COST ESTIMATION OF AMD TREATMENT AT AML SITES[1]

James M. Stiles[2]

Abstract: Cost estimation of AMD treatment is an important component to the West Virginia approach for the ecosystem restoration of watersheds affected by historic AMD sources. Because the degree of ecosystem restoration depends upon post-treatment water quality conditions, a mass balance of the mean net acid load from tributaries and seeps was employed to calculate the required treatment from various treatment technologies. The investigated technologies included passive treatment, at-source pebble quicklime (calcium oxide) dosing, and in-stream pebble quicklime dosing. This analysis assumed that the maximum alkaline production level of passive treatment was 80% of the net acid load, and the maximum excess alkalinity was 1,000 mg/L $CaCO_3$ equivalents for pebble quicklime dosing. The prescribed treatment level was designed to raise the minimum net alkalinity level to 50 mg/L $CaCO_3$ equivalents and reduce the aluminum, iron, and manganese concentrations to the levels specified in the WV stream water quality standards. Treatment technologies were evaluated on the basis of the estimated cost of implementation and operation. This analysis has determined that in-stream pebble quicklime dosing is the most cost effective treatment technology for watersheds affected by historic AMD sources.

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[2] James M. Stiles, Owner, Limestone Engineering, Reedsville, WV 26547.

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Introduction

The objective of this study was to estimate the capital and annual cost associated with the treatment of Acid Mine Drainage (AMD) at Abandoned Mine Land (AML) sites throughout West Virginia. This study estimated the capital and annual cost of this treatment for three treatment technologies: in-stream pebble quicklime (CaO) dosers, at-source pebble quicklime dosers, and passive treatment systems. The passive treatment systems investigated were those that add alkalinity by the dissolution of limestone like open limestone channels.

Methodology

A list of all WV streams impaired by mine drainage before the Surface Mining Control and Reclamation Act of 1977 and the associated water quality data for those streams were obtained from the West Virginia Department of Environmental Protection's Watershed Assessment Program (WVDEP-WAP) (Arcuri and Campbell, 1999). Acid loads were calculated for each impaired stream segment using an average of available water quality data and average stream discharge estimated from the GIS program Watershed Characterization and Modeling System (WCMS) (Fletcher, 2006). The AMD impaired streams were compiled into 10 and 12 digit Hydrologic Units. It was determined that insufficient information was available in the U.S. Office of Surface Mining Reclamation and Enforcement's Abandoned Mine Land Inventory System (AMLIS) and WVDEP Stream Restoration Group (SRG) databases to accurately identify the location and number of specific AMD seeps draining to the investigated stream segments. Because the GIS data available to the investigator did not include the locations of specific AMD seeps, this effort assumed two, three, and five AMD sources on each stream segment when calculating at-source treatment costs. Table A-1, in the Appendix, lists all of the investigated stream sites along with the mean water quality conditions for the sites.

The capital and annual treatment costs were estimated by first calculating the amount of alkalinity that needed to be added to the stream. It was determined that this was the alkalinity that would lower the net acidity to -50 mg/L $CaCO_3$ equivalents and lower the observed concentrations of Al, Fe, or Mn to regulatory levels minus the alkalinity that has been added to upper stream sites. This requirement was expressed in the following spreadsheet formula.

$$A = \max(0, 0.00219\, Q \max(N + 50, T) - A_{us}) \quad (1)$$

Where: A is the alkalinity that needed to be added to the stream, tons/year $CaCO_3$ equivalents; Q is the stream discharge flow rate, gallons per minute; N is the net acidity, mg/L $CaCO_3$ equivalents; A_{us} is the summation of the alkalinity required by upstream stations; and T is the alkalinity required for the removal of metals. This equation subtracted the upstream alkalinity requirements from the current site's requirements to avoid the double treatment of any observed acidity.

If the concentrations of Fe, Al, and Mn were all lower than the regulatory maximum for those metals, then the alkalinity required for metals removal was assumed zero, otherwise the following formula was employed to calculate the alkalinity required for metals removal. For warm water fisheries, the WV regulatory limit for Fe is 1.5 mg/L, and for trout fisheries, the WV regulatory limit is 0.5 mg/L (WVSOS, 2008). Because it was not known which stream sites were warm water fisheries and which were trout fisheries, the trout stream iron standard of 0.5 mg/L was employed for all of the investigated sites. The WV Mn limit of 1.0 mg/L only applies to those sites that less than or equal to 5 miles upstream of a known public or private water intake (WVSOS, 2008). Because it was not known which sites required the application of the Mn standard, this analysis assumed that the Mn standard applied to all of the stream sites. The WV dissolved acute aquatic life standard for Al, 0.75 mg/L, (WVSOS, 2008) was applied to all of the studied stream sites.

$$T = M + 50{,}000\left(10^{-pH} - 10^{-pH_t}\right) \tag{2}$$

Where: M is the metal acidity, mg/L $CaCO_3$ equivalents; pH is the pH of the stream; and pH_t is the level to which the pH of the stream would have to be raised in order to remove the metal acidity. The metal acidity was calculated by summing the normal concentrations produced by each of the acid generating species in solution. The following formula from Hedin, et al. (1994) was employed to calculate the metal acidity, which assumed that all of the iron was in the ferrous oxidation state.

$$M = 50\left[\frac{2\,Fe}{55.845} + \frac{3\,Al}{26.982} + \frac{2\,Mn}{54.938}\right] \tag{3}$$

Where: Fe is the Fe concentration, mg/L; Al is the Al concentration, mg/L; and Mn is the Mn concentration, mg/L. This formula calculated the metal acidity for only Al, Fe, and Mn because these are the only acid-generating metals observed at AMD sites in WV and concentration data for other acid-generating metals were not available.

The net acidity was calculated by adding the metal acidity to the proton acidity and subtracting the total alkalinity. This formula neglected carbonate acidity because it was expected that the magnitude of carbonate acidity would be much smaller than the acidity from metals and proton activity.

$$N = M + 50000(10^{-pH}) - B \tag{4}$$

Where B is the total alkalinity of the stream, mg/L $CaCO_3$ equivalents. The mean stream discharge flow rate, Q, was estimated from the GIS program WCMS. The treatment pH, pH_t, was determined from the observed metal concentrations. If the Mn concentration was greater than the maximum allowable Mn concentration, then the treatment pH was 9.5, otherwise the treatment pH was 8.5.

For the in-stream and at-source quicklime dosers, the required annual quantity of pebble quicklime was calculated with the following formula.

$$C = \frac{Ac}{e} \tag{5}$$

Where: C is the required pebble quicklime, tons/year; c is the quicklime conversion factor, 0.56 tons of quicklime per tons of $CaCO_3$ equivalents; and e is the dimensionless neutralization efficiency, 0.9. These constants were taken from Skousen, Hilton, and Faulkner (1997).

The capital cost of the in-stream pebble quicklime dosers was zero, if the calculated required quicklime was zero; otherwise, the capital cost per doser was assumed to be \$150,000. This assumption was made because the mean capital cost was expected to be approximately \$150,000. Likewise, if the required quicklime was zero, then the annual chemical cost was zero; otherwise, the following formula was employed to calculate the annual cost per doser.

$$C_{ISD} = C_C\, C(1 + O_{ISD}) + L_{ISD} \tag{6}$$

Where: C_{ISD} is the annual cost per in-stream pebble quicklime doser, \$/year; C_C is the cost of the quicklime, \$125 per ton; O_{ISD} is the ratio of the operation and maintenance cost to the chemical cost for the in-stream dosers, 0.035; and L_{ISD} is the labor cost per in-stream doser, \$3,360 per year. These cost assumptions were based upon the experience WVDEP Office of Special Reclamation has had with the design and installation of in-stream dosing systems (Miller and Gutta, 2008).

The capital and annual costs for the at-source dosers were calculated making the assumption of two, three, and five sources per stream location with one doser at each source. The capital cost of the at-source dosers was assumed to be \$150,000 per doser. The following formula was employed to calculate the annual cost of all of the at-source dosers for a particular stream site.

$$C_{ASD} = C_C\, C\,(1 + O_{ASD}) + n\, L_{ASD} \qquad (7)$$

Where: C_{ASD} is the annual cost of all of the at-source dosers for a particular stream site, \$ per year; O_{ASD} is the ratio of the operation and maintenance cost to the chemical cost for at-source dosers (for sludge collection and disposal), 1.0; L_{ASD} is the labor cost per at-source doser, \$3,360 per year per doser; and *n* is the number of sources for each particular stream site. As with the in-stream dosers, the cost assumptions for the at-source dosers were based upon the experience WVDEP Office of Special Reclamation has had with the design and installation of at-source dosers (Miller and Gutta, 2008).

The capital and annual costs of the passive treatment systems were a linear function of the alkalinity required at each stream site. The following formula was employed to estimate the capital cost of the passive treatment systems.

$$C_{PC} = A C_L T_P \qquad (8)$$

Where: C_{PC} is the capital cost of the passive treatment systems, \$; C_L is the cost of the limestone, \$125 per ton; and T_P is the expected lifetime of the passive treatment systems, 20 years. The following formula was employed to estimate the annual cost of the passive treatment systems.

$$C_{PA} = \frac{C_{PC}}{T_P} O_P \qquad (9)$$

Where: C_{PA} is the annual cost of the passive treatment system, \$ per year; and O_P is the ratio of the total maintenance cost to the capital cost, 2.0. These passive treatment cost assumptions were based upon the experience that the WVWRI has had with the design and installation of open limestone channel type passive treatment systems (Gutta, 2008).

Results

The estimated statewide costs for the studied technologies are listed in Table 1. These costs were calculated for a total of 344 stream sites, and each site was downstream of an unknown number of individual mine seeps. These stream sites were in a total of 48 different 10-digit HUC watersheds, which are shown in Fig. 1. For the technologies that involved pebble quicklime dosing, the capital costs are directly proportional to the required number of dosers. The capital cost with passive treatment is much higher than with the quicklime doser technologies because of the construction required to install passive structures.

The annual costs also increase with the additional dosers, but the greatest increase is between the in-stream dosing and the two source dosing. This large increase is due to the increased operational costs expected with the placement of dosers at AMD sources. A smaller increase was also observed with the passive treatment technology over the pebble quicklime technologies.

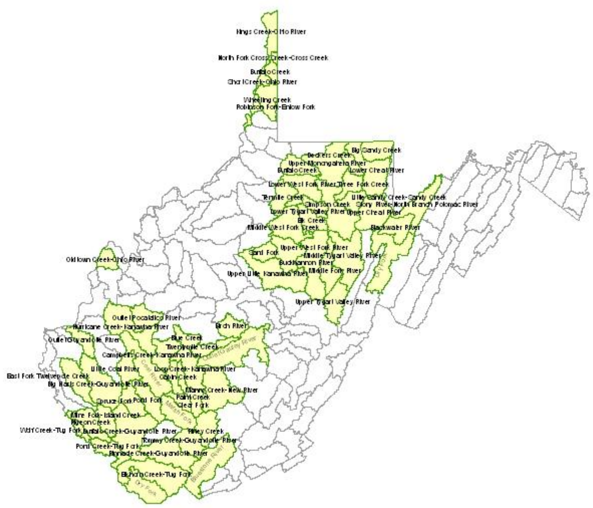

Figure 1. Ten digit HUCS containing at least one AML impaired stream.

Table 1. Estimated statewide costs for the investigated AMD technologies.

Technology	Capital Cost	Annual Cost	Capital + 20 yrs Annual Cost
In-Stream Dosing	31,800,000	58,323,299	1,198,265,988
Two Source Dosing	63,600,000	112,750,204	2,318,604,082
Three Source Dosing	95,400,000	113,462,524	2,364,650,482
Five Source Dosing	159,000,000	114,887,164	2,456,743,282
Passive Treatment	1,789,160,851	178,916,085	5,367,482,554

Because AMD treatment dosers and structures are normally expected to last twenty years, the last column in Table 1 is the sum of the capital cost and twenty years of annual cost. This column shows the least cost for in-stream pebble quicklime dosers and the most cost for passive treatment.

Discussion

The in-stream pebble quicklime doser technology was the most cost effective technology investigated by this study, and the least cost effective technology was the passive treatment. This result was expected because of the additional capital cost associated with placing a doser at each AMD source, the additional operation and maintenance costs expected when locating dosers at AMD sources, and the high construction and maintenance costs expected with passive treatment. It is possible that in-stream doser technology would not be optimal or even possible for some of the investigated sites, but this determination would require specific designs for each site, which would be beyond the scope of the current effort.

This effort neglected the alkalinity produced by SO_4^{2-} reduction because this generic analysis assumed that the passive treatment system would be operating under aerobic conditions. Other treatment functions of aerobic passive structures such as metal retention were neglected because these depend a great deal on local site conditions and are difficult to forecast for a generic passive treatment design. The unavoidable neglect of these effects probably resulted in the underestimation of the treatment obtainable with passive treatment systems.

Because this analysis employed typical costs that have been experienced with AMD treatment, the estimated costs should be viewed as average estimates and should not be interpreted as expected costs for particular stream sites. Since some of the stream sites required treatment for high metal concentrations, the required pH levels for effective treatment may be higher than what may be achieved with passive treatment systems.

Conclusions

On a strict cost basis, in-stream pebble quicklime dosing was the best technology investigated by this analysis. Because this analysis only investigated water treatment costs on AMD impaired stream segments, potential ecological outcomes should be integrated in order to develop the most effective watershed restoration strategies.

Literature Cited

Arcuri, M., Campbell, P., 1999. "Overview of West Virginia Watershed Assessment Program", Appalachian Rivers II Conference, NETL, U.S. Dept. of Energy, Morgantown, WV URL: http://www.netl.doe.gov/publications/proceedings/99/99apprvr/ar2-4.pdf.

Fletcher, J., 2006. "The Watershed Characterization and Modeling System (WCMS): An Overview", OSM Geomorphic Forum 2006, U.S. Office of Surface Mining, 12 Sep 2006, URL: http://www.ott.wrcc.osmre.gov/forums/Geomorphic%20Reclamation/JeraldFletcher.pdf.

Gutta, B., 2008. Personal Communication.

Hedin, R. S., Nairn, R. W., Kleinmann, R. L .P., 1994. "Passive Treatment of Coal Mine Drainage", U.S. Bur. Mines Info. Circ. No. 9389, U.S. Dept. Interior, Washington, DC.

Miller, C.J., Gutta, B., 2008. Personal Communication.

Skousen, J., Hilton, T., Faulkner, B., 1997. "Overview of Acid Mine Drainage Treatment with Chemicals", West Virginia University Extension Service, URL: http://www.wvu.edu/~agexten/landrec/chemtrt.htm.

WVSOS, 2008. "Title 47, Legislative Rules, Department of Environmental Protection, Office of Water Resources, Series 2, Requirements Governing Water Quality Standards", URL: http://www.wvsos.com/csr/verify.asp?TitleSeries=47-02.

Appendix

Table A-1. Investigated stream sites with mean water quality conditions.

ANC Code	Discharge, gpm	pH	Al, mg/L	Fe, mg/L	Mn, mg/L	Net Acidity, mg/L
WVOG-27	18,420	7.09	0.78	0.68	0.10	-64.98
WVBST-70-W-1	27,515	7.69	0.09	0.34	0.03	-108.83
WVBST-109-B	2,340	7.50	0.53	0.36	0.42	-25.73
WVBST-111	902	7.40	0.05	0.05	0.07	-74.80
WVBST-112	1,172	7.80	0.13	0.48	0.09	-110.27
WVBST-113	2,262	8.10	0.05	0.25	0.05	-257.18
WVBST-117	1,466	8.00	0.07	0.29	0.03	-175.00
WVBST-78-E	554	8.40	0.32	0.83	0.11	-302.53
WVBST-78-H	389	8.10	0.05	0.27	0.05	-209.16
WVBST-78-I	268	8.30	0.05	0.17	0.01	-213.41
WVBST-99-L	15,062	8.30	0.05	0.28	0.02	-156.20
WVBST-99-L-1	3,955	8.00	0.05	0.05	0.01	-212.61
WVBST-99-L-4	2,009	7.84	0.07	0.14	0.01	-106.34
WVBST-24	114,015	8.10	0.32	0.62	0.09	-136.96
WVBST-24-N	9,726	7.80	0.12	0.43	0.04	-57.59
WVBST-24-Q	12,983	7.88	0.18	1.03	0.27	-131.67
WVBST-40	13,294	7.90	0.05	0.14	0.06	-85.96
WVBST-40-B	885	5.20	1.50	2.30	1.40	14.30
WVBST-40-C	1,495	7.90	0.30	0.38	0.04	-137.56
WVBST-42	4,896	4.50	3.26	0.05	1.75	20.46
WVBST-43	4,188	7.30	1.18	0.30	0.89	-7.08
WVOG-75-A	7,668	0.00	0.04	0.03	0.00	-185.00
WVOG-75-D	953	7.57	0.10	0.10	0.28	-74.52
WVOG-76-L	3,462	7.65	0.15	0.03	0.05	-56.15
WVOG-92	32,628	8.21	0.04	0.15	0.01	-114.48
WVOG-92-I	4,229	8.33	0.10	0.49	0.08	-158.43
WVOG-92-K	2,265	7.98	0.20	0.34	0.25	-237.83
WVOG-92-K-1	458	7.74	0.08	0.14	0.07	-171.20
WVOG-92-Q	4,576	7.77	0.10	0.24	0.03	-26.96
WVOG-65	83,499	7.40	0.10	0.74	0.15	-177.85
WVOG-65-B	36,740	7.03	0.20	0.43	0.50	-83.21
WVOG-65-B-1	11,248	7.22	1.80	0.54	1.40	-60.49
WVOG-65-B-1-A	1,334	5.62	3.70	0.99	1.60	13.35
WVOG-65-B-1-B	904	5.94	0.29	0.14	0.78	-336.66
WVOG-65-B-1-F	1,647	6.16	0.10	0.28	0.04	-82.83
WVOG-65-B-2	10,179	7.93	0.05	0.29	0.05	-105.12
WVOG-110	34,193	8.45	0.08	0.38	0.02	-224.85
WVOG-138	44,368	8.12	0.35	0.52	0.11	-31.30
WVOG-139	14,117	7.99	0.16	0.49	0.11	-173.03
WVK-41-D.5-2	179	6.90	0.63	0.00	0.00	-119.00
WVKC-47	51,437	8.10	0.05	0.05	0.02	-73.60
WVKC-47-F	451	4.50	3.40	0.05	1.60	20.47
WVKC-47-G	1,886	7.50	1.70	0.05	0.32	-42.88
WVKC-47-G-1	712	4.00	11.00	0.05	1.70	68.29
WVKC-47-P	1,938	7.59	0.39	0.67	0.06	-40.93
WVKC	723,091	7.78	0.13	0.22	0.21	-50.70
WVKC-21	7,468	7.60	0.25	0.18	0.10	-48.11
WVKC-21-A	2,263	7.56	0.09	0.30	0.23	-32.35

ANC Code	Discharge, gpm	pH	Al, mg/L	Fe, mg/L	Mn, mg/L	Net Acidity, mg/L
WVKC-31-C	1,778	7.20	0.05	0.05	0.02	-15.59
WVKC-32	1,137	5.01	2.86	0.16	29.00	64.39
WVKC-35	15,533	7.87	0.81	0.75	0.18	-80.43
WVKC-35.8	1,270	5.32	3.69	0.34	6.09	27.42
WVKC-35-H	904	8.06	0.54	0.70	0.03	-68.90
WVKC-10	310,867	8.50	0.89	0.24	0.05	-254.54
WVKC-10-I	23,835	8.20	0.77	0.13	0.05	-163.41
WVKC-10-I-7	752	7.80	0.02	0.21	0.05	-136.41
WVKC-46	132,533	8.48	0.36	0.25	0.03	-217.50
WVKC-46-G	11,614	7.70	0.05	0.05	0.02	-33.60
WVKC-46-G-1	4,964	7.60	0.19	0.32	0.04	-31.31
WVKC-46-G-2	2,221	7.30	0.05	0.05	0.02	-19.59
WVKC-46-G-3	487	7.29	0.40	0.71	0.09	-9.24
WVKC-46-O	2,151	6.93	0.39	0.95	0.10	-11.46
WVKC-10-U	111,907	8.50	0.05	0.06	0.02	-299.58
WVKC-10-T	102,540	8.60	0.93	0.13	0.01	-254.58
WVKC-10-T-11	25,921	8.70	0.05	0.23	0.02	-499.28
WVKC-10-T-12	1,957	7.62	0.05	0.16	0.06	-15.03
WVKC-10-T-13	2,334	8.13	0.03	0.15	0.01	-110.55
WVKC-10-T-24	4,719	7.51	0.80	2.44	0.10	-37.92
WVKC-10-T-5	1,608	7.05	0.88	0.40	0.15	0.88
WVKE-50-O-2	1,851	5.54	0.03	0.10	0.21	-1.71
WVKE-50-P	7,270	4.50	1.20	1.10	1.00	11.03
WVKE-50-R	153	4.31	0.39	0.07	1.08	5.30
WVKE-14-G-3	948	4.03	1.83	0.06	0.49	10.82
WVKG-26-K-1-A	846	6.60	0.05	0.16	0.90	-8.69
WVKG-30-E	4,675	7.60	0.05	0.30	0.20	-145.83
WVKG-30-P	947	5.66	0.13	0.53	0.16	-2.93
WVKG-30-Q	1,627	6.97	0.03	0.26	0.53	-44.30
WVKG-6	10,675	8.20	0.05	0.05	0.01	-60.40
WVKG-5-B-1-C	1,812	4.40	12.60	0.16	15.80	99.10
WVKG-5-F	4,342	6.41	0.10	0.14	0.01	-4.15
WVKG-5-F-1	472	6.70	13.20	0.54	27.40	63.63
WVK-41-D.5	1,540	4.80	3.60	0.68	1.20	-105.81
WVKN-10-M	338	2.84	25.50	81.60	9.48	371.89
WVKN-17	47,352	7.90	0.01	0.12	0.02	-66.39
WVKN-17-B	2,093	6.30	0.23	4.87	3.27	12.91
WVKN-21	7,506	8.11	0.09	0.26	0.02	-75.50
WVKN-22	39,263	8.40	0.15	0.22	0.04	-151.72
WVKN-22-G	6,760	8.30	0.10	0.43	0.06	-210.55
WVKN-22-K	6,285	7.05	0.14	0.47	0.15	-8.22
WVKN-22-P	613	3.59	1.67	0.96	2.41	23.23
WVKN-5	17,599	8.40	0.10	0.15	0.04	-73.30
WVKN-26	109,881	8.50	0.10	0.11	0.02	-85.10
WVKN-26-A	2,931	7.90	0.10	0.09	0.01	-145.27
WVKN-26-E	11,513	7.54	0.21	1.13	0.32	-32.53
WVKP-1	20,564	6.90	0.28	5.10	0.50	-47.42
WVKP-1-0.9A	310	7.76	0.14	0.30	0.28	-94.87
WVKP-13	19,189	7.40	0.14	0.23	0.21	-63.43
WVKP-13-C.5	2,216	6.16	5.92	2.21	1.50	29.40
WVKP-13-C.5-1	837	4.86	9.35	3.31	1.89	56.98
WVKP-1-A	11,280	6.70	1.80	4.40	0.70	-16.86

ANC Code	Discharge, gpm	pH	Al, mg/L	Fe, mg/L	Mn, mg/L	Net Acidity, mg/L
WVKP-1-A.3	707	4.13	5.96	0.38	1.85	35.86
WVKP-1-A.8	405	7.47	0.80	0.62	0.19	-42.81
WVKP-1-A-0.3	421	6.47	0.37	0.34	0.16	-12.33
WVKP-1-A-0.4	216	3.42	15.10	6.66	1.85	113.15
WVKP-1-A-0.5	244	7.05	0.24	0.68	0.10	-104.28
WVKP-1-A-0.7	0	7.82	0.35	0.41	0.03	-89.38
WVKP-1-A-0.8	452	6.94	0.36	20.50	0.96	-23.34
WVKP-4	2,424	6.70	4.10	0.46	0.88	7.21
WVK-61	58,835	7.50	0.05	0.17	0.25	-44.96
WVK-61-G	1,777	7.50	0.71	0.27	0.32	-31.99
WVK-61-H	9,772	6.61	0.34	0.89	2.10	-62.70
WVK-61-H-1	3,494	5.40	0.83	0.16	0.42	1.86
WVK-61-H-3	953	7.66	0.18	0.27	0.30	-36.57
WVK-61-I	1,437	5.90	0.48	0.09	3.00	3.35
WVK-61-J	2,480	3.54	7.53	3.72	1.97	61.48
WVK-61-J-1	537	2.97	11.70	11.60	2.32	138.51
WVK-61-J-5	365	3.79	7.63	0.09	1.80	48.93
WVK-61-L	5,883	8.10	1.20	1.10	0.25	-105.91
WVK-61-O	5,954	6.93	6.58	15.60	1.78	62.65
WVK-61-O-1	1,682	6.47	0.78	6.23	0.58	-29.22
WVK-61-O-2	1,448	7.95	1.08	0.12	0.41	-7.84
WVK-49-H	467	7.25	1.23	1.42	0.06	-11.12
WVK-53-A-0.4	626	3.23	27.30	4.91	5.94	195.68
WVK-57-C-1	1,026	6.96	0.19	0.26	0.02	-6.94
WVK-58-B.1	399	4.29	13.30	0.43	14.50	98.58
WVK-60	10,677	7.16	0.89	0.19	3.20	-12.89
WVK-60-A-1	414	4.29	14.20	0.05	6.23	87.87
WVK-60-B	1,151	7.12	1.30	0.23	2.01	-76.61
WVK-60-B.1	168	5.40	14.30	0.13	7.98	89.38
WVK-61.5	367	3.93	19.00	10.00	2.70	133.20
WVK-62	539	3.65	9.58	0.84	2.47	65.41
WVK-70	6,098	7.00	1.10	2.10	0.74	-0.79
WVK-70-A	1,431	6.63	0.96	0.00	0.44	-19.85
WVK-71	743	7.48	0.20	2.74	0.38	-249.30
WVK-72-A	2,629	7.93	0.40	0.49	0.20	-77.44
WVK-72-A-1	649	8.12	0.24	0.32	0.80	-90.14
WVK-73	18,536	7.74	0.36	0.14	0.06	-34.24
WVK-73-A	1,121	6.49	0.18	0.02	0.51	-3.02
WVK-73-D	1,710	4.65	3.51	0.08	0.62	16.89
WVK-73-D-1	743	6.58	0.08	0.08	0.00	-7.89
WVK-73-E	5,085	7.58	0.28	0.09	0.04	-28.71
WVK-73-E-2	382	7.43	1.32	0.49	0.25	-8.04
WVK-75	1,527	10.48	0.18	0.05	0.09	-50.15
WVK-75-A	369	4.61	6.45	0.16	2.89	37.60
WVK-76	40,134	8.15	0.09	0.07	0.02	-75.94
WVK-76-C-1-A	1,005	7.91	0.25	0.37	0.02	-63.91
WVK-76-D-1	1,370	6.90	0.24	0.12	0.02	-18.41
WVK-76-F	849	7.33	0.30	0.42	0.03	-21.13
WVK-76-H	1,491	7.27	0.10	0.12	0.02	-8.49
WVK-76-K	627	5.17	0.39	0.22	0.46	-1.27
WVK-65	99,276	7.82	0.76	0.30	0.23	-37.72
WVK-65-M	5,137	4.70	4.40	2.70	1.40	29.81

ANC Code	Discharge, gpm	pH	Al, mg/L	Fe, mg/L	Mn, mg/L	Net Acidity, mg/L
WVK-65-M-1	2,273	4.60	5.00	0.12	0.83	28.76
WVK-65-P	667	4.70	6.70	0.15	1.80	38.76
WVK-65-Q	651	5.15	2.98	0.96	0.35	14.26
WVK-65-Q.3	327	3.60	7.80	1.80	6.30	69.56
WVK-65-S	770	4.00	6.70	0.26	2.20	45.69
WVKNB-18	18,468	7.80	0.10	0.38	0.08	-111.63
WVKNB-28-B	8,860	8.12	0.07	0.27	0.04	-76.86
WVKNB-30	9,957	8.26	0.07	0.28	0.03	-104.06
WVKNB-33	3,210	7.59	0.18	0.51	0.05	-35.78
WVO-2-Q-8	7,065	4.64	5.27	0.64	1.57	29.42
WVO-2-Q-8-A	4,247	3.67	9.97	1.33	1.32	65.85
WVO-2-Q-8-B	2,363	3.94	14.90	1.04	1.88	88.79
WVMC-60-D-2.7	240	3.20	3.06	0.92	0.21	45.57
WVMC-60-D-3-A	2,099	3.14	8.37	8.24	0.46	97.27
WVMC-12-B-0.5-A	1,273	5.61	2.24	0.36	0.66	9.42
WVMC-13.5	2,045	4.92	1.27	0.14	0.75	4.28
WVMC-16	9,315	3.07	6.36	11.80	0.59	95.03
WVMC-16-A	3,020	2.69	31.10	69.00	2.81	402.19
WVMC-16-A-1	1,218	2.72	34.40	71.20	3.15	418.25
WVMC-17	27,200	3.13	11.10	12.80	2.50	125.13
WVMC-17-A	4,444	2.90	39.10	47.00	10.30	381.82
WVMC-17-A-0.5	5,944	2.95	17.70	8.67	1.78	172.15
WVMC-17-A-1	3,108	3.20	31.00	7.80	13.00	241.34
WVMC-17-A-1-B	680	3.83	12.90	0.66	5.59	85.40
WVMC-18	12,381	7.40	0.43	0.39	0.14	3.34
WVMC-19	7,605	7.40	0.31	0.22	0.04	2.19
WVMC-23	6,567	3.16	14.40	19.40	0.96	145.99
WVMC-23-0.2A	1,438	7.27	2.45	1.02	0.59	0.01
WVMC-23-A	2,700	3.10	14.00	4.20	2.40	129.36
WVMC-23-A-1	746	3.11	15.40	15.30	2.26	150.80
WVMC-24	1,820	2.97	15.30	10.20	1.28	158.12
WVMC-24-A	409	6.32	0.15	0.25	0.02	-17.27
WVMC-25	3,976	2.65	48.00	86.90	1.85	536.14
WVMC-27	7,988	3.84	7.86	0.80	1.54	54.12
WVMC-27-C	1,277	3.09	11.60	11.60	0.66	122.00
WVMC-12-0.5A	4,339	4.10	8.60	0.37	2.00	56.05
WVM-23	100,551	7.90	0.10	0.07	0.08	-184.18
WVM-23-E	8,459	8.10	0.10	0.10	0.02	-218.23
WVM-8	51,296	4.60	5.59	0.42	9.22	46.22
WVM-8-D	586	3.60	1.93	0.79	0.87	24.27
WVM-8-H	2,421	5.90	0.82	3.17	0.56	-2.17
WVM-8-I	3,300	6.80	0.10	0.37	0.31	-11.13
WVM-10	17,450	6.70	0.30	0.58	1.14	-13.90
WVM-10-D	3,763	6.80	3.32	0.52	3.00	8.94
WVM-11	1,773	6.50	0.10	0.05	0.05	-29.75
WVM-17	17,384	7.90	0.59	0.21	0.08	-167.18
WVM-2.1	551	2.60	55.20	200.00	0.00	1,092.00
WVM-2.1-A	1,035	2.70	24.30	16.30	4.04	269.22
WVM-2.6	540	2.70	24.30	22.00	3.37	278.18
WVM-21	2,781	6.90	0.10	2.08	0.25	-120.27
WVM-3	7,162	5.80	0.14	0.55	2.80	-8.86
WVM-4	6,208	2.90	98.90	403.00	4.54	1,338.29

ANC Code	Discharge, gpm	pH	Al, mg/L	Fe, mg/L	Mn, mg/L	Net Acidity, mg/L
WVM-6	11,961	7.30	0.14	0.10	0.15	-87.29
WVM-6-A	2,854	7.70	0.10	0.26	0.22	-228.59
WVM-7	11,403	6.80	0.10	0.26	0.33	-130.37
WVMTB-10-A	1,347	7.50	0.06	0.32	0.46	-50.24
WVMTB-11	7,101	7.30	0.12	1.00	0.25	-62.09
WVMTB-11-B	1,890	6.70	0.15	1.00	0.61	-28.26
WVMTB-11-B.7	2,091	3.38	2.72	16.10	4.03	67.03
WVMTB-18-B	4,071	7.80	0.17	2.40	0.27	-284.28
WVMTB-5-B	1,513	7.50	0.14	0.78	1.58	-104.96
WVMT-11	1,036,254	7.50	0.05	0.04	0.02	-83.51
WVMT-11-A	3,113	7.30	0.05	0.18	0.09	-44.23
WVMT-11-B-1	697	6.90	0.13	0.50	0.45	-77.56
WVMT-29	1,924	7.40	0.09	0.50	0.29	-98.08
WVMTM-16	13,071	3.06	56.90	12.30	14.90	403.71
WVMT-36	976	6.80	0.25	1.00	0.85	-52.27
WVMT-37	6,660	3.38	8.89	2.59	1.82	73.17
WVMT-38	4,849	6.28	0.16	0.57	0.06	-13.86
WVMT-41	2,484	3.11	15.70	19.80	1.81	159.68
WVMT-42	23,146	5.55	0.34	0.35	7.67	11.60
WVMT-12	81,916	4.88	1.87	0.05	2.26	10.25
WVMT-12-C	14,913	4.43	8.33	0.12	2.64	48.15
WVMT-12-H	13,774	4.04	16.60	0.17	6.49	103.89
WVMW-21	97,737	8.07	0.37	0.61	0.07	-131.73
WVMW-21-A	1,561	7.75	2.81	3.47	1.55	-13.37
WVMW-21-E	811	7.72	0.10	0.22	0.04	-99.98
WVMW-21-G	17,156	8.11	0.09	0.18	0.03	-107.12
WVMW-21-G-1	1,740	7.60	0.24	0.54	0.21	-106.32
WVMW-21-G-2	1,141	7.90	0.06	0.28	0.07	-139.04
WVMW-21-G-3	1,495	7.72	0.06	0.31	0.12	-125.89
WVMW-21-N	1,818	7.68	0.84	1.34	0.14	-94.68
WVMW-21-O	1,484	8.03	0.06	0.17	0.12	-168.14
WVMW-21-P	2,079	7.98	0.33	0.73	0.16	-155.57
WVMW-21-S	3,914	8.02	0.20	0.39	0.14	-160.94
WVMW-10	565	7.03	1.59	19.00	0.52	-168.29
WVMW-11	6,289	7.06	0.18	0.83	0.64	-59.35
WVMW-11-D	894	7.31	1.42	1.13	0.95	-49.36
WVMW-11-F	252	2.84	14.10	6.94	2.95	167.36
WVMW-11-G	275	6.15	0.15	0.50	0.15	-112.97
WVMW-12-A	668	6.64	0.46	27.70	0.71	-124.68
WVMW-16	5,015	7.69	0.25	4.12	1.83	-47.93
WVMW-16-B	1,139	6.92	3.09	7.19	2.75	30.01
WVMW-17	1,527	7.07	0.38	10.20	4.14	-56.14
WVMW-18	724	6.88	0.33	9.65	2.23	-22.87
WVMW-19	1,984	7.63	0.06	0.24	0.10	-150.06
WVMW-20	8,418	7.93	0.05	0.31	0.06	-167.06
WVMW-2-0.5A	33,696	7.16	2.21	0.55	2.26	-84.63
WVMW-2-0.8A	306	7.28	0.05	3.74	1.12	-44.00
WVMW-20-A	725	7.99	0.05	0.14	0.06	-204.36
WVMW-20-C	889	7.64	0.32	0.48	0.48	-41.49
WVMW-2-D	2,063	6.85	0.64	1.37	1.29	-23.65
WVMW-2-D-1	634	7.29	1.51	0.22	7.25	7.97
WVMW-3	4,771	10.07	0.26	0.60	0.31	-99.92

ANC Code	Discharge, gpm	pH	Al, mg/L	Fe, mg/L	Mn, mg/L	Net Acidity, mg/L
WVMW-7	37,424	8.13	0.03	0.31	0.04	-238.20
WVMW-7.1	266	6.95	3.28	2.20	1.39	-46.32
WVMW-7-A	7,599	8.31	0.19	0.34	0.02	-170.30
WVMW-7-D	2,632	8.09	0.05	0.14	0.04	-197.40
WVMW-8.5	225	6.75	0.05	2.24	0.90	-197.08
WVMW-9	2,404	6.97	0.44	1.27	1.43	-11.68
WVMW-9.5	363	5.39	5.12	17.50	5.77	67.39
WVMW-22	3,623	7.96	0.08	0.13	0.08	-137.18
WVMW-22-A	631	7.92	0.05	0.11	0.12	-143.31
WVMW-23	5,346	7.84	0.06	0.74	0.34	-165.73
WVMW-24	2,103	7.94	0.15	0.27	0.04	-126.61
WVMW-25	7,300	8.11	0.10	0.17	0.04	-125.07
WVMW-25-F	3,242	7.84	0.29	0.61	0.17	-134.99
WVMW-26	16,004	7.96	0.20	0.23	0.09	-109.31
WVMW-27	4,529	7.60	0.05	0.08	0.04	-82.51
WVMW-28	3,764	7.89	0.09	0.15	0.08	-125.09
WVMW-29	5,938	8.05	0.04	0.09	0.03	-144.57
WVMW-30	2,917	7.89	0.08	0.11	0.05	-143.27
WVMW-31	46,589	7.97	0.08	0.19	0.06	-132.10
WVMW-31-A	2,731	7.63	0.22	0.53	0.11	-127.62
WVMW-31-B	1,713	7.48	0.07	1.16	0.43	-92.76
WVMW-32	16,339	7.72	0.04	0.12	0.05	-129.47
WVMW-32-B	716	8.10	0.06	0.11	0.08	-190.32
WVMW-34	1,597	7.50	0.20	0.56	0.58	-104.83
WVMW-36	24,253	7.29	0.05	0.29	0.09	-128.05
WVMW-36-C.5	1,705	7.78	0.07	0.21	0.11	-129.04
WVMW-36-F	4,294	7.66	0.30	0.33	0.06	-122.63
WVMW-37	2,467	7.50	0.15	1.27	0.46	-92.06
WVMW-15	59,140	8.05	0.12	0.25	0.14	-89.93
WVMW-15-B	2,025	4.92	4.63	3.48	2.84	35.70
WVMW-15-D	2,785	8.01	0.09	0.24	0.11	-98.87
WVMW-15-G	5,530	7.76	0.08	0.30	0.06	-132.91
WVMW-15-I	2,698	7.47	0.12	0.07	0.26	-23.73
WVMW-15-J	9,428	7.39	3.63	1.13	1.15	3.28
WVMW-15-J.5	981	7.60	0.15	0.42	0.40	-48.69
WVMW-15-J-0.3	195	3.35	15.50	4.12	3.85	121.80
WVMW-15-J-1	2,559	6.65	3.82	0.89	2.26	23.93
WVMW-15-J-2	1,501	7.41	1.29	0.76	0.74	-39.13
WVMW-15-J-3	1,424	7.58	0.24	0.36	0.36	-76.37
WVMW-15-K	1,133	7.52	0.19	0.75	0.30	-78.06
WVMW-15-K.7	281	7.45	0.18	1.63	0.47	-168.23
WVMW-15-L	3,811	7.93	0.66	5.83	0.75	-119.56
WVMW-15-L-1	593	7.54	0.06	5.21	0.92	-134.69
WVMW-15-L-2	1,105	7.11	0.24	0.78	1.78	-47.03
WVMW-15-M	1,143	8.45	0.14	15.40	0.56	-183.70
WVMW-15-N	731	4.51	6.56	1.75	5.22	49.61
WVMW-13	100,091	8.13	0.04	0.09	0.03	-115.57
WVMW-13-0.5A	417	7.36	1.45	3.72	0.24	-116.86
WVMW-13-A	8,774	6.89	0.11	0.23	0.03	-118.92
WVMW-13-B	22,537	7.99	0.02	0.03	0.01	-163.81
WVMW-13-B-1	749	8.06	0.08	0.10	0.02	-178.34
WVMW-13-B-2	1,489	6.70	0.05	21.90	1.08	-6.64

ANC Code	Discharge, gpm	pH	Al, mg/L	Fe, mg/L	Mn, mg/L	Net Acidity, mg/L
WVMW-13-C	1,703	7.73	0.30	0.41	0.05	-147.51
WVMW-13-C-1	283	7.21	1.94	1.65	0.24	-85.84
WVMW-13-D	1,815	7.97	0.06	0.36	0.29	-166.50
WVMW-13-E	2,043	8.14	0.11	0.36	0.04	-146.67
WVMW-38	38,586	7.52	0.20	0.90	0.18	-32.95
WVMW-38-A.6	494	7.65	0.22	0.35	0.07	-66.73
WVMW-38-E	1,422	7.82	0.05	0.16	0.06	-81.33
WVMW-41	5,264	7.72	0.05	0.16	0.06	-61.33
WVPNB-11	1,677	7.18	2.70	1.43	0.32	6.54
WVPNB-12	3,847	3.96	4.78	3.13	1.45	35.26
WVPNB-16	35,937	7.33	0.18	0.07	0.37	-9.50
WVPNB-16-A	5,284	4.70	1.80	0.15	3.00	13.72
WVPNB-16-D	778	6.22	0.78	1.11	1.04	3.24
WVLK-86-C-3	589	8.00	0.10	0.22	0.06	-93.24
WVLK-82	2,826	7.38	0.04	0.24	0.39	-155.64
WVLK-83	1,352	7.40	0.10	0.27	0.11	-92.86
WVLK-85	1,717	7.30	0.10	0.05	0.06	-38.94
WVLK-85-C	311	7.69	0.18	0.28	0.14	-64.75
WVLK-88	6,832	7.52	0.06	0.03	0.01	-97.48
WVLK-90	7,808	7.26	0.08	0.19	0.17	-58.82
WVLK-90-A	812	7.04	0.27	0.11	0.29	-31.50
WVO-23	8,568	4.67	7.05	6.23	3.17	52.12
WVO-92	131,573	8.01	0.10	0.31	0.04	-178.83
WVO-92-E	409	8.05	0.28	0.93	0.04	-188.71
WVO-92-G	3,708	8.01	0.03	0.03	0.01	-213.76
WVO-101-E	170	7.14	0.10	0.30	0.17	-97.10
WVO-97-A	1,686	8.50	1.20	0.78	0.12	-131.72
WVO-97-B	2,257	8.20	0.48	0.46	0.16	-136.22
WVO-97-D	531	7.90	3.97	1.72	0.30	-228.33
WVO-89	2,085	6.51	7.00	86.40	0.30	161.84
WVO-89-A	460	7.85	0.03	0.14	0.01	-267.57
WVO-90	19,760	8.09	0.09	0.07	0.01	-179.36
WVO-90-C	522	8.03	0.09	0.25	0.01	-196.03
WVO-90-D-1	934	8.34	0.16	0.23	0.01	-290.67
WVO-88	240,046	7.96	1.20	1.52	0.10	-3.84
WVO-88-D-1	4,367	7.98	0.16	0.18	0.01	-161.76