	Diameter(m)	Height(m)	Text( <sup>o</sup> K)	Flow(m3/s)	Emissions 2010 Pro Rated Over Remainder of Year (Ci/year)
S1	Beaver 500 (500-36-28-24)	654227.7	4242644.9	2200.93	1.78	3.76	285.00	23.55	74.32
S2	Beaver 700 (700 36-29-24) (Plugged)	653999.1	4242424.4	2168.04	plugged	plugged	plugged	0.00	0.00
S3	Beaver 900 (900 #2 35-28-24)	653717.5	4242658.6	2169.32	1.83	1.02	285.00	26.31	150.90
S4	Beaver 1050 (1050 35-28-24)	653388.0	4242573.5	2156.90	1.83	2.21	285.00	45.42	354.97
S5	Beaver 1280 (1280-2-29-24) (plugged)	652905.0	4242417.2	2152.30	plugged	plugged	plugged	0.00	0.00
S6	Beaver 1350 (1301-2-29-24)	652793.2	4242368.9	2149.31	1.60	1.52	285.00	12.37	104.63
S7	Beaver 1800 (1800 35-28-24)	652485.3	4242472.5	2152.28	2.03	3.96	285.00	0.00	0.00
S8	Beaver 2200 (2200-36-28-24) (plugged)	654636.6	4242749.5	2145.48	plugged	plugged	plugged	0.00	0.00
S9	Beaver 2300 #1 (2300 #1-1-29-24)	654724.7	4241913.3	2148.22	1.19	1.52	285.00	23.60	81.22
S10	Beaver 2300 #2 (2300 #2 1-29-24)	655001.2	4241659.4	2150.56	1.63	1.96	285.00	25.66	774.56
S11	Beaver 2400 (2400-34-28-24)	652034.5	4242457.4	2145.48	2.21	1.96	285.00	57.03	8.88
S12	Beaver 2500 (2500 #1-34-28-24)	651837.8	4242678.3	2153.06	2.13	1.47	285.00	36.18	72.57
S13	Beaver Shaft	652864.5	4242478.4	2158.20	1.80	0.00	285.00	12.75	60.79
S14	La Sal Portal	654285.5	4241759.5	2132.28	3.35	1.68	285.00	0.00	0.00
S15	Pandora #1 (5000 #1-6-29-25)	656622.7	4242318.8	2219.20	1.83	0.00	285.00	6.13	6.50
S16	Pandora #2 (5000 #2-6-29-25)	656981.7	4242297.8	2204.12	1.42	2.41	285.00	0.00	0.00
S17	Pandora #3 (4000 #1-6-29-25)	656316.6	4241966.8	2244.52	0.74	0.48	285.00	1.83	24.52
S18	Pandora #5 (3000 #3-36-28-24)	655736.0	4242662.6	2246.51	1.60	1.96	285.00	6.73	311.05
S19	Pandora #6 (4100 #1-31-28-25)	656348.2	4242560.4	2210.91	1.70	1.78	285.00	0.00	0.00
S20	Pandora #7 (3000 #1-1-29-24)	654767.9	4242274.2	2197.04	1.83	1.02	285.00	13.48	6.30
S21	Pandora #8 (4100 #2-6-29-25)(AKA #1672)	656711.2	4242449.2	2236.52	1.60	1.83	285.00	1.53	6.85
S22	Pandora #9 (5000 #3-5-29-25)	657475.8	4242322.7	2237.50	2.00	2.00	285.00	0.00	0.00
S23	Pandora #10 (4013-5-29-25)	657511.4	4241974.3	2272.67	1.93	1.19	285.00	43.61	582.49
S24	Pandora #11 (4500-5-29-25)	657838.9	4242321.8	2294.10	1.98	0.91	285.00	0.00	0.00
S25	Pandora #12 (4014-6-29-25)	657216.6	4242061.6	2211.01	2.44	0.46	285.00	36.55	522.55
S26	Pandora Portal	655747.9	4241607.6	2128.03	4.09	2.04	285.00	36.68	189.23
S27	Snowball #2 (3000 #2-1-29-24)	655464.7	4242461.7	2241.67	1.65	2.24	285.00	36.06	1107.59

Notes: Locations provided by Denison. Vent diameters, flows, and radon concentrations also provided by Denison.

Table 2 Source Receptor Distances (m)

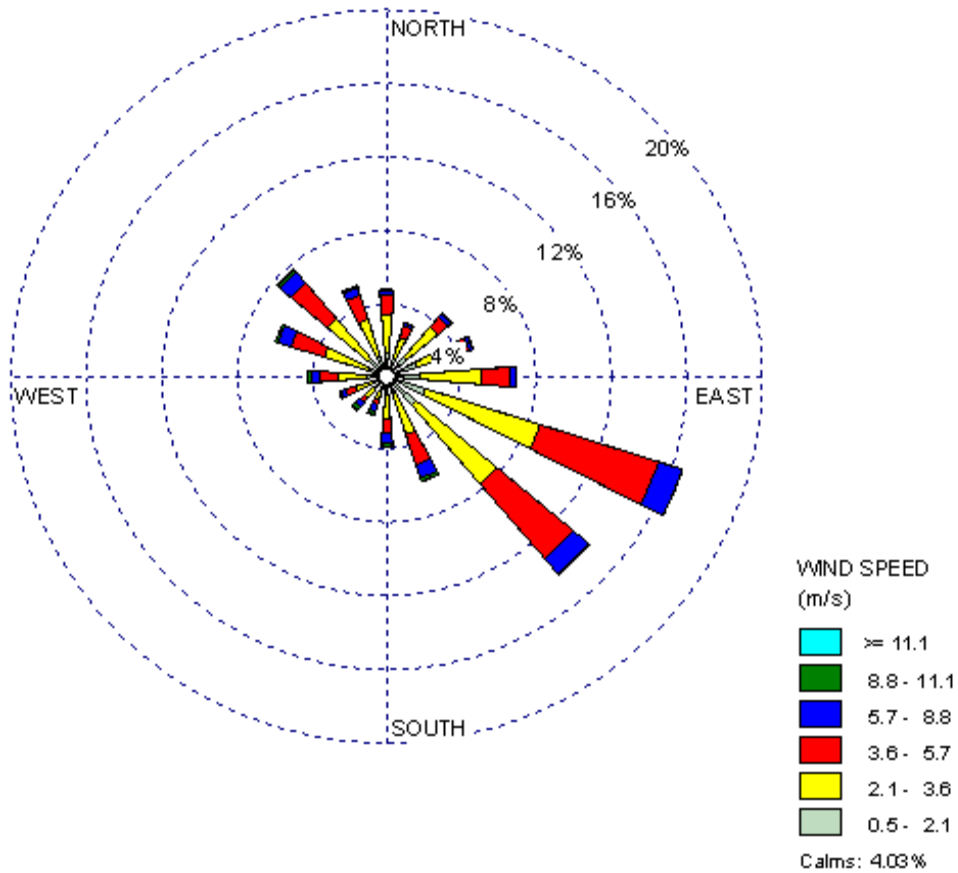
Source Name	Src. No.	RESIDENCE #1	RESIDENCE #2	RESIDENCE #3	LA SAL LIVESTOCK	CATHOLIC CHURCH	STORE/POST OFFICE	ROAD MAINTENANCE SHED	ELEMENTARY SCHOOL	RESIDENCE #4	RESIDENCE #5
Beaver 500 (500-36-28-24)	S1	2266.60	2103.79	1923.70	1387.67	904.10	1412.79	761.89	1565.26	1797.84	2252.14
Beaver 700 (700 36-29-24) (Plugged)	S2	2505.81	2378.04	2225.62	1082.23	597.85	1108.41	487.03	1267.89	1516.69	1964.86
Beaver 900 (900 #2 35-28-24)	S3	2776.84	2603.53	2393.00	989.01	766.81	1009.09	749.10	1134.84	1330.63	1789.26
Beaver 1050 (1050 35-28-24)	S4	3107.35	2942.42	2732.29	719.50	761.49	733.83	835.46	831.94	1000.04	1458.40
Beaver 1280 (1280-2-29-24) (plugged)	S5	3597.17	3445.58	3239.96	480.46	975.90	472.71	1134.12	456.15	515.79	966.30
Beaver 1350 (1301-2-29-24)	S6	3712.09	3564.52	3361.26	477.07	1048.91	462.30	1218.68	399.56	402.72	847.64
Beaver 1800 (1800 35-28-24)	S7	4013.17	3849.67	3625.40	750.05	1371.16	728.16	1543.48	601.36	405.70	717.32
Beaver 2200 (2200-36-28-24) (plugged)	S8	1860.09	1682.33	1509.96	1797.81	1249.95	1823.84	1070.32	1981.03	2218.95	2672.19
Beaver 2300 #1 (2300 #1-1-29-24)	S9	1918.65	1943.17	1976.71	1699.78	997.54	1729.39	790.64	1910.09	2205.49	2607.16
Beaver 2300 #2 (2300 #2 1-29-24)	S10	1794.48	1907.21	2032.44	1997.41	1294.86	2026.87	1103.36	2207.71	2510.13	2889.77
Beaver 2400 (2400-34-28-24)	S11	4464.17	4297.72	4065.20	1112.28	1784.87	1085.43	1968.83	920.61	625.57	606.92
Beaver 2500 (2500 #1-34-28-24)	S12	4656.53	4467.91	4210.71	1392.02	2046.72	1366.22	2222.41	1207.32	918.37	868.57
Beaver Shaft	S13	3634.07	3474.45	3259.77	550.38	1043.39	541.29	1197.16	510.86	532.27	971.66
La Sal Portal	S14	2383.32	2391.87	2386.52	1274.76	573.57	1304.20	395.36	1485.03	1787.75	2169.50
Pandora #1 (5000 #1-6-29-25)	S15	359.67	818.63	1293.97	3615.95	2926.59	3645.27	2714.43	3823.17	4105.60	4528.20
Pandora #2 (5000 #2-6-29-25)	S16	604.13	1034.66	1520.88	3971.41	3279.53	4000.78	3067.87	4179.12	4462.88	4883.54
Pandora #3 (4000 #1-6-29-25)	S17	710.55	1099.82	1512.61	3291.27	2590.30	3320.86	2382.16	3501.15	3793.28	4199.90
Pandora #5 (3000 #3-36-28-24)	S18	758.37	684.61	815.68	2802.17	2151.36	2830.49	1940.29	3001.52	3265.71	3706.56
Pandora #6 (4100 #1-31-28-25)	S19	173.93	509.36	955.15	3378.06	2704.74	3406.96	2491.68	3581.76	3854.99	4288.25
Pandora #7 (3000 #1-1-29-24)	S20	1767.84	1714.85	1681.77	1772.06	1108.54	1800.95	897.24	1976.02	2252.60	2682.50
Pandora #8 (4100 #2-6-29-25)(AKA #1672)	S21	298.87	747.78	1233.08	3719.26	3035.46	3748.42	2822.68	3925.16	4203.80	4631.20
Pandora #9 (5000 #3-5-29-25)	S22	1036.12	1400.57	1868.64	4465.81	3773.06	4495.20	3561.64	4673.65	4957.58	5377.87
Pandora #10 (4013-5-29-25)	S23	1223.77	1639.24	2121.49	4486.10	3784.92	4515.69	3576.99	4695.96	4987.61	5394.54
Pandora #11 (4500-5-29-25)	S24	1385.26	1719.58	2170.96	4827.75	4133.96	4857.16	3922.82	5035.79	5320.26	5739.68
Pandora #12 (4014-6-29-25)	S25	934.68	1367.53	1853.51	4192.67	3493.34	4222.22	3284.22	4402.10	4691.92	5102.57
Pandora Portal	S26	1285.95	1555.74	1848.08	2744.20	2040.36	2773.71	1843.79	2954.70	3255.98	3638.20
Snowball #2 (3000 #2-1-29-24)	S27	1047.59	1022.19	1106.30	2491.95	1828.33	2520.68	1616.04	2694.46	2966.10	3400.81

Table 3 Monthly Radon Emissions

Vent	January	February	March	April	May	June	July	August	September	October	November	December	2010 Cumulative to Date
Beaver 500 (500-36-28-24)	0.00	0.00	0.00	3.64	8.34	5.93	8.88	11.00	17.95	0.00	0.00	0.00	55.74
Beaver 700 (700 36-29-24) (Plugged)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beaver 900 (900 #2 35-28-24)	0.00	0.00	0.22	14.27	9.98	18.27	29.04	22.55	18.85	0.00	0.00	0.00	113.18
Beaver 1050 (1050 35-28-24)	48.50	60.38	63.83	37.23	21.89	27.45	6.96	0.00	0.00	0.00	0.00	0.00	266.23
Beaver 1280 (1280-2-29-24) (plugged)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beaver 1350 (1301-2-29-24)	11.71	12.64	13.53	1.61	0.03	0.14	2.01	14.36	22.43	0.00	0.00	0.00	78.47
Beaver 1800 (1800 35-28-24)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beaver 2200 (2200-36-28-24) (plugged)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beaver 2300 #1 (2300 #1-1-29-24)	16.68	18.18	16.39	4.15	1.82	1.28	2.03	0.31	0.07	0.00	0.00	0.00	60.91
Beaver 2300 #2 (2300 #2 1-29-24)	19.00	17.78	29.74	64.68	77.61	85.85	18.64	131.68	135.94	0.00	0.00	0.00	580.92
Beaver 2400 (2400-34-28-24)	0.00	0.00	0.00	0.00	0.00	0.00	6.66	0.00	0.00	0.00	0.00	0.00	6.66
Beaver 2500 (2500 #1-34-28-24)	0.00	0.00	0.00	0.00	0.99	3.13	19.74	16.55	14.03	0.00	0.00	0.00	54.43
Beaver Shaft	1.53	1.38	1.57	3.99	1.49	0.62	3.85	11.34	19.82	0.00	0.00	0.00	45.59
La Sal Portal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pandora #1 (5000 #1-6-29-25)	0.00	0.00	0.00	0.00	0.85	0.90	0.93	0.59	1.61	0.00	0.00	0.00	4.87
Pandora #2 (5000 #2-6-29-25)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pandora #3 (4000 #1-6-29-25)	3.61	3.26	3.61	3.50	1.69	0.11	0.56	0.80	1.24	0.00	0.00	0.00	18.39
Pandora #5 (3000 #3-36-28-24)	79.53	69.81	57.32	15.56	2.76	0.19	0.02	1.30	6.81	0.00	0.00	0.00	233.29
Pandora #6 (4100 #1-31-28-25)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pandora #7 (3000 #1-1-29-24)	0.00	1.96	2.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.73
Pandora #8 (4100 #2-6-29-25)(AKA #1672)	0.00	0.00	0.00	0.00	1.85	1.95	1.34	0.00	0.00	0.00	0.00	0.00	5.14
Pandora #9 (5000 #3-5-29-25)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pandora #10 (4013-5-29-25)	39.11	38.86	43.42	43.50	54.22	40.82	55.09	66.32	55.53	0.00	0.00	0.00	436.87
Pandora #11 (4500-5-29-25)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pandora #12 (4014-6-29-25)	44.61	40.29	44.61	43.17	44.61	45.16	54.55	51.06	23.84	0.00	0.00	0.00	391.92
Pandora Portal	2.30	6.06	8.33	4.28	4.84	14.90	22.58	31.31	47.32	0.00	0.00	0.00	141.92
Snowball #2 (3000 #2-1-29-24)	204.73	198.37	191.21	109.01	43.82	35.48	19.66	15.41	13.00	0.00	0.00	0.00	830.69
Snowball Portal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010 Cumulative All Vents by Month	471.31	468.99	476.56	348.59	276.79	282.18	252.52	374.59	378.43	0.00	0.00	0.00	3329.95
2009 Cumulative all vents by Month	1320.9	381.1	232.4	367.5	298.7	235.6	155.5	202.9	203.8	340.2	301.5	303.7	4343.8
2010 actuals as % of 2009 by Month	35.68%	123.06%	205.06%	94.85%	92.67%	119.77%	162.39%	184.62%	185.69%	0.00%	0.00%	0.00%	76.66%



Figure 2 Wind Rose Grand Junction Airport (1987-1991)



The model inputs are provided in the exemplar COMPLY-R files provided in Appendix A.

## 2.0 Results

The COMPLY-R model was evaluated using annual average meteorology and radon emissions for September 2010 as well as for projected annual radon emissions and annual meteorology, assuming that radon emissions in October, November and December are the average of emissions to date. The average annual emissions projected for 2010 were used in the COMPLY-R modelling are set out in Table 1.

The AERMOD model was evaluated using monthly radon emissions estimates and hourly meteorological data with results compiled by month. Projected radon emissions for each of October, November, and December were calculated as the average of monthly rates for January through September 2010.

Table 4 shows the results for radon emissions for September. Table 5 shows the results for annualized emissions with actual emissions to 30 September and forecast emissions for the remainder of the year.

It can be seen from these tables that for annualized results, when the terrain adjusted results from COMPLY-R are considered and, without correction for occupancy, that only two receptors R1 and R7 are predicted to exceed the 10 mrem per year limit.. However, R1 (Residence) is only occupied part of a year from April 1 through October 31. When occupancy is considered, the dose to this receptor is expected to be below 10 mrem per year. Similarly, R 7 is a maintenance shed which is only occupied during part of the working year. For present purposes, we have assumed that a person is present at this location 2000 hours in a year. This is thought to be a very conservative assumption. Based on this assumption, the potential dose to receptor R7 is also expected to be below 10 mrem per year.

When the AERMOD results are considered, all of the receptors are predicted to receive annual doses in 2010 below the 10 mrem per year limit, even without the correction for occupancy.

**Table 4 Comparison with COMPLY-R\* – September 2010**

Receptor	Description	COMPLY-R	AERMOD
R1	Residence #1	0.80	0.6
R1b	Residence #1 (Apr-Oct)	0.80	0.6
R2	Residence #2	0.60	0.3
R3	Residence #3	0.50	0.2
R4	Livestock	0.80	0.7
R5	Church	1.10	0.8
R6	Post Office	0.80	0.7
R7	Maintenance Shed	2.00	0.9
R7b	Maintenance Shed (2000 hr)	0.46	0.2
R8	La Sal School	0.90	0.7
R9	Residence #4	0.80	0.7
R10	Residence #5	0.50	0.4

**Table 5 Comparison with COMPLY-R – Full Year 2010**

	<b>Description</b>	<b>COMPLY-R</b>	<b>AERMOD</b>
R1	Residence #1	16.1	9.6
R1b	Residence #1 (Apr-Oct)	9.4	4.8
R2	Residence #2	9.7	5.8
R3	Residence #3	7.1	3.8
R4	Livestock	5.0	6.7
R5	Church	8.2	8.4
R6	Post Office	5.0	6.7
R7	Maintenance Shed	14.4	9.9
R7b	Maintenance Shed (2000 hr)	3.3	2.3
R8	La Sal School	5.9	6.6
R9	Residence #4	5.6	6.3
R10	Residence #5	3.6	4.3

Overall, our conclusion is that the potential doses to people who live or work around the La sal uranium mine arising from radon emissions are predicted to be less than 10 mrem per year for 2010. .

We would be pleased to respond to any questions you may have.

Yours very truly,

**SENES Consultants Limited**



Douglas B. Chambers, Ph.D.  
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Director of Radioactivity and Risk Studies

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Letter to Dave Frydenlund (Continued)

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**Appendix A**

**Exemplar COMPLY-R file**

