THE OCCURRENCE OF SELENIUM IN THE UPPER KANAWHA FORMATION OF THE PENNSYLVANIAN SYSTEM IN THE SOUTHERN WEST VIRGINIA COAL FIELDS

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ABSTRACT A search of the literature on selenium reveals that there are little or no studies available on the concentrations of selenium in rock overburden anywhere in the United States. The Environmental Protection Agency's (EPA) concern with the in-stream concentrations of selenium in the Draft Programmatic Environmental Impact Statement conducted in 6 watersheds in West Virginia for mountaintop mining, brought the lack of data on selenium to the attention of West Virginia's Department of Environmental Protection (DEP). To acquire data for a mining National Pollution Discharge Elimination System Permit (NPDES), the DEP's Water Resource section required the drilling of holes to secure data on selenium in the overburden of selected surface mine permits. The results, procedures and conclusions drawn from the initial drilling under this requirement are presented in this paper.

DISCUSSION

The EPA conducted extensive water testing in 6 watersheds in West Virginia in conjunction with the mountaintop mining EIS (*28*). This study was started in 1999 and a draft report on findings is available. In addition to the typical metals that are analyzed for in a surface mine (SMCRA) permit, selenium was noted as a trace metal of concern by the EPA. This concern arose from selenium concentrations in excess of the 5 ppb in-stream chronic water quality limit that exists in West Virginia (*39*). Because the EIS study purposely picked areas that were/are being surface mined in the state, the conclusion has been drawn that surface mining areas, particularly valley fills, are contributing to the selenium concentrations noted. A literature search on selenium revealed that extensive research on selenium in fly ash (Lemly) and soils (Vance) were available, but no papers or research was noted on the concentrations of selenium in rock overburden. This was important to the WVDEP, because we needed to know where the selenium was concentrated on a surface mine job to suggest ways to handle overburden or use other techniques to mine the coal without harming the aquatic environment with toxic selenium, which can cause harm to fish tissue, animals etc. through bio-concentration *30,31,40)*. A study by the West Virginia Geologic Survey (WVGS) was posted on the internet that indicated that coal seams of the Upper Kanawha Formation of the Pennsylvanian System (*34,35)* was much higher in selenium than other strata in the coal areas of the Appalachians. The principal mineable seams in this geological section are the Winifrede, Coalburg, Stockton and #5 Block seams.

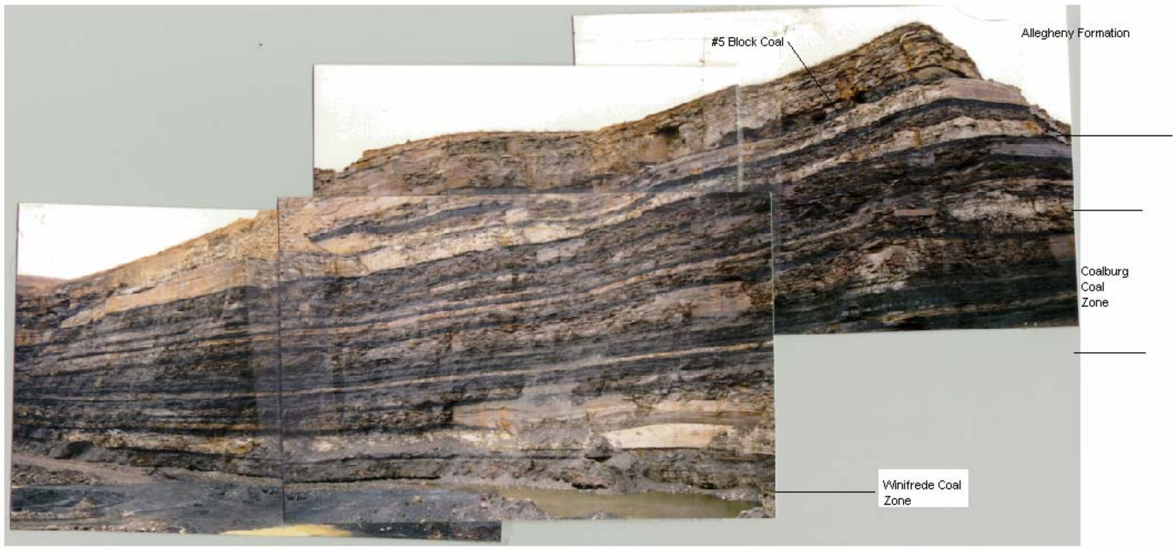

Figure1. Highwall covering the Winifrede to 6-Block coal seams. Picture taken near Sharples, West Virginia at the now inactive Dal-Tex strip mine complex.

This WVGS study was done by measuring the trace metals in the fly ash of the coal seams that were burned in the state, and back calculating the amount of selenium in the total coal seam. The WVGS study, and other research reviewed, plus conversations with analytical laboratory personnel (*41,42*), indicated that the selenium was associated with organic/carbon based material, like coal seams, carbonaceous shale, etc. Previous work on coal ash and associated materials by one of the authors of this paper for various coal companies also indicated that the coal seams and associated "pit cleanings" (carbonaceous roof, floor and parting material) held the highest concentrations of selenium in the overburden. If the vertical location of the selenium in the "pit cleanings" was correct, then it was possible to design a materials handling plan to isolate this material that would be not cost prohibitive in the mining sequence.

PROTOCOL USED TO ACQUIRE AND ANALYZE THE OVERBURDEN SAMPLES FOR SELENIUM

1. Since 1999, the WVDEP has required that all of the baseline water sites that are submitted for a surface mine permit be tested for trace metals and other compounds, such as phenols, on a one time basis. This data, plus data from several other sources (1.) NPDES renewal Table IV-C analyses. (2.) Data from the Department of Environmental Protection (DEP) trend sites. (3) Data from the EIS in certain watersheds. (4) Data from Water Resources for TMDL's (Total Maximum Daily Loads) etc. (5) and the latest 303(d)

impaired streams list from the Division of Water Resources are checked to see if Selenium or any other metal is above the Title 46-1 State Water Quality Limits (*39)* or of concern.. Any area that has had previous mining and reflects over 5 ppb selenium (current instream chronic water quality standard for selenium) will be selected for drilling to sample the overburden.

2. The drilling will be on approximately 2000' spacing, or other spacing required by the geologist reviewing the surface mining (SMCRA) permit. The holes will be located on the tops of the ridges and drilled down to 10' below the lowest seam to be mined. This will insure that all the overburden to be removed is covered in it's entirety.
3. The core from the drilling will be broken down into vertical sections of 5' or less if the strata type changes. The object is to break the core down into small recognizable sections that can be separated by high selenium content in the mining sequence. This breakdown will also mirror the acid/base testing breakdown, which has been used for decades in surface mining in WV.
4. Each 5' or less section is then analyzed for total selenium by the 3050B (for Acid digestion of Solids) method. Any strata that has a total selenium concentration of 1mg/kg (*25,33,36)* or greater is considered potentially toxic and will have to undergo further testing or an encapsulation/isolation plan provided to deal with the selenium laden overburden.
5. There are several leachate tests available for the next level, if the applicant does not want to do the materials handling plan based on the total selenium analyses. They are (1) Column Leaching (2) Soxhlet (3) Phosphate(*25)* etc. Any leachate test that results in a reading of greater that 5 ug/kg will be considered toxic for selenium and will be included in a specific materials handling plan.

RESULTS FROM DRILLING IN LOGAN AND MINGO COUNTIES IN SOUTHERN WEST VIRGINIA

The protocol was applied to 3 mining areas in the spring of 2004. The results of 1 hole from northern Logan County, 5 holes from southern Logan County and 1 hole from Mingo County (locations shown in figure 2) are included in this report. All of these drilling areas were or are going to be mountaintop mined for the Coalburg and above/Upper Kanawha strata The cross section of the Phoenix #4 area in southern Logan County, and the drill logs with selenium content in the other two areas indicate that the selenium is concentrated in the "pit cleanings" as theorized at the beginning of the study. These "pit cleanings" are the immediate dark shale roof of the Coalburg, Stockton and Five Block coal seams, partings in the coal seams and sometimes the immediate floor of the coal seams. These strata exhibit selenium concentrations of almost one order of magnitude above the background concentrations of selenium in the sandstones, limestones and other strata encountered in the mining sequence. That is .05 to .25 mg/kg in the sandstones and .5 to 1+ mg/kg in the carbonaceous shales, coal partings, floor of the coal seam and the seam itself (see Table 1). The potentially toxic selenium concentrations of 1mg/kg and above are almost solely concentrated in the coal seams, partings and roof and floor of the seams to be mined. Leachate tests on these holes are in progress and could be the subject of a follow-up paper. The current results definitively indicate that the selenium has an affinity for organic material in the overburden column.

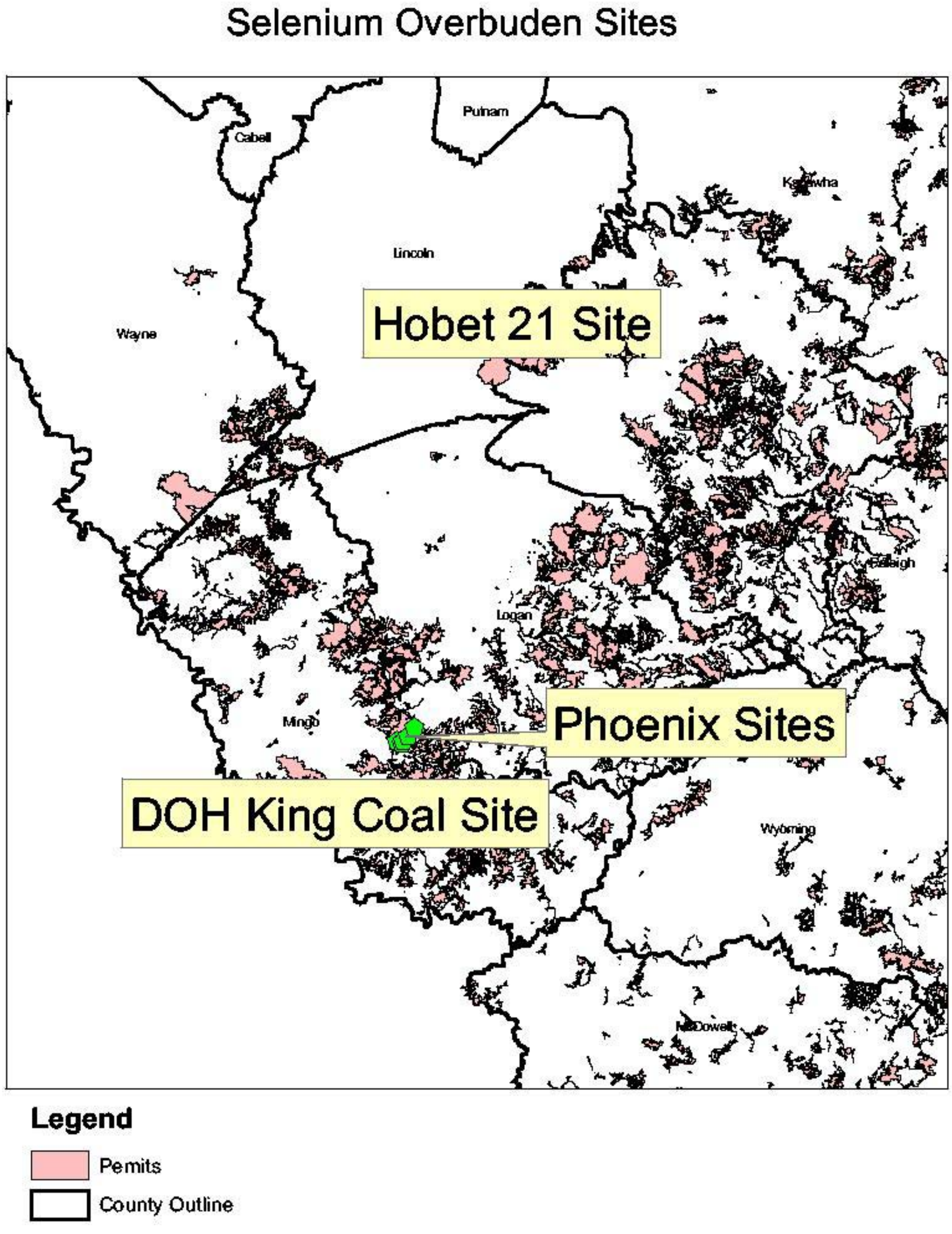

Figure 2. Location of selenium overburden sampling in southern West Virginia.

RECOMMENDED MATERIALS HANDLING PLAN

1. Because the toxic selenium material that needs to be isolated is concentrated in small vertical zones that have to be set aside to recover the coal seam, and the material is a black/dark gray material that is visibly differentiated in the field, the mining company can split this material out in the coal pits. (see figure 3).

Figure 3. #5 Block coal and other black "Pit Cleanings" gathered in piles for removal to special handling areas. Pen Coal strip mine in Wayne County, West Virginia.

2. It is important to rip up 6" to 1' of the floor of the bottom coal seam so that no selenium laden material is left to contaminate the water/rock interface.
3. The toxic material should be removed to an area on the job that is high and dry away from water courses, and under no circumstance should any of this material be put in a valley fill.
4. The material should then be put on a free draining pad of @10' of coarse non-selenium laden material and covered with at least 4' of the most impervious material on the surface mine job. This method will keep water from leaching through the selenium laden overburden.

CONCLUSIONS

It is apparent from the analytical results and research to date that the selenium is concentrated in the "pit cleanings" and particularly in the Upper Kanawha strata in West Virginia. The cut-off of 1 mg/kg limit for identifying the material that has to undergo further leachate testing looks valid in differentiating the high selenium material to be isolated from the lower concentration material. The visual difference of the black /darker selenium laden material from the other overburden in the Upper Kanawha series is very useful in separating the toxic material from the non-toxic in the field. Further work needs to be done on the different methods of leachate tests to calculate what percentage of selenium in the overburden will be mobilized into the hydrologic environment. Also, it is imperative that a study of how selenium is dispersed in flowing streams versus standing bodies of water is critical to the understanding of what impact selenium may have to the aquatic environment. The moral to the story is to isolate the black/darker selenium laden material and to keep any of this material from the valley fills. This material, besides having high concentrations of selenium, is also typically high in iron and manganese and other trace metals, as well as more acidic, so that the materials handling plan suggested will pay extra dividends.

BIBLIOGRAPHY

1. Besser, J. M. et al, (1993) "Bioaccumulation of organic and inorganic selenium in the laboratory food chain, Environmental & Toxicological Chemistry, #12, pp 57-72

2. Cumbie, P. M., Van Horn, S.L., (1978), "Selenium accumulation associated with fish mortality and reproductive failure", Proceedings of the Conference of SE Association of Fish and Wildlife Agencies, pp 612-624

3. Ensminger, J. T., (1981) "Coal: origin, classification and physical and chemical properties" in Braunstein, H. et al, Environmental, Health, and Control Aspects of Coal Conversion, Ann Arbor Science, pp 2-1 to 2-63

4. Hansen, D. et al, (1998) "Selenium removal by constructed wetlands" Environmental Science Technology, #32, pp 591-597

5. Herring, J. R. et al (1999) "Chemical composition of weathered and unweathered strata of the Meade Peak phosphatic shale member of the Permian Phosphoria formation, Open File report 99-147-A, USGS, Denver, CO.

6. Jenkins, G.T., Schaer, A., "Selenium materials handling and occurrence in WV", presentation to the WV Coal Association Meeting at Flatwoods WV in 2004.

7. Lemly, A. Dennis, (1985) "Toxicology of selenium in a freshwater reservoir " Ecotoicology & Environmental Safety #10, pp 314-338

8. Lemly, A. Dennis, (1985) "Ecological basis for regulating aquatic emissions from the power industry: the case with selenium" Ecotoxicology & Environmental Safety #5, pp465-486

9. Lemly, A. Dennis, (1994) "Mining in Northern Canada: expanding the industry while protecting Arctic fish" Ecotoxicology & Environmental Safety, #29, pp 229-242

10. Lemly, A. Dennis (1994) “Agriculture and wildlife: ecological implications of subsurface irrigation drainage “ Journal of Arid Environments, #28, pp 85-94

11. Lemly, A. Dennis, (1994) “Irrigated agriculture and freshwater wetlands” Wetlands Ecology Management, #3, pp 3-15

12. Lemly, A. Dennis, (1995), “Hazard of selenium to fish and migratory birds at the Ouray National Wildlife Refuge, Utah, Technical Report, USFS, Southern Research Station, Blacksburg, VA

13. Lemly, A. Dennis, (1997), “Environmental Implications of Excessive Selenium”, Biomedical and Environmental Sciences, #10, pp 415 et al

14. Lemly, A. Dennis, (1999), “Preliminary assessment of selenium hazards on Caribou National Forest in Idaho” Technical Report, USFS, Southern Research Station, Blacksburg, VA

15. Lemly, A. Dennis, (2002), “Selenium assessment in Aquatic System”, Springer, NY, NY

16. Lemly, A. Dennis, (2002), “Symptoms and implication of selenium toxicity in fish: the Belews Lake example, Aquatic Toxicology, #57, pp39-49

17. “Lemly, A. D., Ohlendorf, H. M., (2002) “Regulatory implications of using constructed wetlands to treat selenium laden water”, Ecotoxicology & Environmental Safety, #52, pp 46-56.

18. Lemly, A. Dennis, (2003), “Aquatic selenium pollution is a global environmental safety issue”, Ecotoxicology and Environmental Safety”, #59, pp 44-56

19. Lemly, A. Dennis, (2004), “Recommendations for Pre-mine Assessment of Selenium hazards Associated with Coal Mining”, prepared for the WVDEP and Joe Lovett, Esq., dated 1/9/04 (copy in possession of author)

20. McDonald, L. E., Strosher, M. M., (1998) “Selenium mobilization from surface coal mining in the Elk River basin, BC.” Technical Report, British Columbia Ministry of the Envrironment”, Vancouver, BC Canada

21. Potesta and Associates, (2004), “Revised selenium rock core analyses-Red Jacket project of the King Coal Highway”, prepared for Nicewonder Contracting, Inc. and the WVDEP Division of Water Resources, (copy in possession of author), Charleston, WV

22. Presser, T. S. etal, “Bioaccumulation of selenium form natural geologic sources in the western states and it’s potential consequences”, Environmental Management, #18, pp423-436

23. Santhanam, C. J. et al, (1979) "Health and environmental impacts of increased generation of coal ash and FGD sludge", Environmental Health Perspective, #33, pp 131-157

24. Shamberger, R. J., (1981) "Selenium in the environment", Science Total Environment, #17, pp 59-74

25. Spackman, L. K., Vance, G. F. et al, (1994) "Standard operating procedures for the sampling and analysis of selenium in soil and overburden/spoil material", Univ. of Wyoming, MP-82

26. USEPA, (1998), "Wastes from combustion of coal fired power plants-report to Congress" EPA/530-SW-98-002, USEPA, Washington, D.C.

27. USEPA, (1999), "Proposed revision of selenium ambient limits to aquatic life based limits", website www.epa.gov

28. USEPA, (2001) "Programmatic Mountaintop EIS Study in West Virginia", Draft available on the Region #3 EPA web site, pp 73-83

29. USEPA, (2003), "Technical fact sheet on selenium, website, www.epa.gov

30. USFWS, (2004), "Letter from David Dinsmore of the USFWS, State College, PA to Allyn Turner, Director of Water Resources for the WVDEP (dated 1/16/04-copy in possession of author) outlining 2003 survey of fish, water and sediments in various water bodies in Southern WV", WVDEP, Charleston WV

31. USFWS, (2003), "Unpublished selenium monitoring data for mountaintop removal/valley fill coal mining sites in West Virginia", US Fish and Wildlife Service, Ecological Services Field Office, State College, PA.

32. USGS, (2003), "Letter from Theresa Presser of the USGS Water Resources Division to John Forren, EPA, Region #3 stating technical comments on the draft EIS on mountaintop coal mining and associated valley fills in Appalachia concerning selenium sources, monitoring and prediction of ecosystem effects", (copy in possession of author), WVDEP, Charleston, WV

33. Vance, G. F., (various) several of Professor Vance's publications, etc. on Selenium were reviewed, the complete list of 361+ publications by Professor Vance can be viewed at website uwadmnweb.uwyo.edu/Renewable Resources/soil/vance.htm

34. WV Geologic and Economic Survey, "Trace Elements in West Virginia Coals" website www.wvgs.wvnet.edu, Morgantown, WV

35. WV Geologic and Economic Survey, (2002), “Geographic distribution of selenium in all WV coals”, website www.wvgs.wvnet.edu

36. WV Surface Mine Board, (2004) “Testimony and exhibits from the Phoenix #4 hearing for Coal Mac Coal Co.”, WVDEP, Charleston, WV

37. WV Surface Coal Mining Act and Regulations, 6/1/04 Edition

38. WVDEP, Division of Water Resources 303(d) list for impacted streams, WVDEP, Charleston, WV

39. State of WV, Title 46-1 Legislative Water Quality Rules, Charleston, WV

40. Participation of both authors in the Federal and State Interagency meetings on Selenium in April 2004 at Charleston, WV.

41. Private conversations with John Sturm of Sturm Environmental Services, Anmoore, WV

42. Private conversations with personnel at REIC laboratories, Beckley, WV

Table 1. Sample Selenium Data from Phoenix Coal site shown in figure 2. Data from core PX-04-10. REIC Job#: 0405081

SAMPLE NUMBER	**SAMPLE INTERVAL**	**THICKNESS (feet)**	**ROCK TYPE**	**SELENIUM (mg/kg)**
1	23.00-27.50	4.50	Sandstone	ND
2	43.00-45.00	2.00	Sandstone	ND
3	45.00-45.90	0.90	Shale	0.82
4	45.90-46.15	0.25	Coal	0.94
5	46.40-46.65	0.25	Shale	2.74
6	**46.65-51.25**	**4.60**	**Coal**	**1.14**
7	51.25-52.20	0.95	Shale/Sandstone	1.80
8	52.20-57.00	4.80	Sandstone	ND
9	57.00-62.00	5.00	Sandstone	ND
10	62.00-67.00	5.00	Sandstone	ND
11	67.00-72.00	5.00	Sandstone	ND
12	72.00-77.00	5.00	Sandstone	ND
13	77.00-82.00	5.00	Sandstone	ND
14	82.00-87.00	5.00	Sandstone	ND
15	87.00-92.00	5.00	Sandstone	ND
16	92.00-95.70	3.70	Sandstone	ND
17	95.70-96.60	0.90	Sandstone/ Mudstone/ Coal	0.40
18	96.60-99.75	3.15	Sandstone	0.20
19	99.75-100.30	0.55	Shale	0.34
20	**100.30-101.80**	**1.59**	**Coal**	**0.48**
21	101.80-102.30	0.50	Mudstone	2.28*
22	102.30-105.00	2.70	Shale	0.42
23	105.00-108.00	3.00	Shale	0.20
24	108.00-111.00	3.00	Shale	0.24
25	111.00-114.00	3.00	Shale	0.36
26	114.00-117.00	3.00	Shale	0.36
27	117.00-120.00	3.00	Shale	0.46
28	120.00-123.00	3.00	Shale	0.40
29	123.00-125.00	2.00	Shale	0.44
30	125.00-126.95	1.95	Shale	0.38
31	126.95-129.30	2.35	Shale	1.32
32	129.30-129.50	0.20	Shale	2.12
33	129.50-131.03	1.53	Coal	1.82
SAMPLE NUMBER	SAMPLE INTERVAL	THICKNESS (feet)	ROCK TYPE	SELENIUM (mgflcg)
34	131.03-131.37	0.34	Shale/Coal	3.00

35	131.37-131.70	0.33	Coal	1.90
36	131.70-132.90	1.20	Shale	0.82
37	132.90-135.00	2.10	Mudstone/ Shale	ND
38	135.00-137.00	2.00	Sandstone/ Mudstone	0.20
39	137.00-139.85	2.85	Shale	0.54
40	139.85-140.60	0.75	Shale/Coal	2.60
41	140.60-141.60	1.00	Coal	5.08
42	141.60-143.00	1.40	Mudstone	1.48
43	143.00-146.00	3.00	Mudstone	ND
44	146.00-149.35	3.35	Sandstone	ND
45	149.35-150.40	1.05	Shale	ND
46	150.40-155.00	4.60	Sandstone	ND
47	155.00-160.00	5.00	Sandstone	ND
48	160.00-165.00	5.00	Sandstone	ND
49	165.00-170.00	5.00	Sandstone	ND
50	170.00-175.00	5.00	Sandstone	ND
51	175.00-180.00	5.00	Sandstone	ND
52	180.00-183.65	3.65	Sandstone	ND
53	183.65-184.50	0.85	Shale/Sandstone	ND
54	184.50-189.00	4.50	Sandstone	ND
55	189.00-194.00	5.00	Sandstone	ND
56	194.00-199.00	5.00	Sandstone	ND
57	199.00-204.00	5.00	Sandstone	ND
58	204.00-209.00	5.00	Sandstone	ND
59	209.00-213.00	4.00	Sandstone	0.30
60	213.00-217.00	4.00	Sandstone	ND
61	217.00-220.20	3.20	Mudstone/Sandstone	0.32
62	220.20-225.00	4.80	Sandstone	ND
63	225.00-230.00	5.00	Sandstone	ND
64	230.00-235.00	5.00	Sandstone	ND
65	235.00-240.00	5.00	Sandstone	ND
66	240.00-244.90	4.90	Sandstone	ND
67	244.90-248.60	3.70	Sandstone	ND
68	248.60-250.70	2.10	Sandstone	1.26
69	250.70-251.64	0.94	Coal	3.98
70	251.64-253.10	1.46	Coal	1.60
71	253.10-253.55	0.45	Carbolith	2.64
72	253.55-254.46	0.91	Carbolith/Coal	2.66

73	254.46-254.93	0.47	Coal	2.80
74	254.93-256.45	1.52	Coal	2.54

SAMPLE NUMBER	SAMPLE INTERVAL	THICKNESS (feet)	ROCK TYPE	SELENIUM (mg/kg)
75	256.45-257.05	0.60	Shale	3.28
76	257.05-260.00	2.95	Sh	0.62
77	260.00-260.85	0.85	Shale/Coal	2.38
78	260.85-261.15	0.30	Coal	1.20
79	261.15-261.45	0.30	Carbolith	1.40
80	261.45-263.50	2.05	Coal	0.92
81	263.50-264.25	0.75	Shale	0.62
82	264.25-267.10	2.85	Shale	0.28
83	267.10-269.95	2.85	Shale	ND
84	269.95-271.95	2.00	Sandstone/ Shale	0.26
85	271.95272.41	0.46	Coal	1.86
86	272.41-274.10	1.69	Shale	0.26
87	274.10-277.00	2.90	Mudstone	ND
88	277.00-280.00	3.00	Sandstone/Shale	ND
89	280.00-283.00	3.00	Shale	ND
90	283.00-285.50	2.50	Shale	0.38
91	**285.50-285.92**	**0.42**	Coal	**1.60**
92	**285.92-286.15**	**0.23**	Carbolith	**8.64**
93	**286.15-287.55**	**1.40**	Coal	**2.10**
94	287.55-287.75	0.20	Shale	0.76
95	287.75-293.00	5.25	Sandstone	0.20
96	293.00-298.00	5.00	Sandstone	ND
97	298.00-303.00	5.00	Sandstone	ND
98	303.00-308.00	5.00	Sandstone	ND
99	308.00-313.00	5.00	Sandstone	ND

ND - Not Detected at the MDL of 0.2 mg/kg.

* - The matrix spike for selenium exceeded method control limits due to matrix interference.