Evaluation and Recommendations for Bear Run Passive Treatment Systems, Bloss Township, Tioga County

Technical Report provided by Hedin Environmental through the Trout Unlimited AMD Technical Assistance Program

May 2009

Background

In February of 2009 the Babb Creek Watershed Association (BCWA) requested technical assistance in the form of a determination of maintenance requirements for the Bear Run Passive Treatment Systems. There are two separate passive treatment systems that treat discharges from the Bear Run mine complex site (Figure 1). Each system consists of a single Vertical Flow Pond (VFP) that discharges to Babb Creek. Although the two systems are identical in construction, one VFP is roughly three times larger (by area) than the other. The systems were constructed in 2000 by Stotts Coal Co. as part of a consent order and have consistently produced net alkaline effluent with few metals. In 2005 the organic substrate in both systems was mixed in response to an apparent loss of permeability. The mixing of the organic substrate improved the permeability and the systems continue to produce excellent water quality. Despite the net alkaline effluent further maintenance is inevitable. The purpose of this Technical Assistance is to investigate the systems by analyzing available water quality data and also through excavations of the organic substrate to determine the appropriate course of action to ensure continued system performance.

Figure 1. Site layout

Small VFP (Main Entry)

<u>Discharge and Treatment System Description</u>

The smaller of the two VFPs treats the discharge from the main entry and is represented by sample stations 17.5 (raw) and 17.5A (effluent). The discharge contains elevated but not severe concentrations of iron, manganese and aluminum (Table 1) and the flow rate appears to be fairly steady with an average of 53 gpm. Every effluent sample has been net alkaline with pH greater than 6.5.

Table 1. Average influent and effluent water quality and flow the Small VFP

Location	Flow (gpm)	pH	Acidity (mg/L)	Fe (mg/L)	Mn (mg/L)	Al (mg/L)	SO_4 (mg/L)
Influent	53	3.1	127	6.5	2.9	8.4	175
Effluent	n.m.	7.1	-126	1.3	2.4	1.3	201

n.m. – effluent flow rates were not measured

The Small VFP contains two feet of no. 3 limestone topped with two feet of an organic substrate comprised of spent mushroom compost (SMC), no. 3 limestone and wood chips. The relative quantity of limestone used to amend the SMC is unusually high. Table 2 shows the quantities specified in the original project scope of work.

Table 2. Small VFP contents

Total Limestone (tons)	Spent Mushroom Compost (yd^3)	Wood Chips (yd^3)	Calculated Limestone Amendment (yd^3)*
1,942	275	275	384

**Calculated by subtracting the amount of limestone in the bottom 2 feet (1,424) from the total limestone*

The system discharges via an underdrain of perforated PVC pipes embedded in the limestone at the base of the system. The underdrain is connected to an Agri Drain inline water level control structure that is in turn connected to the final outfall of the system.

Performance Evaluation

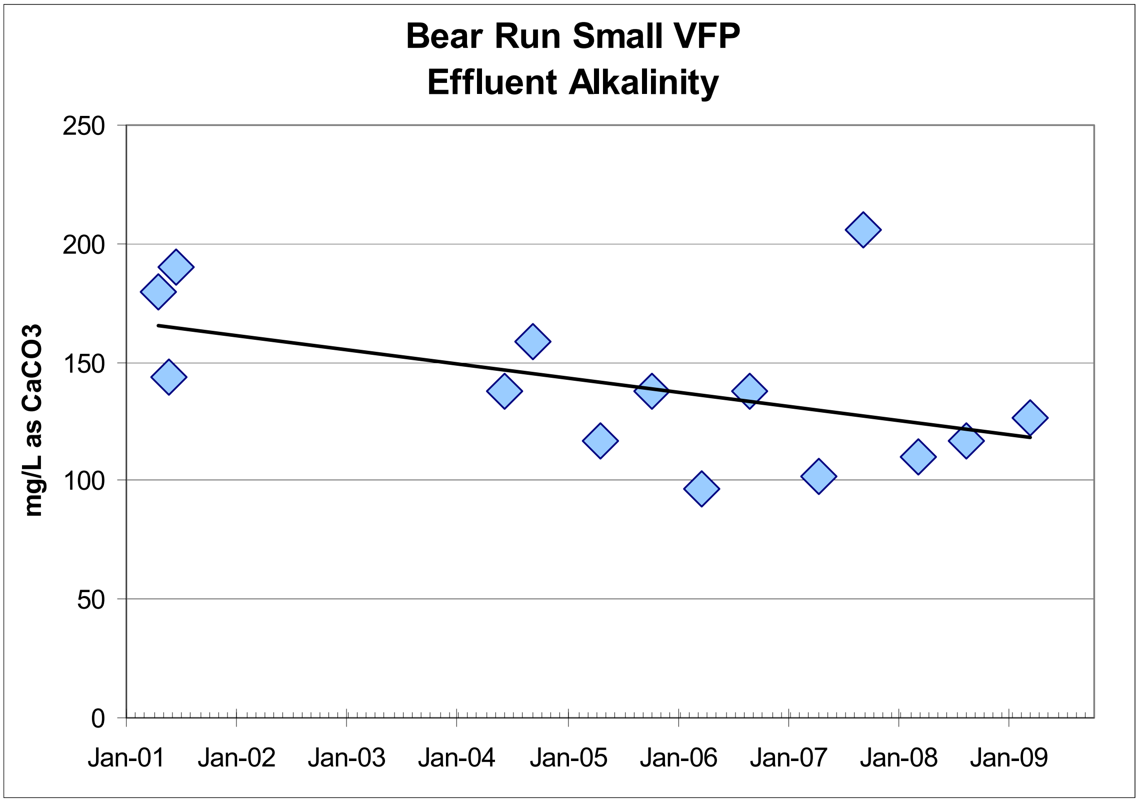
All available water quality data were entered into a spreadsheet for analysis. These data combined with treatment system dimensions provided in the original specifications allow for the performance to be calculated. While not all sampling events included flow measurement, there are sufficient flow measurements in the data set to allow for general system performance assessment. The results of these calculations are shown in Table 3.

Table 3. Small VFP performance

Influent acidity loading, (g/m^2)/day)	Effluent net acidity loading, (g/m^2)/day)	Net alkalinity generation, (g/m^2)/day)
17	-13	30

The Small VFP is not overloaded in terms of acidity per unit area with an average loading of 17 (g/m^2)/day. Typically, VFPs are designed to receive 35-40 (g/m^2)/day of acidity loading. The modest loading rate has allowed for highly reliable performance for nearly a decade. However, a trend of decreasing effluent alkalinity is apparent in the data (Figure 2). The trend is gradual and is a natural part of the life cycle of passive treatment systems. Future maintenance is required to maintain treatment system effectiveness but the risk of net acidic discharge is quite small for years to come.

Figure 2. Small VFP effluent alkalinity over time



Sulfate reduction rates could be used as a measure of the effectiveness of the organic substrate layer. A comparison of influent and effluent sulfate concentrations was conducted but the sulfate values are highly erratic and often indicated that the system was actually a source of sulfate rather than a location for its removal. This is likely due to the laboratory method used to measure sulfate. As a result, sulfate reduction rates are not a useful indicator of maintenance need for this system.

Organic Substrate Investigation

On March 27, 2009 the Small VFP was drained to allow access to the system's contents for investigation. A shovel was used to dig holes through the organic substrate layer to the top of the limestone layer. The thickness of the organic substrate layer was found to be approximately 18 inches or 6 inches less than what was originally specified. This is likely the result of compaction and consumption of the materials by the treatment process. Photo 1 shows one of the holes. The organic substrate layer contained very little visible SMC and was made up largely of limestone aggregate and wood chips. Only minor metals accumulation was noted on the top of the organic substrate layer. The material has compacted over time and has reduced permeability, though not enough to prevent treatment of the full discharge flow.

Photo 1. Small VFP organic substrate layer contents

Big VFP (Secondary Entry)

Discharge and Treatment System Description

The larger of the two VFPs treats flow from a secondary mine entry and is represented by sample stations 17.6 (raw) and 17.6A (effluent). The discharge contains elevated but not severe concentrations of iron, manganese and aluminum (Table 4). Every effluent sample has been net alkaline with pH greater than 6.5.

Table 4. Average influent and effluent water quality and flow for the Big VFP

Location	Flow (gpm)	pH	Acidity (mg/L)	Fe (mg/L)	Mn (mg/L)	Al (mg/L)	SO_4 (mg/L)
Influent	323	3.1	121	4.4	2.8	7.6	174
Effluent	254	7.1	-159	1.2	3.3	0.6	225

The flow rate is highly variable ranging from 25 gpm to 800 gpm. It appears that the Main Entry is restricted and the Secondary Entry acts as an overflow from the mine. During high flow events a portion of the raw water is discharged untreated through the emergency spillway. This fact is evident from the difference between the influent and effluent flow rates. The reason for this bypass of untreated water is a loss of substrate permeability that is discussed in more detail in later sections.

The Big VFP contains two feet of No. 3 limestone topped with two feet of an organic substrate comprised of spent mushroom compost (SMC), no. 3 limestone and wood chips. The relative quantity of limestone used to amend the SMC is unusually high. Table 5 shows the quantities specified in the original project scope of work.

Table 5. Big VFP contents

Total Limestone (tons)	**Spent Mushroom Compost (yd^3)**	**Wood Chips (yd^3)**	**Calculated Limestone Amendment (yd^3)***
7,282	1,000	1,000	1,925

**Calculated by subtracting the amount of limestone in the bottom 2 feet (4,683) from the total limestone*

The system discharges via an underdrain of perforated PVC pipes embedded in the limestone at the base of the system. The underdrain is connected to an Agri Drain inline water level control structure that is in turn connected to the final outfall of the system.

<u>Performance Evaluation</u>

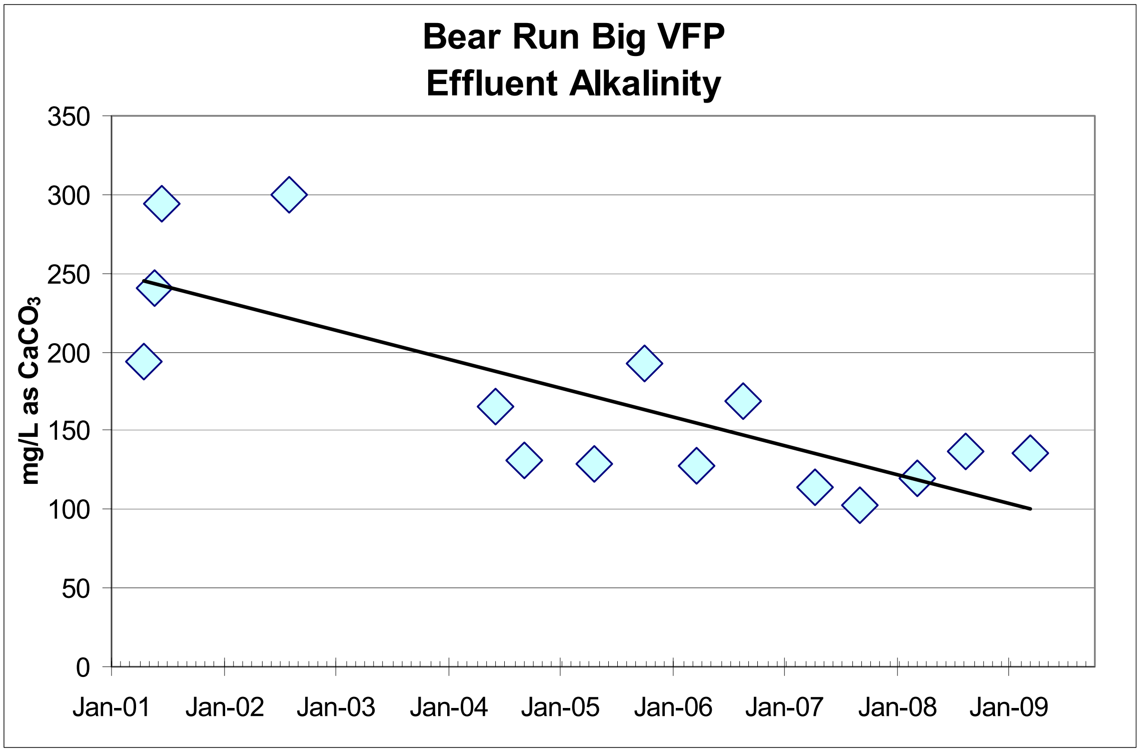
All available water quality data were entered into a spreadsheet for analysis. These data combined with treatment system dimensions provided in the original specifications allow performance evaluations. While not all sampling events included flow measurement, there are sufficient flow measurements in the data set to allow for general system performance assessment. The results of these calculations are shown in Table 6.

Table 6. Big VFP performance

Influent acidity loading, (g/m^2)/day)	**Effluent net acidity loading, (g/m^2)/day)**	**Net alkalinity generation, (g/m^2)/day)**
22	-18	40

The Big VFP is not overloaded in terms of acidity per unit area with an average loading of 22 (g/m^2)/day. Typically, VFPs are designed to receive 35-40 (g/m^2)/day of acidity loading. The modest loading rate has allowed for highly reliable performance for nearly a decade. However, a trend of decreasing effluent alkalinity is apparent in the data (Figure 3). The trend is gradual and is a natural part of the life cycle of passive treatment systems. Future maintenance is required to maintain treatment system effectiveness.

Figure 3. Big VFP effluent alkalinity over time



<u>Organic Substrate Investigation</u>

On March 27, 2009 the Big VFP was drained to allow access to the system's contents for investigation. A shovel was used to dig holes through the organic substrate layer to the top of the limestone layer. Photo 2 shows one of the holes. The organic substrate layer contained very little visible SMC and was made up largely of limestone aggregate and wood chips. What little SMC that was found occurred in a thin layer about one foot below the surface. This thin layer of SMC was probably an isolated pocket that wasn't completely mixed during construction. The top 2-3 inches of material was cemented with metals solids (Photo 3). Much of the organic substrate had standing water on top of it despite the fact that the system was drained (Photo 4). The permeability of the organic substrate layer is very low.

Photo 2. Big VFP organic substrate layer contents

Photo 3. Materials cemented by metals solids at the top of the Big VFP organic substrate layer

Photo 4. Standing water on top of organic substrate layer in drained Big VFP

Recommendations

The existing sampling regimen should be continued. Effluent alkalinity is perhaps the most significant parameter to consider for these systems. While a downward trend exists, any significant deviation from that trend should trigger additional sampling.

Another key component of the monitoring is careful flow measurements. A means for measuring the flow into and out of each VFP as well as any water bypassed by the Big VFP should be installed. Stainless steel weirs could be used on the outlet channels to prevent damage from porcupines.

Because of the remote nature and close proximity to one another of the two treatment systems their maintenance should be conducted jointly. As a result, the maintenance plan proposed here treats the maintenance of both systems as a single project.

The function of a passive treatment system can be broken down into two basic categories; physical and chemical. The physical function of the system involves the movement of water through the treatment media. The chemical function of the system involves the chemical modification of water passing through it. Since these two functions occur concurrently they influence one another and it is often difficult to separate their effects. For example: a system with a short circuit (physical failure) will appear to have a chemical failure due to reduced residence time. If the recommended action to address this problem targets the chemical failure then the root cause (the short circuit) is missed.

It is for this reason that the maintenance proposed here is broken down based on the needs of the system to improve physical or chemical function.

Physical Function Improvement
Permeability loss is a major concern in the Big VFP. High flows frequently overwhelm the permeability of the system and untreated water is bypassed to the stream. The Small VFP is developing a similar permeability problem but it is not as apparent due to the fact that it does not receive large erratic flows.

The recommended action is to physically disturb the full thickness of the organic substrate layer in both systems. The specified thickness of the organic substrate layer was two feet. Test holes dug in the organic substrate layer reveal that it has compacted to approximately 18 inches. The full thickness of the organic substrate layer should be mixed to reestablish permeability. Care should be taken to produce a final surface that is regular, level and protected from compaction.

Chemical Function Improvement
The organic substrate layer is intended to maintain reducing conditions within the underlying limestone layer. However, the organic substrate layer was found to be completely lacking in SMC yet the system's performance has not suffered. As a result the need to augment the systems with additional SMC appears to be low. High material costs at this remote site make it important to establish that SMC addition is necessary before proceeding with a plan to add more SMC. For this reason it is recommended that no additional SMC be added until after the organic substrate layer is mixed and the results considered.

Cost
An estimate of the cost of mixing the organic substrate layer was prepared and is summarized in Table 7.

Table 7. Immediate project quantities and estimated costs

Item	**Quantity**	**Unit Cost**	**Total Cost**
Machine mob/demob	1	400	$400
Machine time to mix existing organic substrate layer	16 hours	$80	$1,280
TOTAL			$1,680

Since new SMC may ultimately be required, a general cost estimate was prepared. The estimate assumes that the organic substrate layer will require mixing a second time to incorporate the new SMC. This may not be necessary.

The remote nature of the site and poor condition of the roads that provide access will increase the cost of the project relative to more easily accessible sites. Table 8 shows anticipated quantities, unit costs and total costs to perform a major maintenance operation. The need to perform a maintenance operation of this scale is low at this time but may be necessary in the next 5-10 years.

Table 8. Project quantities and costs (for reference only)

Item	Quantity	Unit Cost	Total Cost
Machine mob/demob	1	1,000	$1,000
Machine time to mix existing organic substrate layer	16 hours	$80	$1,280
Spent mushroom compost (delivered to systems)	1,913 yd^3	$20	$38,260
Machine time to place spent mushroom compost	80 hours (Loader and excavator)	$80	$6,400
TOTAL			$46,940

Future Maintenance Needs – A Caveat

The method for determining an appropriate maintenance interval is still being developed. However, the nine year history of these two systems provides a template for future maintenance needs. In the last nine years a single maintenance event has been required (year 5). If the maintenance recommended in this report is implemented then the second maintenance event will occur in year 10 or 11. Thus it is reasonable to expect that future maintenance events will continue to occur at five year intervals for the foreseeable future.

If the severity of the treated water influences the maintenance interval then there is reason to believe that the maintenance interval may extend beyond five years in the future. Since the treatment systems were constructed the raw discharge water quality has moderated. Table 8 shows that acidity has declined 23% when comparing the average acidity from 1997-2002 to 2004-2009.

Table 8. Bear Run mine complex discharge moderation with time

Timeframe*	Acidity (mg/L)	Fe (mg/L)	Mn (mg/L)	Al (mg/L)
1997-2002	146	8.0	9.2	3.3
2004-2009	113	3.9	7.4	2.7
% change	-23%	-51%	-20%	-19%

**There were no data available for 2003*

The decline in acidity over time was largely driven by the 51% decline in iron concentration. This is critical to system maintenance interval because the permeability loss observed in the Big VFP appeared to be largely due to an accumulation of iron solids in the top 2-3 inches of the organic substrate layer. If the system receives less iron the time required for this problem to redevelop will be greater and thus so will the maintenance interval.

As the iron concentration declines so does the importance of organic material to the chemical function of the system. Over the next decade the organic substrate layer may become unnecessary and the system can be allowed to function as an oxic limestone bed - eliminating the need for future spent mushroom compost addition.

Summary

Both systems are performing very well in that they produce good quality effluent. However, it is clear that permeability problems are beginning to arise, particularly in the Big VFP. The following items are recommended to ensure long term performance of the systems is sustained.

1. Continue monitoring water quality and flows. Pay particular attention to effluent alkalinity concentrations.
2. Improve flow measurement by installing stainless steel weirs at the effluent of both VFPs and also in the Big VFP bypass. Track the portion of flow that is bypassed.
3. Mix the organic substrate layer of both VFPs. The full thickness should be disturbed to re-establish permeability.
4. Monitor effects of substrate mixing. The Big VFP should not bypass any flow following the mixing. Determine if additional SMC is required.
5. Add additional SMC (if required).