Existing Passive AMD Treatment Systems Evaluation and Recommendations
Lower Cold Stream AMD Discharges – Shotgun, Chiller, Mine Drift, Stump/Stump Jr., and Fossil Rock
Cold Stream Watershed, Centre County

Technical Report prepared by Skelly and Loy, Inc. through the Trout Unlimited AMD Technical Assistance Program

December 2014

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Background

The Centre County Conservation District (CCCD) requested technical assistance through the Trout Unlimited AMD Technical Assistance Program to evaluate and provide recommendations for the existing lower Cold Stream AMD passive treatment systems within the Cold Stream watershed. On January 14-15 and April 28, 2014, Skelly and Loy, Inc., CCCD, and former Woodduck Chapter personnel visited the lower Cold Stream AMD passive treatment systems to conduct water sampling, flow measurements where possible, and field water quality measurements at the site. This report provides a summary of historic and data collected during the site visit as well as recommendations for improving the existing treatment systems effectiveness that in turn may provide considerable restoration efforts for the lower Cold Stream watershed.

Existing Data

Flow and water chemistry data have been collected for the multiple raw AMD seeps/discharges as part of a watershed assessment study from 1998 to 2000. The six existing passive treatment systems since their construction ranging from 2001 to 2004 have also been periodically monitored for flow and water quality, particularly during snapshot sampling events in 2009, 2010, and 2012 through the eFACTS program. In 2013, the Pennsylvania Department of Environmental Protection (PA DEP) conducted monitoring within the mainstem of Cold Stream to assess the potential for direct AMD impacts to the stream from previously unidentified sources or leakage from the Project 70 ditch. Unfortunately, several of the AMD sources are not currently being treated and the current Project 70 ditch constructed in 1999 allows for these sources to combine with the passive treatment system outfalls to bypass the reservoir and enter Cold Stream immediately downstream of the dam. The quality of the water chemistry data appears to be reasonable. However, all of the historic metal concentrations were reported as total recoverable. Dissolved metals concentrations are more useful in correlating reported hot acidity concentrations and understanding the treatment effectiveness for adding alkalinity and precipitating the dissolved metals. Dissolved metals concentrations are also necessary to conduct geochemical modeling to predict treatment capabilities of the most common treatment materials including limestone and lime. Total recoverable metal concentrations provide a worst-case scenario for predicting treatment needs since one must assume that the entire concentration is dissolved, depending on the pH, and contributes to the acidity that requires alkaline treatment. Simultaneous flow and water sampling are highly recommended to correlate concentration with flow, determine loading estimates, and evaluate trends in treatment based on flow conditions.

Since most of the water quality sampling events for the final treatment system outfalls did include flow measurement, it was reasonable to develop a correlation between variability in water quality of the treatment system based on flow. However, nearly all of the treatment systems utilize automatic dosing siphons as the outfall structure of the limestone containing ponds except for the Shotgun system. Automatic dosing siphons provide variable flow rates during their discharge period, which is initiated once the water level within the pond and manhole housing structure reach a specific high water elevation. If the unit is operating correctly, the siphon is triggered and operates until the water level is reduced to a specific low water elevation. The fluctuation in flow from the automatic dosing siphon during its operation cycle establishes flows downstream in the system including the final outfall that is not indicative of the actual AMD flow rate. Historic data and continued monitoring of the raw AMD source are the best options for understanding the actual flow rates without the influence of the automatic dosing siphon(s). The measured flow of each raw AMD source from historic and recent data are summarized in Table 1 including averages, maximums, and minimums. No data were obtained for the raw AMD discharge or seeps that are captured within the PennDOT Limestone Pond. Prior to the system's construction and as part of the watershed assessment study, flow and water chemistry data were collected from 1998 to 2000 to characterize all identified AMD discharges. Some additional follow-up sampling events were conducted through the eFACTS program from 2009 to 2012 that characterized the quality of the raw AMD sources and the treatment systems effectiveness. This information revealed the following historic averages information for the primary AMD discharges with passive treatment systems (Table 1):

Table 1
Historic Average Flow and Water Quality of Target Cold Stream AMD Discharges (1998-2012)

AMD Discharge	Field pH	Lab Cond. (µS/cm)	Sulfate (mg/L)	T Fe (mg/L)	T Mn (mg/L)	T Al (mg/L)	Hot Acidity (mg/L)	Flow (gpm)
Mine Drift	2.10	1640	607	25.83	14.09	26.49	355	21.6
Stump and Stump Jr.	2.97	843	415	0.32	12.52	20.59	171	18.6
Chiller	2.32	1607	545	10.92	16.07	34.26	339	65
Fossil Rock	2.91	552	221	0.11	7.22	11.18	110	23
Shotgun	2.61	1940	748	29.64	10.67	39.23	438	8.3

The watershed assessment for Cold Stream determined that these five AMD sources were amendable to passive treatment. The new roughly two-mile stretch of Project 70 ditch was constructed in 1999 to replace the existing ditch that was breached in multiple locations and was not adequately capturing many of the AMD sources prior to entering Cold Stream above the reservoir. Other major sources such as the Blue Pipe discharge and the Artesian discharge were considered either too costly to address or not amendable to passive treatment technologies available at the time. The raw AMD source that enters the PennDOT-constructed limestone pond adjacent to the Shotgun system has minimal historic characterization data for water quality and flow rate. Combined, the five primary AMD discharges (untreated) annually contribute 3.3 tons of iron, 8.3 tons of aluminum, 4.0 tons of manganese, and 86 tons of acidity to Cold Stream.

The Blue Pipe discharge, Artesian discharge, seeps from the soccer field entering the reservoir, and some other miscellaneous sources identified during the field visits were sampled for water quality and flow rates measured wherever possible. These data will be provided in tables with the report and/or as an appendix to this report. It is apparent by the flow rates and water quality that it will be difficult to fully restore Cold Stream without some level of remediating these additional AMD sources in the lower portion of the watershed.

Existing System Characterization

As previously indicated, the eFACTS program was helpful in providing characterization data of the treatment systems from 2009 through 2012. These sampling events were conducted several years after the systems were constructed with essentially no maintenance performed at the sites. These data were helpful in determining the effectiveness of the systems during that time period and how the treatment has trended from construction until present day. Each AMD source was managed independently by constructing a passive treatment system at the source. The final outfall of the Mine Drift and Stump/Stump Jr. treatment systems combine and enter the first settling pond in the Chiller treatment system. The final outfall of the Shotgun system combines with the outfall of the PennDOT limestone pond within the limestone channel (OLC) leading to the constructed mitigative wetland.

Mine Drift

The source of this discharge is believed to be a buried and abandoned drift mine entry. This AMD discharge is characterized as consistent with respect to flow rate and has historically been one of most contaminated discharges of the five primary AMD sources. The AMD is strongly net acidic with high dissolved iron, aluminum, and manganese concentrations. The passive treatment system was designed to treat the AMD discharge with a vertical flow wetland (VFW) for alkalinity generation followed by a large settling pond for detention of the treated water to capture the aluminum and iron precipitates. The VFW contains 380 tons of limestone in a 5-foot-deep layer overlain by a 6-inch layer of compost. Water is then directed into the settling pond for metals precipitation, settling, and retention. The water is then directed out of the settling pond and combined with the final outfall of the Stump/Stump Jr. system and enters the first settling pond of the Chiller treatment system. A single perforated pipe near the bottom of the limestone layer in the VFW serves as the normal outfall pathway connected to the automatic dosing siphon in a manhole adjacent to the pond. Because of this outfall structure, the water is discharged from the VFW intermittently. Based on the flow and water chemistry, it was calculated that the amount of limestone used in the VFW would produce enough alkalinity to raise the pH and precipitate the dissolved aluminum and iron from the AMD discharge. However, in evaluating the areal acidity loading approach for VFW design, based on the historic data for the raw AMD the Mine Drift VFW should be approximately 13,000 square feet (ft^2) in total area. The actual area of the existing VFW is only 3,250 ft^2, which is approximately ¼ of the size needed to treat the acidity loading of the Mine Drift AMD. The final settling basin provides the retention and capacity to receive the discharge from the VFW to settle and retain the aluminum and iron precipitates. An inline water level control structure was installed in the berm of the settling pond as the final outfall structure to control the water level and provide a means of draining the pond for any necessary maintenance.

The automatic dosing siphon was included to regularly remove aluminum and iron precipitates from the void spaces in the limestone layer of the VFW. The dosing siphon allows the VFW to fill to a specified elevation at which point water begins to discharge through it until a set lower water elevation is reached at which point the discharge stops and the cycle repeats. This rapid drawdown provides the velocity required to flush aluminum and iron precipitates from the void spaces in the limestone. The dosing siphon, located in a concrete manhole, is hydraulically connected to the VFW by a solid and perforated PVC pipe near the bottom of the limestone layer. The settling pond was constructed following the VFW for the purpose of metal precipitate removal using detention time and settling mechanisms. An inline water level control structure was installed in the berm of the settling pond to allow for adjustment of the water elevation for adequate retention in the settling pond in response to sediment and/or metals accumulation.

Stump/Stump Jr.

These two AMD sources were originally from one small seep zone hydraulically separated during the watershed assessment work in order to create two separate sources for the purpose of constructing a passive treatment system in the available area. The historically low flow seepage emanates from abandoned mine workings in the area just downslope of the Mine Drift AMD source. The AMD is net acidic with high dissolved aluminum and manganese concentrations. Separate limestone treatment ponds were constructed for these two AMD sources, which were historically low- to moderate-flow discharges with moderate dissolved aluminum concentrations. Alkalinity generation was to be accomplished through the use of the two limestone-containing ponds, one containing approximately a two-foot layer (Stump) and the second with an approximate three-foot layer. There are approximately 50 tons of limestone combined between the two small limestone ponds. The flow for the Stump seepage is directed through a culvert underneath the access road that outlets into the corresponding limestone pond. The flow for the Stump Jr. seepage enters the limestone pond along the embankment and directly within the limestone layer. Following the two alkalinity generation ponds (containing limestone), one settling pond was constructed to receive the two outfalls in order to settle out the metal precipitates, primarily aluminum, and to help prevent those precipitates from clogging the limestone void spaces and impacting treatment efficiency. Based on the flow rate, the estimated alkalinity generation rate of the quantity of limestone used for these two discharges was estimated to sufficiently neutralize the acidity and precipitate the aluminum. The single settling pond was designed for metal precipitate settling and retention prior to final discharge and combining with the Mine Drift treatment system outfall to the confluence with the first settling pond in the Chiller treatment system.

An automatic dosing siphon was included for each limestone pond to passively remove aluminum precipitates from the void spaces in the limestone layers. The automatic dosing siphons are located in concrete manholes and are hydraulically connected to the limestone pond by a solid and perforated PVC pipe. The dosing siphon contained within the manhole does also have an overflow pipe built into the structure that allows the water to outfall in case of dosing siphon or high flow problems. The settling pond was constructed following the two limestone ponds for the purpose of metal precipitate removal using detention time and settling mechanisms. An inline water level control structure was installed in the berm of the settling pond to allow for adjustment of the water elevation for adequate retention in the settling pond in response to sediment and/or metals accumulation and drain the pond for maintenance purposes.

Chiller

This AMD discharge seeps out of the abandoned Molson B seam deep mine as a large kill zone along the historic Project 70 ditch (old). The highest flow of the target AMD sources, the water quality of the Chiller seeps is strongly net acidic with high dissolved aluminum and manganese and moderate dissolved iron concentrations. The AMD seeps were captured in a modified collection ditch to ensure capturing all of the water in order to route it into the constructed passive treatment system. The water first enters a forebay to pretreat the AMD by removing any precipitated iron or debris that may clog the compost layer in the VFW. The forebay and VFW are separated by a rock berm, which also serves as the conduit for allowing the AMD to enter the VFW. The large VFW is comprised of an approximately 4-foot layer of limestone (2,700 tons) overlain by an approximate 1-foot layer of spent mushroom compost material. Based on the flow rate, estimated alkalinity generation rate, and a 20-year design life, the 2,700 tons of limestone used in the VFW were considered adequate for treatment of the typical Chiller seeps flow. However, in evaluating the areal acidity loading approach for VFW design, based on the historic data for the raw AMD the Chiller VFW should be approximately 37,000 ft^2 in total area. The actual area of the existing VFW is only 20,000 ft^2, which is approximately ½ of the size needed to treat the acidity loading of the Chiller AMD. An automatic dosing siphon housed within a manhole to serve as the primary outfall structure and to aid in the removal of the aluminum and iron precipitates from the void spaces in the limestone layer through flushing/ operating events. The outfall of the dosing siphon from the VFW discharges into a settling pond (Settling Pond #1), which also receives the combined outfalls of the Mine Drift and Stump/ Stump Jr. treatment systems. This and the following Settling Pond #2 provide for combination of the AMD discharges after the limestone treatment and for metal precipitate settling and retention. Settling Pond #1 uses an inlet structure to allow control of the water level in the pond in response to accumulated sludge and draining of the pond for maintenance. Settling Pond #2 uses a principal spillway to discharge the water into two polishing wetlands operated in series before the final discharge that flows downslope to the Project 70 ditch. Wetland 1 uses a principal spillway as well, while Wetland 2 uses an inlet structure to allow for control of the water level in the pond in response to accumulated sludge accumulation and draining of the pond for maintenance.

The automatic dosing siphon was included to regularly remove aluminum and iron precipitates from the void spaces in the limestone layer of the VFW. The dosing siphon allows the VFW to fill to a specified elevation at which point water begins to discharge through it until a set lower water elevation is reached at which point the discharge stops and the cycle repeats. This rapid drawdown provides the velocity required to flush aluminum and iron precipitates from the void spaces in the limestone. The dosing siphon, located in a concrete manhole, is hydraulically connected to the VFW by a solid and perforated PVC pipe near the bottom of the limestone layer.

Fossil Rock

This AMD source originally entered the old Project 70 diversion ditch approximately 1,000 feet downstream of the Chiller seeps near the Turtle Spring stream. A limestone treatment pond was constructed for this AMD source, which was historically a low flow net acidic discharge with moderate dissolved aluminum concentrations. Alkalinity generation was to be accomplished through the use of a 75-ton limestone-containing pond in an approximately 2-foot layer. The flow for the Fossil Rock seepage enters the limestone pond along the embankment and directly within the limestone layer. Following the alkalinity generation ponds (containing limestone), one small settling pond was constructed to receive the outfall in order to settle out the metal precipitates, primarily aluminum, and to help prevent those precipitates from clogging the limestone void spaces and impacting treatment efficiency. Based on the flow rate and the estimated alkalinity generation rate, the quantity of limestone used for this AMD discharge was estimated to sufficiently neutralize the acidity and precipitate the aluminum. The single settling pond was designed for metal precipitate settling and retention prior to final discharge and combining with the Turtle Spring stream and eventually into the Project 70 ditch.

An automatic dosing siphon was included for the limestone pond to passively remove aluminum precipitates from the void spaces in the limestone layers. The automatic dosing siphon is located in a concrete manhole hydraulically connected to the limestone pond by a solid and two perforated PVC pipes (located on the bottom of the limestone layer). The dosing siphon contained within the manhole does have an overflow pipe built into the structure that allows the water to outfall in case of dosing siphon or high flow problems. The settling pond was constructed following the limestone ponds for the purpose of metal precipitate removal using detention time and settling mechanisms. A rock-lined principal spillway was installed in the berm of the settling pond to allow for establishing the water elevation for adequate retention in the settling pond.

Shotgun Bioreactor/PennDOT Limestone Pond andWetland

The source of this discharge is believed to be an unreclaimed surface mine and partially daylighted deep mine. This AMD discharge is characterized as having low flow rate and has historically been the most contaminated discharge of the five primary AMD sources. The AMD is strongly net acidic with high dissolved iron, aluminum, and manganese concentrations. The passive treatment system was designed to treat the AMD discharge with a modified vertical flow type pipe similar to what is historically been referred to as a sulfate-reducing bioreactor (SRB) for alkalinity generation followed by a settling pond/wetland for detention of the treated water to capture the aluminum and iron precipitates. However, in evaluating the areal acidity loading approach for typical VFW design, based on the historic data for the raw AMD the Shotgun VFW should be approximately 6,100 ft^2 in total area. The actual area of the existing VFW is roughly 7,000 ft^2, which is adequately sized to treat the acidity loading of the Shotgun AMD. The SRB contains a mixture of materials typical of an SRB type treatment pond, including 200 tons of crushed limestone, 40 tons of manure, 200 tons of woodchips, and 40 tons of sawdust. This material mixture was placed into a 2- to 4-foot-deep layer over a 2-foot limestone envelope layer (40 tons of limestone) around an underdrain system connected to an inline structure in the downstream berm between the SRB and settling pond/wetland. The inline structure serves as the normal outfall structure but also allows for the manual flushing of the SRB as needed or to drain the pond for maintenance. Water is then directed into the settling pond/wetland for metals precipitation, settling, and retention. The water is then directed out of the settling pond and combined with the outfall of the PennDOT Limestone Pond in a limestone channel that leads to a PennDOT mitigation wetland for polishing and treatment prior to entering the Project 70 ditch.

A single perforated pipe within the limestone layer in the bottom of the SRB serves as the normal outfall pathway connected to the inline structure constructed in the berm between the SRB and settling pond/wetland. Based on the flow and water chemistry, it was calculated that the SRB would produce enough alkalinity with the limestone material and bicarbonate formed from the sulfate reduction process to raise the pH and precipitate the dissolved aluminum and iron from the AMD discharge. The inline structure in the SRB was included to allow for periodic flushing to remove aluminum and iron precipitates from the void spaces in the limestone layer around the underdrain and within the SRB materials. The inline structure is hydraulically connected to the SRB by a solid and perforated PVC pipe near the bottom of the SRB in a limestone layer. The settling pond was constructed following the VFW for the purpose of metal precipitate removal using detention time and settling mechanisms. The settling pond/wetland provides the retention and capacity to receive the discharge from the SRB to settle and retain the aluminum and iron precipitates. An inline water level control structure was installed in the berm of the settling pond as the final outfall structure, to allow for adjustment of the water elevation for adequate retention in the settling pond in response to sediment and/or metals accumulation, and provide a means of draining the pond for any necessary maintenance.

An AMD source adjacent to the Shotgun Seep site was determined to be a reasonable and consistent hydrologic source for constructing a mitigative wetland by PennDOT. However, the water required some level of alkalinity treatment combined with the treated outfall of the Shotgun system to provide for the establishment and maintaining a large wetland between the site and the Project 70 ditch. A limestone treatment pond was constructed for this additional AMD source, which was historically a reasonable flow net acidic discharge with moderate dissolved aluminum concentrations. Alkalinity generation was to be accomplished through the use of a 350-ton limestone-containing pond in an approximately 2- to 3-foot layer constructed within the old diversion ditch. Flow from the old diversion ditch was diverted to the Project 70 ditch by constructing a new segment of limestone channel immediately upstream of the limestone pond. AMD seepage enters the limestone pond along the upslope embankment and directly within the limestone layer. Following the alkalinity generation pond (containing limestone), the water is discharged from an automatic dosing siphon into a limestone channel and combined with the final outfall of the Shotgun system and directed to the large wetland area for polishing treatment. Based on the flow rate, estimated alkalinity generation rate the quantity of limestone used for this AMD discharge was estimated to sufficiently neutralize the acidity and precipitate the aluminum.

An automatic dosing siphon was included for the limestone pond to passively remove aluminum precipitates from the void spaces in the limestone layer. The automatic dosing siphon is located in a concrete manhole hydraulically connected to the limestone pond by a solid and perforated PVC pipe (located on the bottom of the limestone layer). The dosing siphon contained within the manhole does have an overflow pipe built into the structure that allows the water to outfall in case of dosing siphon or high flow problems.

Summary of Site Visit Sampling and Investigation

Table 2
Mine Drift System VFW Outfall Snapshot Sampling – January 14, 2014, Data vs. Historic Data (2009 – 2012)

Date	pH	Acidity (mg/L)	Alkalinity (mg/L)	Total Fe (mg/L)	Total Al (mg/L)	Total Mn (mg/L)	Sulfate (mg/L)
10/23/09	2.35	291	0	14.1	32.8	16.6	836
3/24/10	2.20	188	0	5.67	21.1	9.53	453
5/17/12	2.82	107	0	3.71	10.05	8.32	433
1/14/14	5.49	149	7	9.96	15.44	14.56	677

The final outfall data from the historic and recent sampling events indicate that the water quality and effectiveness of the treatment system is not performing as anticipated and is removing similar amounts of contaminants previously observed from the historic averages data. Flow rates are difficult to correlate to the system issues since the automatic dosing siphon controls the flow rate from the VFW and ultimately the final outfall. The operating cycle of the dosing siphon creates varying flow rates and ultimately varying water quality from the system components. The variability of the operation cycle of a dosing siphon prevents the ability to adequately assess the retention time in the VFW using dye tests. Further evaluation of the different treatment system components was necessary to determine the problem areas that could be improved or modified to enhance the overall treatment system effectiveness under all flow conditions.

Table 3
Stump/Stump Jr. System Outfall Snapshot Sampling – January 15 and April 28, 2014, Data vs. Historic Data (2010)

Date	pH	Acidity (mg/L)	Alkalinity (mg/L)	Total Fe (mg/L)	Total Al (mg/L)	Total Mn (mg/L)	Sulfate (mg/L)
Historic Averages	3.01	154	0	0.23	18.2	9.41	385
1/15/14	4.96	142	3	0.16	15.92	9.54	348
*4/28/14	4.31	123	6	0.27	16.11	9.72	403

*Data collected on 4/28/14 were from the final outfall of the settling pond, not the Stump limestone pond.

Because of the difficulty in sampling the final outfall from the settling pond that receives both limestone pond outfalls in the Stump and Stump Jr. system, the final outfall was not sampled during both of the snapshot events from 2009 to 2010. The 2010 and January 2014 sampling events did characterize the automatic dosing siphon outfall from the Stump limestone pond (see Table 3). Flow rates are difficult to correlate to the system issues since the automatic dosing siphon controls the flow rate from the limestone ponds and ultimately the final outfall, which are not indicative of the actual AMD flows. The operating cycle of the dosing siphon creates varying flow rates and ultimately varying water quality from the system components. The variability of the operation cycle of a dosing siphon prevents the ability to adequately assess the retention time in the limestone ponds using dye tests. However, the data from the historic and recent sampling events indicate that the water quality and effectiveness of the treatment system is not performing as anticipated and is removing similar amounts of contaminants previously observed from the historic averages data. The Stump limestone pond automatic dosing siphon was observed discharging, while the Stump Jr. limestone pond automatic dosing siphon was not observed discharging during the sampling events in 2014. Table 4 compares data from 2009-2010 (averages) with sampling data on January 14, 2014, for the combined Mine Drift and Stump/Stump Jr. systems outfall at the discharge into the Chiller System Settling Pond #1. The data indicate improved treatment during the observed low flow conditions in January 2014 but still far short of the treatment objectives for these two systems and their subsequent impacts on the Chiller AMD system without further alkalinity addition.

Table 4
Mine Drift and Stump/Stump Jr. Systems Combined Outfall Snapshot Sampling – January 15, 2014, Data vs. Historic Data (2009-2010)

Date	Flow (gpm)	pH	Acidity (mg/L)	Alkalinity (mg/L)	Total Fe (mg/L)	Total Al (mg/L)	Total Mn (mg/L)	Sulfate (mg/L)
Historic Averages	60	2.48	184	0	2.73	20.35	10.61	476
1/15/14	17	4.70	124	6	0.12	15.33	9.74	353

Table 5
Chiller System VFW Outfall Snapshot Sampling – January 14 and April 28, 2014, Data vs. Historic Data (2009 – 2010)

Date	pH	Acidity (mg/L)	Alkalinity (mg/L)	Total Fe (mg/L)	Total Al (mg/L)	Total Mn (mg/L)	Sulfate (mg/L)
Historic Averages	2.14	314	0	5.94	33.5	13.8	483
1/14/14	4.28	302	0	4.37	34.35	12.6	623
4/28/14	2.81	Field measurements only, no sample for lab analysis					

The VFW outfall data (Table 5) from the historic and recent sampling events indicate that the water quality and effectiveness of the Chiller treatment system is not performing as anticipated and is removing similar amounts of contaminants previously observed from the historic averages data (2009-2010). Flow rates are difficult to correlate to the system issues since the automatic dosing siphon controls the flow rate from the VFW and ultimately the final outfall. The operating cycle of the dosing siphon creates varying flow rates and ultimately varying water quality from the system components. The variability of the operation cycle of a dosing siphon prevents the ability to adequately assess the retention time in the VFW using dye tests. Further evaluation of the different treatment system components was necessary to determine the problem areas that could be improved or modified to enhance the overall treatment system effectiveness under all flow conditions.

Table 6
Mine Drift, Stump/Stump Jr., and Chiller Systems Combined Outfall Snapshot Sampling – January 15 and April 28, 2014, Data vs. Historic Data (2009-2012)

Date	Flow (gpm)	pH	Acidity (mg/L)	Alkalinity (mg/L)	Total Fe (mg/L)	Total Al (mg/L)	Total Mn (mg/L)	Sulfate (mg/L)
Historic Averages	90	2.70	225	0	3.78	24.39	10.72	444
1/15/14	45	4.62	248	0	3.20	26.41	12.12	565
4/28/14	80	2.85	222	0	5.30	23.09	9.80	516

The limited effectiveness of the four combined systems has shown that the final outfall as summarized in Table 6 is typically not meeting the remediation goals of the system(s). Each discharge has its own alkalinity-producing pond, a VFW, or limestone pond, and with their limited effectiveness in neutralizing the acidity the combining of the sources leads to net acidic water with no additional alkalinity added throughout the remainder of the Chiller system. The lack of any significant maintenance to these systems since their construction has taken its toll on the treatment ponds and has resulted in their inability to adequately treat the AMD sources. Additionally, the use of automatic dosing siphons appears to also be limiting the effectiveness of the limestone containing ponds due to operational issues or the lack of other available technology to allow for automatic flushing when the systems were constructed. Dye testing of the limestone containing ponds was not performed due to the impact of the dosing siphons on the detention time in each pond that would not allow for an accurate characterization of the detention time and the potential for short-circuiting from accumulated materials in the ponds. The following tables (Tables 7 through 11) summarize the data collected for each of the Mine Drift, Stump/Stump Jr., and Chiller treatment system components realizing that the final outfalls of the Mine Drift and Stump/Stump Jr. systems combine with the Chiller AMD water in the first settling, which is the water characterized by the Settling Pond #1 outfall. The quantity of water entering Settling Pond #1 in the Chiller system from the combined Mine Drift and Stump/Stump Jr. systems could be measured and the proportion of this water to the total flow from the Chiller system final outfall can be determined.

Table 7
Mine Drift System AMD Source and Treatment Snapshot Sampling – January 14 and April 28, 2014

Parameter	Raw AMD	VFW Outfall	Final Outfall 1-14-14	Final Outfall 4-28-14
Flow (gpm)	5	9*	N.M.	5-10
Field pH	2.99	5.49	5.52	2.86
Field Cond. (µS/cm)	2270	1510	109	1125
Hot Acidity (mg/L)	466	149	144	191
Alkalinity (mg/L)	0	7	0	0
Dissolved/Total Fe (mg/L)	24.66/25.56	6.08/9.96	2.70/6.90	5.41/5.78
Dissolved/Total Al (mg/L)	29.58/30.20	13.51/15.44	13.72/13.85	17.84/18.87
Dissolved/Total Mn (mg/L)	12.41/12.56	13.75/14.56	12.49/12.23	9.91/9.67
Dissolved Ca (mg/L)	43.13	146,0	112.99	57.6
Sulfate (mg/L)	717	677	579	794
Total Inorganic Carbon (mg/L)	1.5	5.3	N.M.	N.M.

*Note: Flow from the VFW was measured during a flush event from the automatic dosing siphon, which is not indicative of the actual AMD source flow rate. The raw AMD source flowing into the VFW was measured to more accurately characterize the AMD flow.

Based on the data provided in Table 7, the effectiveness of the Mine Drift VFW is not working as expected since it is removing approximately 50% of the hot acidity and metals from the AMD source. The VFW does appear to be generating alkalinity since the January 2014 sampling event indicated an increase in dissolved calcium and carbon dioxide levels (TIC) from the raw AMD (TIC=1.5 mg/L) to the VFW outfall (TIC=5.3 mg/L). However, the VFW is not generating enough alkalinity to neutralize all of the acidity resulting in variable change in pH and removal of aluminum from the AMD. The dissolution of limestone should create dissolved calcium and carbon dioxide (TIC) and the slight increase in concentration in the outfall of the VFW indicates there is some limestone dissolution taking place. Significant debris accumulation such as leaves and sediment coat the surface of the compost layer in the VFW that promotes short-circuiting through the compost and limestone materials. However, due to the operation of the dosing siphon outfall for the VFW, it was sampled to determine the level of water quality improvements, which does not offer a consistent quality outfall based on the flushing pattern. Based on observations during the site 2014 visits, when the dosing siphon operated for a short duration the water level in the VFW did not visibly lower, which is supposed to happen based on the desired drawdown elevation for the specific pond. This indicates that the dosing siphon unit is not functioning properly and/or the materials within the VFW including pipes are clogged or plugged. The final outfall of the treatment system from the settling pond is difficult to access to sample and measure flow rate from the inline structure within the berm. Additionally, the outfall pipe from the inline structure of the settling pond does not surface until after it combines with the Stump/Stump Jr. system outfall where they enter the Chiller system Settling Pond #1.

An additional seepage was observed in the area between the Mine Drift VFW and settling pond emanating from the toe of the VFW berm and entering the settling pond. Water quality data were not collected for this seepage, but it did saturate the access road making it difficult to drive through this area. Further characterization/investigation of this seepage including a remediation plan is needed.

Table 8
Stump/Stump Jr. System AMD Source and Treatment Snapshot Sampling – January 15 and April 28, 2014

Parameter	Raw AMD (Stump)	LS Pond Outfall (Stump)	Final Outfall 1-15-14	Final Outfall 4-28-14
Flow (gpm)	10	30*	N.M.	5
Field pH	4.57	4.96	5.39	4.31
Field Cond. (µS/cm)	888	896	850	721
Hot Acidity (mg/L)	155	142	113	123
Alkalinity (mg/L)	0	3	0	6
Dissolved/Total Fe (mg/L)	0.24/0.19	0.14/0.16	0.90/1.12	0.13/0.27
Dissolved/Total Al (mg/L)	17.21/17.43	15.3/15.92	14.19/14.85	15.85/16.11
Dissolved/Total Mn (mg/L)	9.9/10.1	9.24/9.54	10.55/10.41	9.27/9.72
Dissolved Ca (mg/L)	34.11	37.15	69.16	42.55
Sulfate (mg/L)	360	348	433	403

Parameter	Raw AMD (Stump)	LS Pond Outfall (Stump)	Final Outfall 1-15-14	Final Outfall 4-28-14
Total Inorganic Carbon (mg/L)	1.3	1.3	N.M.	N.M.

*Note: Flow from the Stump LS Pond was measured during a flush event from the automatic dosing siphon, which is not indicative of the actual AMD source flow rate. The raw AMD source flowing into the LS Pond was measured to more accurately characterize the AMD flow.

Based on the data provided in Table 8, the effectiveness of the Stump and Stump Jr. system is limited since it is removing only small amounts of the hot acidity and metals specifically aluminum from the AMD source(s). The Stump Jr. system is very difficult to assess due to the nature of the source entering the limestone pond and the lack of outfall from the associated dosing siphon during the multiple site visits. The Stump limestone pond does not appear to be generating alkalinity/dissolved limestone since the January 2014 sampling event indicated minimal increase in dissolved calcium and no increase in carbon dioxide levels from the raw AMD (TIC=1.3 mg/L) to the limestone pond outfall (TIC=1.3 mg/L). However, during the January 2014 sampling event, the final outfall water from the settling pond contained a significantly higher level of dissolved calcium, which may be coming from the Stump Jr. system. Alternatively, the time of sampling for the Stump limestone pond dosing siphon outfall may have been during the end of the flush when the lowest dissolved calcium water is expected. The Stump limestone pond is not generating nearly enough alkalinity to neutralize most of the acidity resulting in minimal change in pH and low removal of aluminum from the AMD. The dissolution of limestone should create dissolved carbon dioxide and the same concentration in the raw AMD versus the outfall of the limestone pond indicates there is minimal dissolution taking place.

There was minimal debris accumulation on the surface of the limestone layer in the Stump and Stump Jr. limestone ponds, and water was not observed over the top of the limestone. However, some vegetation was observed growing in the limestone bed of the Stump system that may promote short-circuiting or plugging within the limestone due to sediment accumulation. Both limestone ponds were originally constructed with a PVC standpipe to allow for observation of the water level in the limestone layer. The standpipe in the Stump limestone pond was broken off (part within the limestone material was not observed), and the standpipe in the Stump Jr. limestone pond was still in place. The water level in the standpipe of the Stump Jr. limestone pond was estimated to be approximately one foot below the top of limestone. Operation of the Stump Jr. limestone pond dosing siphon was not observed during any of the site visits and was not sampled. The Stump limestone pond dosing siphon was observed discharging during the January 2014 site visit and was subsequently sampled to assess the quality of the discharged water into the settling pond. The final outfall of the system from the settling pond is difficult to access for sampling and measuring flow rate from the inline structure within the berm.

Table 9
Chiller System AMD Source and Treatment Snapshot Sampling – January 15 and April 28, 2014

Parameter	Raw AMD	VFW Outfall	Final Outfall 1-15-14	Final Outfall 4-28-14
Flow (gpm)	14	225*	45	80
Field pH	3.85	4.28	4.62	2.85
Field Cond. (µS/cm)	1970	1690	1430	1150
Hot Acidity (mg/L)	368	302	248	222
Alkalinity (mg/L)	0	0	0	0
Dissolved/Total Fe (mg/L)	7.0/7.38	4.12/4.37	3.0/3.2	4.9/5.3
Dissolved/Total Al (mg/L)	31.56/33.99	31.08/34.35	25.25/26.41	21.80/23.09
Dissolved/Total Mn (mg/L)	13.07/13.61	12.19/12.60	11.50/12.12	9.03/9.80
Dissolved Ca (mg/L)	40.08	57.88	58.58	49.62
Sulfate (mg/L)	652	623	565	516
Total Inorganic Carbon (mg/L)	N.D.	4.4	N.M.	N.M.

*Note: Flow from the VFW was measured during a flush event from the automatic dosing siphon, which is not indicative of the actual AMD source flow rate. The raw AMD source flowing into the forebay/VFW was measured to more accurately characterize the AMD flow.

Based on the data provided in Table 9, the effectiveness of the Chiller VFW is not working as consistently as expected since it is removing approximately 20% of the hot acidity and variable amounts of metals from the AMD source. The VFW does appear to be generating alkalinity since the January 2014 sampling event indicated a 45% increase in dissolved calcium and an increase in carbon dioxide (TIC) levels from the raw AMD (TIC=<1.0 mg/L) to the VFW outfall (TIC=4.4 mg/L). However, the VFW is not generating nearly enough alkalinity to neutralize all of the acidity resulting in variable change in pH and removal of dissolved metals from the AMD. Less than 50% of the acidity, iron, aluminum, and manganese are removed by the VFW, while the final outfall incorporates the net acidic final outfall of the Stump/Stump Jr. and Mine Drift systems and is not completely indicative of the system effectiveness on the Chiller AMD source. The only viable assessment of the Chiller system is able to be determined for the effectiveness from the VFW outfall since the subsequent Settling Pond #1 receives both the VFW outfall and final outfalls of the Stump/Stump Jr. and Mine Drift systems.

The dissolution of limestone should create dissolved calcium and carbon dioxide, and the moderate increase in concentrations in the outfall of the VFW indicates that there is some dissolution taking place. Significant debris accumulation such as leaves and sediment coat the surface of the compost layer in the VFW that promotes short-circuiting through the compost and limestone materials. However, due to the operation of the dosing siphon for the VFW outfall, it was sampled to determine the level of water quality improvements, which does not offer a consistent quality outfall based on the flushing pattern. Based on observations during the site visit, when the dosing siphon operated for a very short duration (approximately five minutes), the water level in the VFW did not visibly lower, which is supposed to happen based on the desired drawdown elevation for the specific pond. This indicates that the dosing siphon unit is not functioning properly and/or the materials within the VFW including pipes are clogged or plugged. The final outfall of the system from the polishing wetland (Wetland Cell #2) was accessed to sample and measure flow rate from the inline structure within the berm. This final outfall is a combination of water from the Chiller system, Mine Drift system, and Stump/Stump Jr. system that eventually enters the Project 70 ditch.

Table 10
Fossil Rock System AMD Source and Treatment Snapshot Sampling – January 15 and April 28, 2014

Parameter	Raw AMD (Historic Avgs)	LS Pond Outfall	Final Outfall 1-15-14	Final Outfall 4-28-14
Flow (gpm)	23	No Visible Flow Observed During January & April Site Visits	2.5	No Visible Flow Observed During April Site Visit
Field pH	2.91		4.57	
Field Cond. (µS/cm)	N.M.		1030	
Hot Acidity (mg/L)	110		57	
Alkalinity (mg/L)	1.3		14	
Dissolved/Total Fe (mg/L)	N.M./0.11		<0.05/<0.05	
Dissolved/Total Al (mg/L)	N.M./11.18		4.8/5.13	
Dissolved/Total Mn (mg/L)	N.M./7.22		4.35/4.61	
Dissolved Ca (mg/L)	N.M.		19.87	
Sulfate (mg/L)	221		169	
Total Inorganic Carbon (mg/L)	N.M.		N.M.	

Notes: Flow from the Fossil Rock AMD source(s) was not observed on the surface entering the limestone pond during either site visit. The Fossil Rock LS Pond was not observed discharging water from the automatic dosing siphon during either of the site visits, despite some flow out of the final outfall consisting of a rock-lined spillway from the subsequent settling pond. No flow was observed from any component of the treatment system in April 2014.

Based on the limited new data provided in Table 10, the effectiveness of the Fossil Rock system is limited since it appears to be removing some of the hot acidity and aluminum estimated from the historic averages for the raw AMD source(s). The Fossil Rock system is very difficult to assess due to the nature of the source entering the limestone pond and the lack of outfall from the associated dosing siphon during the multiple site visits. The Fossil Rock limestone pond does appear to be generating alkalinity/dissolved limestone comparing the January 2014 data for the final system outfall with the raw AMD historic averages. Comparing these data indicates a minimal increase in dissolved calcium and alkalinity and moderate decrease in hot acidity and aluminum from the raw AMD historic averages. The Fossil Rock limestone pond is not generating enough alkalinity to neutralize the acidity resulting in a moderate change in pH and partial removal of aluminum from the AMD. There was minimal debris accumulation on the surface of the limestone layer in the Fossil Rock limestone pond, and water was not observed over top of the limestone. However, some vegetation was observed growing in the limestone bed of the Fossil Rock system that may promote short-circuiting or plugging within the limestone. Operation of the limestone pond dosing siphon was not observed during any of the site visits and could thus not be sampled. The final outfall of the system from the settling pond is difficult to sample and measure flow rate from the principal rock-lined spillway and channel that leads to the Turtle Spring stream channel. The Turtle Spring water quality was measured upstream of the Fossil Rock outfall confluence and the data indicate that the water is minimally impacted by the historic mining activities (AMD) in the area.

Table 11
Shotgun Bioreactor and PennDOT Limestone Pond System AMD Source and Treatment Snapshot Sampling – January 15 and April 28, 2014

Parameter	Raw AMD (Shotgun) 4-28-14	LS Pond Outfall (PennDOT) 1-15-14	Upstream End OLC 1-15-14	Downstream End OLC 4-28-14
Flow (gpm)	<1	4.0	4.0	N.M.
Field pH	2.41	3.73	4.00	2.59
Field Cond. (µS/cm)	959	2220	2200	1723
Hot Acidity (mg/L)	431	511	474	374
Alkalinity (mg/L)	<1	<1	<1	<1
Dissolved/Total Fe (mg/L)	19.17/24.54	23.66/24.87	21.51/22.59	18.70/19.97
Dissolved/Total Al (mg/L)	37.37/39.58	49.75/50.74	47.14/50.44	35.55/38.14
Dissolved/Total Mn (mg/L)	8.00/8.21	10.38/10.93	11.0/11.63	8.65/8.95
Dissolved Ca (mg/L)	45.99	68.76	74.36	59.54
Sulfate (mg/L)	809	905	973	777
Total Inorganic Carbon (mg/L)	N.D.	1.7	N.M.	N.M.

Notes: No flow was observed from any of the Shotgun AMD sources or treatment ponds during the 1/15/14 sampling event. Flow from the PennDOT LS Pond was only observed flowing over the emergency spillway. The final outfall pipes from the Shotgun system polishing wetland and PennDOT LS Pond dosing siphon could not be located during the two sampling events due to ATV damage in the area. No flow was observed from any component of the treatment system in April 2014.

Based on the limited new data provided in Table 11, the effectiveness of the Shotgun and PennDOT Limestone Pond combined system is limited since the combined water quality in the OLC routing the water to the large wetland shows that the water is still very contaminated. The Shotgun system appears to be removing some of the hot acidity and aluminum estimated from the historic averages for the raw AMD source(s). The Shotgun system was difficult to assess the operation since there was no visible flow into the bioreactor, from the bioreactor, or from the polishing wetland during the January 2014 sampling event. During the April 2014 sampling event, a very small amount of raw AMD flow was sampled entering the bioreactor, which had a significant amount of silt and sediment accumulated on the surface from runoff in the area immediately upstream of the pond caused by ATVs. The disturbance from the ATVs appears to have impacted the raw AMD source(s) entering the bioreactor and the off-site stormwater diversion channel just upslope of the pond. Since no outfall was observed from the bioreactor during the two sampling events and the final outfall pipe from the settling pond/polishing wetland was not found, the effectiveness of the system is still in question. ATV damage has impacted the area around the final outfall pipe coming from an inline structure in the berm of the wetland, which has resulted in covering of the pipe and the pipe or any source of water from the system could not be found during the two sampling events. Both the bioreactor and polishing wetland had water in them during the January 2014 sampling event, but both were frozen and not observed discharging water.

The raw AMD source that enters the PennDOT limestone pond is unable to be reasonably accessed and sampled. Significant debris accumulation including leaves on the surface of the limestone layer in the pond has resulted in the AMD not flowing vertically down through the limestone and the water was observed during both sampling events flowing across the surface of the pond and out of the emergency spillway over the access road and into the OLC. The outfall pipe from the automatic dosing siphon for the limestone pond could not be found due to the disturbance caused by the ATVs along the access road that runs between the pond and the polishing wetland for the Shotgun system. Operation of the limestone pond dosing siphon was not observed during any of the site visits and was not sampled. Therefore, the water discharging from the limestone pond emergency spillway was sampled during the January 2014 sampling event and appeared to have minimal limestone treatment based on the high levels of acidity, dissolved iron, and dissolved aluminum in the outfall. In order to assess quality of water conveyed in the OLC to the large constructed PennDOT mitigation wetland, samples were collected during both the January and April 2014 sampling events. During the January 2014 sampling event, the water was sampled near the upstream end of the OLC and the quality and flow was very similar to the outfall of the limestone pond from the emergency spillway with some possible dilution caused by the simultaneous snow melt. During the April 2014 sampling event, the water was sampled further downstream in the OLC and the quality indicated that the water was nearly as contaminated as it was from the January 2014 sampling event with high dissolved aluminum and iron concentrations and high hot acidity levels. Therefore, the combined water conveyed from the Shotgun system and PennDOT limestone pond is minimally treated and is severely contaminated AMD that will receive minimal additional treatment from the wetland before entering the Project 70 ditch.

Table 12
Known and Previously Unknown AMD Sources (Not Receiving Treatment)
Characterization Sampling – January 15 and April 28, 2014

Parameter	Source Entering Project 70 Ditch (Iron Gate Discharge)	Soccer Field Seeps	Blue Pipe AMD Source	Artesian AMD Discharge
Flow (gpm)	60	2-3	52.5	N.M.
Field pH	3.86	6.90	3.85	N.M.
Field Cond. (μS/cm)	341	1370	2050	N.M.
Hot Acidity (mg/L)	49	73	412	421
Alkalinity (mg/L)	1	27	0	0

Parameter	Source Entering Project 70 Ditch (Iron Gate Discharge)	Soccer Field Seeps	Blue Pipe AMD Source	Artesian AMD Discharge
Dissolved/Total Fe (mg/L)	0.08/0.09	64.84/68.49	39.73/41.55	171.87/184.22
Dissolved/Total Al (mg/L)	4.28/4.41	<0.05/<0.05	23.01/23.45	14.14/14.58
Dissolved/Total Mn (mg/L)	3.08/3.12	2.59/2.70	3.84/3.94	6.19/6.43
Dissolved Ca (mg/L)	12.92	92.45	31.59	104.77
Sulfate (mg/L)	118	335	483	892
Total Inorganic Carbon (mg/L)	N.M.	N.M.	N.D.	2.0

Notes: Both the source entering the Project 70 ditch and soccer field AMD seeps are relatively new AMD sources. The soccer field AMD seeps directly enter the upstream wetland end of the Cold Stream reservoir. During the sampling effort for the Artesian discharge, a problem with the field water quality meter did not allow for the measurements to be collected.

The moderately high flow AMD source observed entering the Project 70 ditch during the April 2014 sampling event appears to be located along Dike Road due west of the Fossil Rock treatment system. This AMD source is believed to be the Iron Gate Discharge previously identified in the Cold Stream Watershed Assessment and is not severely contaminated. Based on the water quality and flow information, the Iron Gate AMD discharge is capable of passive treatment depending on further evaluation of the actual source of the water. The soccer field seeps surface within capture ditches along the low point and the northwestern end of the township soccer fields complex. From the ditches, these AMD seeps flow via culverts under an access road and enter a wetland area that appears to form the southeastern extent of the Cold Stream reservoir. These AMD seeps and the immediate downstream area of the reservoir were observed to cause considerable iron staining and additional seeps are suspected of surfacing in this area that could not be identified. The sampled AMD seeps from the soccer field indicate that the water contains high levels of dissolved iron and pH levels near neutral. These low flow and high dissolved ferrous iron seeps could likely be passively treated if a reasonable area was available for a small remediation system.

The Blue Pipe AMD discharge is a collection of multiple toe seeps just east of the Project 70 ditch that combine to form a channel that flows temporarily parallel to the ditch and then enters it near the Township recycling center along Dike Road. This AMD source is well-documented and, based on historical and new data, is severely contaminated with iron and aluminum and hot acidity. No treatment plan is in place for remediating this discharge that will be necessary to fully restore the lower half of Cold Stream. Finally, the Artesian AMD discharge originates on private property near the mouth of Cold Stream. It is a highly variable flow AMD source that has a large “kill-zone” most likely resulting from low pH iron oxidation particularly during high flows. This AMD source is severely contaminated with very high dissolved iron and moderate to high dissolved aluminum concentrations. This AMD discharge is imperative for restoration in order to restore Cold Stream from the mouth to the confluence which covers the lower few hundred feet of the stream and significantly impacts the Cold Stream and Red Moshannon Creek.

Table 13
Cold Stream Snapshot Sampling (PA DEP) – December 12, 2013

Parameter	Upstream of Reservoir & Project 70 Ditch	Downstream of Reservoir/Dam & Upstream of Project 70 Ditch	Downstream of Reservoir & Project 70 Ditch
Flow (gpm)	N.M.	N.M.	N.M.
Field pH	7.10	6.90	6.50
Field Cond. (µS/cm)	N.M.	N.M.	N.M.
Hot Acidity (mg/L)	-11.4	14.2	11.4
Alkalinity (mg/L)	10.4	9.0	6
Total Fe (mg/L)	<0.3	0.60	1.74
Total Al (mg/L)	<0.5	13.61	<0.5
Total Mn (mg/L)	<0.05	0.33	0.39
Sulfate (mg/L)	<20	26.9	39.8

Table 14
Cold Stream Snapshot Sampling – January 15, 2014

Parameter	Upstream of Reservoir & Project 70 Ditch	Downstream of Reservoir/Dam & Upstream of Project 70 Ditch	Downstream of Reservoir & Project 70 Ditch
Flow (gpm)	10,100	N.M.	8,740
Field pH	6.92	6.95	6.48
Field Cond. (µS/cm)	82	88	141
Hot Acidity (mg/L)	N/A	Not Sampled for Lab Analyses	18
Alkalinity (mg/L)	N/A		7
Dissolved/Total Fe (mg/L)	<0.05/0.07		0.84/1.56
Dissolved/Total Al (mg/L)	0.06/0.06		0.26/0.71
Dissolved/Total Mn (mg/L)	0.07/0.03		0.38/0.38
Sulfate (mg/L)	113*		33

*Sample result was impacted by sampling error, wet chemistry sample was accidentally acidified in the field (Hot Acidity and Alkalinity were not provided above).

The above data (Tables 13 and 14) for Cold Stream indicate that the stream is of very good quality upstream of the reservoir and AMD impacts targeted for this TAG project. A sampling error impacted the analytical results for the hot acidity, alkalinity, and sulfate analyses from the January 2014 event for the Cold Stream upstream location. PA DEP sampled the same locations one month before the January 2014 event (December 2013), and their results showed similar impacts to Cold Stream downstream of the reservoir and Project 70 ditch confluence. However, due to the declining performance of the five Cold Stream passive treatment systems and several untreated AMD sources combined within the Project 70 ditch, the stream becomes impacted from the poor water quality of the ditch. The 1.8-mile Project 70 ditch was constructed in 1999 as an improved means of capturing most of the AMD sources from the east side of Cold Stream replacing the previous Operation Scarlift ditch constructed in the 1970s. The purpose of the Project 70 ditch was to divert the AMD sources away from the segment of Cold Stream upstream of the reservoir. However, a few previously unidentified AMD seeps were observed entering Cold Stream either into the reservoir or just upstream of it. The water quality of the Project 70 ditch upstream of the known AMD sources (headwaters) and at the mouth of the ditch is summarized in Table 15.

Table 15
Project 70 Snapshot Sampling – January 15, 2014

Parameter	Upstream of AMD Systems Confluence (Headwaters)	Project 70 Ditch Mouth
Flow (gpm)	N.M.	430
Field pH	4.72	4.57
Field Cond. (µS/cm)	724	1030
Hot Acidity (mg/L)	99	144
Alkalinity (mg/L)	0	0
Dissolved/Total Fe (mg/L)	1.22/1.33	18.00/19.11
Dissolved/Total Al (mg/L)	7.93/8.43	9.04/9.42
Dissolved/Total Mn (mg/L)	8.85/9.24	4.95/5.24
Sulfate (mg/L)	213	267

The water quality and flow data for the mouth of the Project 70 ditch indicate that this water is a significant source of AMD contaminant loading to Cold Stream. Based on the snapshot conditions in January 2014, the Project 70 ditch is contributing the following contaminant loading to Cold Stream annually: 18 tons of iron, 4.9 tons of manganese, 8.9 tons of aluminum, and 135.7 tons of acidity. The water quality in general appears to become worse from the upstream extent of the ditch, just upstream of the confluence of the Chiller system outfall, to the mouth where the ditch enters Cold Stream only a few hundred feet downstream of the Cold Stream dam. The lack of effective treatment from the existing treatment systems combined with the Blue Pipe AMD discharge are the most likely primary contributors for this degradation of water quality in the Project 70 ditch. However, the relatively unimpacted Turtle Spring enters the Project 70 ditch in the area of the Shotgun/PennDOT limestone pond treatment system, which based on upstream characterization of this water is of reasonable quality. Table 16 summarizes the water quality of Turtle Spring stream, which was sampled adjacent to the Fossil Rock treatment system and again for only field water quality at the confluence with the Project 70 ditch.

Table 16
Turtle Spring Snapshot Sampling – January 15, 2014

Parameter	Adjacent to Fossil Rock System	Mouth (Confluence with Project 70 Ditch)
Flow (gpm)	90	N.M.
Field pH	6.25	5.93
Field Cond. (µS/cm)	392	510
Hot Acidity (mg/L)	26	Not Sampled for Lab Analyses
Alkalinity (mg/L)	6	
Dissolved/Total Fe (mg/L)	<0.05/<0.05	
Dissolved/Total Al (mg/L)	0.48/0.41	
Dissolved/Total Mn (mg/L)	0.33/0.29	
Sulfate (mg/L)	41	

Cold Stream downstream of the dam and Project 70 ditch confluence shows impacts including decreased pH and increased acidity and metal concentrations, which are detrimental to trying to establish aquatic life communities in the stream. While the construction of the Project 70 ditch and Glass City AMD Passsive Treatment Systems (headwaters of Cold Stream) significantly improved the water quality both in the reservoir and upstream in Cold Stream, the impacts that are still occurring from the confluence of the ditch to the mouth are preventing restoration of the stream. Moving even farther downstream to the mouth of Cold Stream where the impacts of the Artesian AMD discharge are observed most likely prevents any establishment of biological activity in the lower reaches of the stream and at the confluence with Red Moshannon Creek.

Table 17
Cold Stream and Project 70 Ditch Data Comparison – Historic Averages (1998-2000) vs. Recent Data (January 15, 2104)

Parameter	Project 70 Ditch Mouth (Historic Avgs)	Project 70 Ditch Mouth (Jan. 2014)	Cold Stream Downstream of Project 70 Ditch (Historic Avgs)	Cold Stream Downstream of Project 70 Ditch (Jan. 2014)
Flow (gpm)	2,744	430	28,798	8,740
Field pH	3.37*	4.57	4.80*	6.48
Field Cond. (µS/cm)	N.M.	1030	N.M.	141
Hot Acidity (mg/L)	141.5	144	16.6	18
Alkalinity (mg/L)	0.2	0	7.6	7
Total Fe (mg/L)	27.08	19.11	3.10	1.56
Total Al (mg/L)	10.41	9.42	1.12	0.71
Total Mn (mg/L)	7.29	5.24	1.08	0.38
Sulfate (mg/L)	259	267	53.6	33

Recommendations/Conclusions

The following recommended tasks are provided for each of the Cold Stream passive treatment systems to improve their treatment effectiveness and to improve the water quality within the Project 70 ditch and Cold Stream downstream of the confluence. Following the task descriptions are two tables (Tables 18 and 19) summarizing the estimated costs for each recommended improvement task.

- Mine Drift VFW System
  - Removal of accumulated debris on compost layer
  - Evaluate compost material and stir/replace/replenish as needed
  - Stir limestone bed/additional limestone as needed
  - Ensure that pipes are clear and provide additional piping network in bottom of limestone layer
  - Replace dosing siphon with inline structure and housing
  - Install floating baffle(s) in settling pond
  - Remove inline structure from settling pond and replace with inlet structure and provide walkway
  - Install French drain along access road between VFW and settling pond to route seeps into upstream end of settling pond
  - Install weir and high flow bypass structure at entry to VFW

- Stump/Stump Jr. Limestone Ponds System
  - Clean/stir limestone in both ponds
  - Enlarge both limestone ponds where possible and supplement limestone as needed in each pond
  - Replace dosing siphons with automatic inline structure with housing for Stump and inline structure with housing for Stump Jr.
  - Install floating baffle(s) in settling pond
  - Remove inline structure from settling pond and replace with inlet structure and provide walkway (perforate select stoplogs to manage water level between flush events)
  - Investigate Stump Jr. source and ensure entering limestone pond
  - Clean and stabilize ditch at upstream end of culvert that supplies AMD into Stump limestone pond

- Chiller Seeps VFW System
  - Clean out, rework, and stabilize capture channel and install high flow bypass structure
  - Determine need for cleaning out forebay and settling ponds (2)
  - Remove accumulated debris on compost layer in VFW
  - Evaluate compost material and stir/replace/replenish as needed

- Stir limestone bed/additional limestone as needed
  - Ensure that pipes are clear and provide additional piping network in bottom of limestone layer
  - Replace dosing siphon with inline structure and housing
  - Install floating baffles in Settling Pond #1 and Settling Pond #2
  - Install inlet structure with walkway in Settling Pond #2
  - Convert approximately ½ of Wetland Cell #1 into a 1,250-ton flushable limestone bed (FLB) with an automatic inline structure

- Fossil Rock Limestone Pond System

  - Clean/stir limestone material in first pond
  - Supplement limestone as needed
  - Replace dosing siphon with automatic inline structure with housing
  - Install floating baffle in settling pond
  - Evaluate and enlarge settling pond
  - Investigate AMD source and ensure entering limestone pond, enlarge pond where possible
  - Install perforated riser pipe, walkway, and outfall pipe to manage water level in settling pond between flush events
  - Clean, rework, and stabilize emergency spillway in settling pond

- Shotgun Bioreactor System

  - Regrade and stabilize areas around ponds from ATV damage including diversion channel upslope of bioreactor pond
  - Remove accumulated material from surface of bioreactor pond
  - Ensure flow of AMD source(s) into bioreactor pond and stabilize with riprap as needed (install pipe or weir if possible)
  - Investigate nature of bioreactor mixture and replace/replenish as needed
  - Check that piping network is clear from bioreactor to inline structure and to settling pond; replace inline structure with housing as needed if unable to remove stoplogs
  - Install floating baffle in settling pond/wetland
  - Remove inline structure from settling pond and replace with inlet structure and provide walkway, check that piping is clear (downstream pipe could not be found)

- PennDOT Limestone Pond and Wetland System

  - Remove accumulated debris and clean/stir limestone in pond
  - Supplement limestone as needed
  - Check operation of automatic dosing siphon, ensure that pipes to and from siphon are clear (downstream end of discharge pipe not found), replacement with automatic inline structure with housing is recommended

- Rework and stabilize emergency spillway and access road crossing to OLC
- Replenish limestone and ensure appropriate lining thickness in OLC

- Other Untreated AMD Sources

  - Soccer field seeps could be readily remediated in a small passive treatment system since the water appears to need aeration and settling mechanisms for removing most of the dissolved ferrous iron prior to entering the reservoir
  - Iron gate discharge is capable of passive treatment based on the low to moderate concentration of AMD constituents, primarily aluminum, which would involve construction of a FLB system
  - Develop remediation plans for the Blue Pipe and Artesian AMD sources

Table 18
Existing Passive Treatment Systems Recommended Improvements Cost Estimate

System Component	Recommended Task	Cost Estimate
MINE DRIFT		
VFW	Removal of surface debris	$1,500
	Stir compost and replenish/replace as needed	$10,000* (assumes additional 200 tons of compost & limestone fines needed)
	Stir/clean limestone and replenish as needed	$2,500
	Install high flow bypass structure and weir in inflow channel for monitoring AMD flow	$5,000
	Inspect piping network and replace dosing siphon with inline structure	$5,000
Settling Pond	Replace inline structure with inlet structure (include v-notch stop log for final outfall flow monitoring)	$3,500
	Install floating baffle(s)	$4,000
Misc.	Remediation plan for seep at toe of berm between VFW & settling pond on access road	$3,000
		SUBTOTAL = $34,500

STUMP/STUMP JR.		
Stump Limestone Pond	Evaluate and enlarge pond where possible	$7,000
	Stir/clean limestone and replenish as needed	$3,500* (assumes additional 50 tons of limestone)
	Replace dosing siphon with automatic inline structure	$11,000
	Clean and stabilize ditch an upstream end of culvert supplying AMD source	$1,000
Settling Pond	Replace inline structure with inlet structure (include v-notch stop log for final outfall flow monitoring)	$3,500
	Install floating baffle(s)	$2,500
Stump Jr. Limestone Pond	Investigate AMD source to ensure entering pond and enlarging pond where possible	$7,000
	Replace dosing siphon with automatic inline structure	$11,000
	Stir/clean limestone and replenish as needed	$3,500* (assumes additional 50 tons of limestone)
		SUBTOTAL = $50,000
CHILLER		
VFW & Forebay	Clean and rework AMD Capture Channel and install high flow bypass structure	$6,000
	Remove accumulated debris/ materials on compost layer	$7,500
	Stir, replenish, replace compost	$35,000* (assumes additional 500 tons of compost & limestone fines)
	Stir/clean limestone and replenish as needed	$25,000* (assumes additional 300 tons of limestone)
	Inspect piping network and replace dosing siphon with inline structure(s)	$10,000
Settling Ponds #1 & #2	Install floating baffle(s)	$5,000
	Install inlet structure with walkway in Settling Pond #2	$5,000
	Determine if settling ponds including forebay need cleaned out (sludge/sediment)	$1,500

Wetland Cell #1	Convert into 1,250-ton FLB with automatic inline structure	$80,000
		SUBTOTAL = $175,000
	FOSSIL ROCK	
Limestone Pond	Investigate AMD source to ensure entering pond and enlarging pond where possible	$7,500
	Stir/clean limestone and replenish as needed	$5,000* (assumes additional 80 tons of limestone)
	Replace dosing siphon with automatic inline structure	$12,000
Settling Pond	Investigate and enlarge pond if possible	$5,000
	Install floating baffle	$2,000
	Install perforated riser and outfall pipe with walkway	$2,500
	Clean/rework and stabilize emergency spillway to Turtle Spring	$2,500
		SUBTOTAL = $36,500
	SHOTGUN AND PENNDOT LIMESTONE POND	
SRB/Bioreactor	Remove accumulated material from surface	$2,500
	Ensure AMD source enters bioreactor, rework and stabilize with riprap including installation of a sump with pipe or weir to monitor flow	$2,500
	Investigate nature of bioreactor mixture and replenish/replace as needed	$25,000* (assumes 50% of the mixture must be replaced)
	Inspect piping network and replace inline structure as needed	$5,000
Settling Pond/Wetland	Install floating baffle(s)	$3,000
	Replace inline structure with inlet structure (include v-notch stop log for final outfall flow monitoring) and inspect downstream pipe	$5,000

PennDOT Limestone Pond	Remove accumulated debris from surface of limestone	$2,500
	Stir/clean limestone and replenish as needed	$5,000* (assumes additional 60 tons of limestone)
	Replace dosing siphon with automatic inline structure	$12,000
	Clean/rework and stabilize emergency spillway thru access road to OLC	$5,000
Misc.	Perform excavation around ponds to improve areas damaged by ATVs including diversion channel upslope of bioreactor	$20,000
		SUBTOTAL = $87,500
		TOTAL ESTIMATED COST (INCLUDES 15% CONTINGENCY) = $440,000

*Indicates that additional treatment materials will be needed to replace and/or supplement the existing treatment materials in the respective treatment pond; these are approximate quantities and should be confirmed/corrected as part of the final engineering design process

In addition to the existing treatment systems recommended improvements to improve their function and capacity to effectively remediate the target AMD sources, at least four other AMD discharges require detailed remediation plans to finalize restoration efforts in Cold Stream. The order of priority of the four primary sources evaluated as part of this project are listed in Table 19 with the Artesian Discharge as the highest priority due to the amount of contaminant loading and the Iron Gate Discharge is the lowest priority since it has low contaminant concentration. Recommended remediation plans were determined based on the severity and volume of each AMD source and include rough estimated construction costs for the respective treatment technology. Additional data including flow and water quality are recommended for each of the four AMD sources before proceeding with an engineering design plan for the remediation systems necessary to abate their impacts to Cold Stream.

Table 19
Untreated AMD Sources Remediation Recommendations Capital Cost Estimate

AMD Source	Recommend Remediation	Cost Estimate Range
Artesian Discharge	Semi-Active Treatment	$500,000-750,000
Blue Pipe Discharge	Semi-Active Treatment or Combination Passive and Active Treatment	$500,000-750,000
Soccer Field Seeps	Passive Treatment (Aeration and Wetland)	$25,000-40,000
Iron Gate Discharge	Passive Treatment (FLB)	$150,000-250,000