Treatment of the Jamison Mine Borehole Discharge, Phase II
Final Report

Prepared for Kiskiminetas Watershed Association by Hedin Environmental
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Project Background

The Wolford passive treatment system was installed in 1994 by NRCS to treat an upwelling of acid mine drainage (AMD) from a borehole into an underground mine. The AMD has pH 5-6 and contains 80-120 mg/L Fe, 2-3 mg/L Al, and 2-3 mg/L Mn. The installed passive system consists of an anoxic limestone drain (ALD) followed by three ponds. The ALD was intended to generate alkalinity and the ponds were intended to oxidize and precipitate Fe. The system's effectiveness was evaluated in a project conducted in 2005 and 2006 by the Kiskiminetas Watershed Association. The source of the water was determined to be the abandoned Jamison Mine. The borehole was established during mining to drain the mine and was located at the lowest point available to the mining company. The treatment system was not effectively treating water in 2005/06 because of several problems. The connection between the borehole and the system leaked and a substantial portion of the AMD flowed directly to Wolford Run. The anoxic limestone drain was much too small and did not generate enough alkalinity. The ponds were filled with iron sludge which decreased the residence time of water in the system and reduced iron removal.

The current project developed from the 2005/06 study. Its general goal was to advance the effective treatment of the Jamison Borehole discharge and thus decrease pollution to Wolford Run and the Kiskiminetas River. The current project had three specific goals: 1) renovate the Jamison borehole so that the AMD discharge can be reliably piped to a treatment system; 2) clean out the existing settling ponds and improve their capacity for Fe removal; and 3) identify the preferred treatment option and secure a site for its eventual construction.

This is the final report for the project.

Jamison Borehole Rehabilitation

The condition of the Jamison borehole was investigated in 2011 using a downhole camera. The investigation revealed that NRCS had installed a PVC pipe in the borehole to a depth of about 6 ft. The pipe was not tightly secured, which allowed water to flow around the pipe and bypass the treatment system. Below the plastic pipe the borehole was in competent rock and showed no signs of collapse or failure. The borehole descends 110 ft to a mine void that is part of the Jamison Mine.

The camera investigation resulted in a scope of work to capture the discharge in a leak-proof manner that was implemented in January 2013. The work included the installation of an 8" threaded connection Schedule 40 PVC pipe down the borehole into the mine void. Shale traps were set at 80 ft depth and cement grout was installed from the traps to the surface. The cement grout prevents the flow of water around the outside of the plastic pipe. The bottom 10-15 ft of pipe extending below the shale traps were heavily perforated so that the pipe would collect water even if the open end of the pipe became plugged (by caving of mine roof).

The top of the pipe was designed to allow the control of the discharge. An 8" tee was installed with one end on horizontal and the other end in vertical position. An 8" threaded plug was glued to the vertical end. An 8" butterfly valve was installed on the horizontal end. Photo 4 shows the borehole improvements.

The work was conducted by S&T Service and Supply Inc. (Pleasantville, PA) in January 2012. Details of the job are provided below. These details may be useful to other groups attempting to capture AMD flow from an abandoned well so that it can be more easily treated.

Specifics of Borehole Rehabilitation Work started on January 16 2012 and was completed on the 17th. S&T Services installed 110' of 8" Schedule 40 PVC pipe with two sets of rubber shale traps with a rag trap sandwiched in between. Photos 1, 2 and 3 show the pipe installation. This triple stack of traps were installed just above the roof of the mine into solid rock at about 78 feet. The annulus between the 8" pipe and well bore was then cement grouted from the top shale trap at about 78' from top of the hole to the surface. Before the annulus was grouted off and the pipe was set into the mine, a 3 inch water pump was used to pump the flow of water from within the pipe to prevent flow of water on outside of pipe. By stopping the flow of water during cementing operations the grout could be introduced down the annulus down to the top of rag packer by tremie tube. A tremie tube is in this instance a 1 inch steel pipe in 20 ft lengths that would be assembled together one by one as these were lowered into the annulus until setting upon the top packer. The tremie tube would be attached to the concrete pump to pump cement grout slurry down the tube all the while the tremie tube is delivering the grout at the bottom forcing water to the surface by displacement. As the cement grout was being introduced into the annulus the tremie tube was being raised in 20 ft increments and a section removed. The cement grout slurry displaced the water in the annulus forcing the water up the annulus and out of the well. After cement grout flowed to the surface all tremie tubes were removed. The 3 inch pump kept pace with flow of water inside the mine to prevent pressure of water from pushing the cement grout slurry. The extreme high density of the grout forced the cement to the bottom of packer. The water pump was filled with gasoline and allowed to pump water into the night to allow the concrete slurry to harden. On the following day it was found that all water was flowing inside the 8 inch pipe. No leaks were observed on outside of the new 8” well casing. It was decided to allow a couple of weeks for cement to cure before adding and closing the butterfly valve.

Head Tests After the borehole rehabilitation was complete and the mine water securely captured, head tests were initiated. The purpose of these tests was to determine how much head could be placed on the borehole before AMD discharged to other locations. The results of these tests would provide a limit on how high the discharge could be raised.

A concrete vault was set around the borehole location in March 2012 to protect the new plumbing from freezing and vandalism. Santella Excavating (Derry, PA) installed the vault and made modifications to the plumbing. This vault was fitted with locking removable lid for full access to the inside of the vault. Photo 5 shows the vault. Plumbing was added to the top of the Tee that allowed connection of both ¾ inch tygon plastic tubing with ¾ inch throttle gate valve and a pressure gauge to monitor amount of pressure on the wellhead when valve was closed. Tygon tubing is clear plastic flexible tubing that allows fluid levels to be observed from the outside.

After the vault was set and the borehole secured, the butterfly valve on the horizontal side of Tee was shut on March 13, 2012. Over the following three weeks, regular measurements were made of pressure (psi) at the pressure gauge. Head was calculated from the psi measurement by assuming that one foot of head was equal to 0.435 psi. As a separate measurement of head, the Tygon tubing was raised above the well and the level of water in the tubing was measured. Measurements made by both methods were similar.

After 20 days of valve being closed at the borehole the pressure started to stabilize at 5.85 psi or 13.5 feet of head. The 13.5 feet of head represents to of new borehole elevation which is now 3.5 feet higher than original borehole elevation due to valve and Tee addition. Water was observed flowing shortly after from the vertical airshaft located upstream of treatment system just north of Route 981 along Wolford Run. The airshaft is capped with a concrete pad. The pad does not create a watertight seal as the full flow of water was able to discharge from the pad. A review of the mine maps suggest that if the airshaft was sealed, the next point of discharge from the mine would be entries located on the south side of Route 981. This location does not provide good treatment opportunities as it is in a ravine and there are several active gas wells on the property.

The head experiments established that the discharge could be raised approximately 17 feet (above the ground surface at the borehole, which was the original discharge elevation) before it discharges at the air shaft. This increase in elevation increases the size of the footprint of land potentially suitable for treatment. Specifically, by raising the discharge 17 ft, abandoned land between the borehole and airshaft and a refuse pile across the creek both become feasible for a gravity-powered treatment system.

Wolford Run Treatment System Iron Removal

The existing treatment system contains three ponds that have received high-Fe AMD from the Jamison borehole since 1994. Over this period the ponds accumulated enough iron sludge to substantially decrease their retention time. A primary goal of this project was to remove the sludge and make the ponds more suitable for future passive treatment. It was also recognized that the experience gained in the sludge removal would be useful in the future, should an upgraded passive treatment system be installed.

Sludge is generally removed from mine water systems by pumping 10-20% solids slurry from the treatment pond to a sludge dewatering device or basin. Iron sludge can be dewatered using mechanical devices such as filter presses, belt presses, and centrifuges. This method generally can produce a 40-50% solids product, but the approach is energy intensive and costly. A simpler approach is to pump the liquid sludge into a geotextile tube which releases water through the woven fabric while retaining most of the solids. Dewatering occurs primarily during pumping when the geotubes are pressurized, but it also occurs passively after pumping ceases. Depending on the characteristics of the sludge, after several months the contents of the geotube will have sludge with 30-50% solids. Geotubes are expensive and, if the solids are to be recovered, must be destroyed after one use. In a recent iron recovery project, the geotubes were 40% of the total sludge recovery cost. The least costly sludge dewatering method is a basin that dewaters passively over a several month period. The dewatering can occur through an intentionally leaky pond bottom or through an installed dewatering system (drainage pipe in the pond bottom). Dewatering basins are inexpensive to construct and in some cases can be reused for multiple sludge recovery efforts.

After a review of options and meetings with the property owner (Charles Anderson), it was decided to install a temporary dewatering basin. Test pits were dug and a suitable wooded area comprising about one acre was identified. Mr. Anderson was paid $3000 for the loss of trees and property damage. The agreement included removal of the basin and appropriate seeding and mulching at the project’s completion.

The dewatering basin pond was constructed on a hillside overlooking the treatment system using an excavator and bulldozer. The basin was installed by Santella Excavating in June 2012. In September 2012 Santella Excavating returned to the site and pumped sludge from the treatment ponds to the basin. A Houle manure pump powered by a John Deere tractor was used to stir and pump iron oxide from the ponds. Once the iron was mobilized the tractor pump transferred sludge via 6 inch water hose to a 4 inch diesel powered water pump for boosting the sludge to the dewatering basin. An excavator was used to excavate sumps into bottom of ponds for placement of the pumps and to also stir up the sludge and push it towards the pump intake. The sludge removal was completed in one week. Photos 6 – 8 show the sludge removal operation.

Once all the material had been pumped to the dewatering basin, the sludge was allowed to settle and dewater for several months. Photo 9 shows the basin with dewatering sludge in December 2012. After three months the sludge had dewater sufficiently to allow it to be stacked by an excavator into small piles, which promoted further dewatering and drying. The stacking also created room in the basin to allow trucks access when the iron was removed. In September 2013 (one year after the sludge pumping), the material was 45% solids which is suitable for trucking. Fifteen triaxle loads of iron oxide solids were removed and trucked to the Iron Oxide Recovery (IOR) processing plant in Shippenville (Clarion County). The iron material was restacked to enhance further drying and sampled to determine chemical composition.

After the iron was removed from the dewatering basin the site was reclaimed. All berms and slopes were backfilled and graded back to approximate original contour. The site was then seeded and mulched along with necessary soil amendments to establish vegetation.

Approximately 300 tons of dewatered iron oxide sludge were removed from the site. At the measured solids content of 45%, this is equivalent to 135 tons solid. Table 1 shows the cost of the various sludge management activities relative to the solids produced. Sludge removal and dewatering to a condition suitable for trucking off-site was $103/ton. This cost is useful for estimating the cost of sludge removal at other sites. Dewatering was accomplished in a basin constructed for $6,795. If geotubes had been used, the cost for two 100 ft X 60 ft geotubes plus an aggregate underdrain would have been $10,000 – $15,000. While the basin was economical, compared to geotubes, it is unfortunate that it was reclaimed. If there are future sludge recovery operations at the site, the basin will need to be rebuilt.

Table 1. Costs for removal and disposal of sludge From the Wolford passive treatment ponds.

	Cost	$/ton-solid
Construct basin	$6,795	$50
Pump sludge to basin	$12,125	$90
Stack sludge	$1,704	$13
Load and truck sludge away	$7,073	$52
Reclaim basin	$6,300	$47
Total	$33,997	$252

The iron oxide is currently being processed by Iron Oxide Recovery, Inc. Processing consists of passive drying, screening to less than 1 cm, and storage under cover. All processing at the IOR plant have been paid by IOR. Approximately 1/3 of the material has been processed to a dried (60% solids) screened condition, while the remaining material is stacked and awaiting further processing. A detailed analysis of the chemistry of the collected material has been made. The results are shown in Table 2 along with data for sludge sampled from the Wolford ponds previous to recovery and for other iron oxides materials recovered from mine drainage. The recovered Wolford iron oxide is less pure than the samples collected from the ponds. This is likely due to mobilization of clay and silt during the recovery process. The Marchand material is the cleanest iron solid recovered to date and is about 95% pure iron oxide. The recovered Wolford material is 85-90% iron oxide which is more pure than iron solids collected recently from the St Vincent College Wetland 1 site (SVC W1).

Plans to sell the recovered Wolford material as pigment have not developed because the iron oxide was found to have weaker pigmentary characteristics than other iron oxide materials available in western PA. IOR is exploring use of the material in soil remediation projects where the high iron content is useful for sorption of metal contaminants.

Table 2. Elemental content of iron solids collected from mine drainage treatment systems. All values are % of solid weight. Unaccounted weight is largely oxygen and hydrogen.

	Si	Al	Fe	Mn	Mg	Ca	Na	K	P	S	C
Wolford in-ponds	3.2	2.1	49.5	<0.1	0.1	0.2	<0.1	0.1	<0.1	0.7	1.4
Wolford recovered	3.5	2.2	44.4	<0.1	0.1	0.8	0.1	0.2	<0.1	1.9	1.1
Marchand	2.0	0.2	52.6	<0.1	0.1	0.6	0.1	0.0	<0.1	0.2	0.6
SVC W1	10.6	5.5	32.2	<0.1	0.1	0.4	0.2	0.5	0.1	0.4	1.3

Discharge and Stream Chemistry

Improved Water Chemistry For the last two years water has been flowing from both the borehole and the airshaft. The results of sampling both discharges are shown in Table 3 and Figures 1 and 2. Water flowing from the airshaft is less contaminated than from the borehole. The airshaft contains more alkalinity, less Fe and less acidity. Since the second sampling event, the difference in chemistry has been consistent. Two explanations are proposed. The flow path to the air shaft may involve more contact with alkaline strata than the flow path through the borehole. Also, the increase in head of 17 ft should result in an increase in the amount of the abandoned mine that is flooded. Flooded conditions lessen pyrite oxidation and provide better opportunities for carbonate dissolution. It would be interesting to flood the mines further, but this is not possible unless the air shaft is sealed.

The chemistry of the air shaft improved over the two year period at a statistically significant rate. (Figures 1 and 2). The chemistry of the borehole showed no such improvement. The rate of improvement over the monitoring period is -29 mg/L acidity per year and -7 mg/L Fe per year. It is not known if this improvement will continue. Based on observations at other sites, it is likely that the improvement will level off at a point determined by a new geochemical equilibrium in the deep mine.

Capitalizing on the improved chemistry at the air shaft requires that the discharge be controlled. This would allow the discharge to be piped or pumped to a treatment system. Control of the air shaft discharge will require collection of the flow in a sealed manner, similar to what was installed at the borehole. The condition of the airshaft is unknown. If treatment of the airshaft discharge is a preferred option, the first step should be to collect the flow into a pipe that can be pressurized without leakage.

Table 3. Average chemistry of the Wolford Borehole and Airshaft discharges, May 2013 - February 2015 (9 samples)

	pH	**Alk**	**Acid**	**Fe**	**Al**	**Mn**	**SO4**
		mg/L CaCO		*mg/L*	*mg/L*	*mg/L*	*mg/L*
Borehole	5.3	17	161	101	3	3	878
Air shaft	5.7	40	128	87	3	2	808

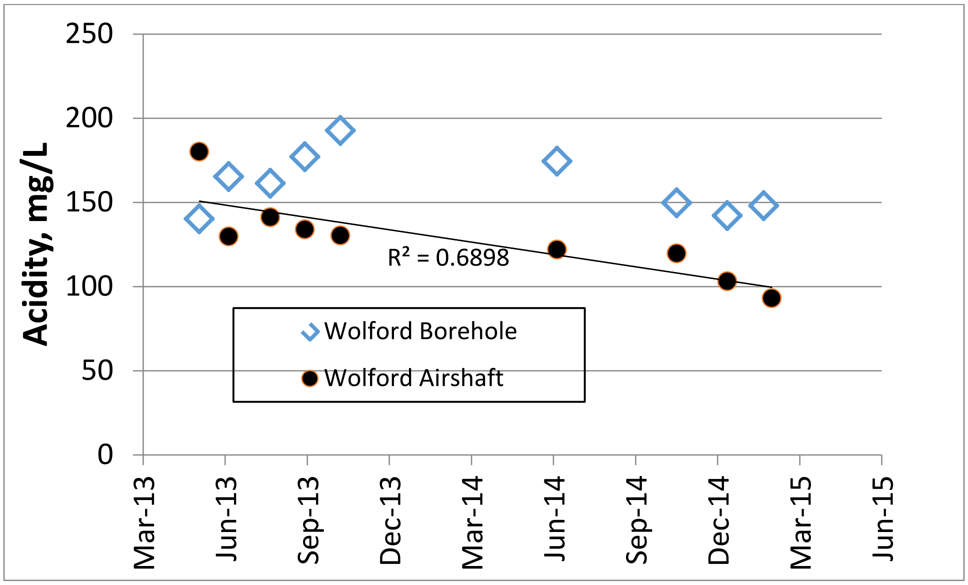


Figure 1. Acidity concentrations at the Wolford Borehole and Jamison Air Shaft while both were flowing between 2013 and 2015. The downward trend for airshaft is statistically significant at the 0.01 level. The trend for the borehole is not significant.

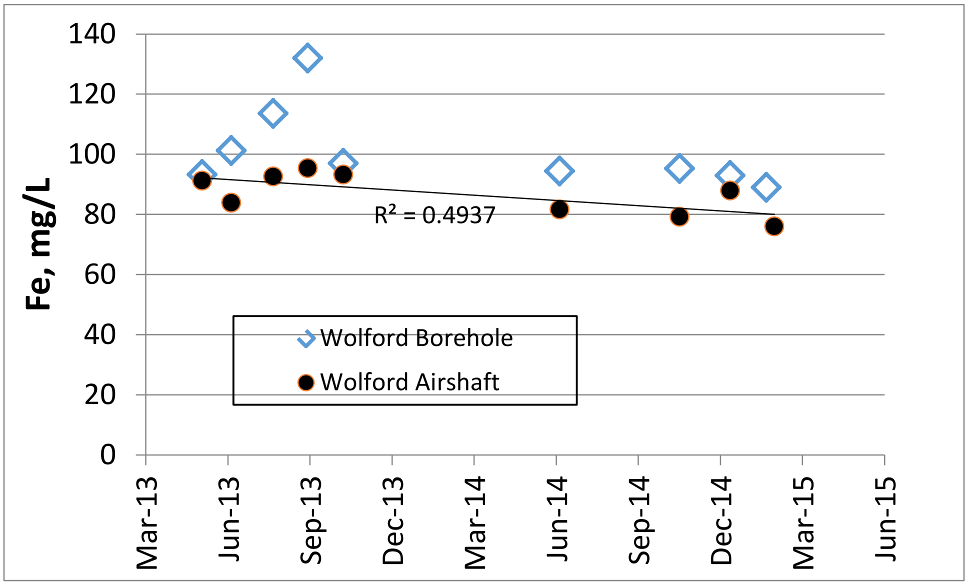


Figure 2. Fe concentrations at the Wolford Borehole and Jamison Air Shaft while both were flowing between 2013 and 2015. The downward trend for airshaft is statistically significant at the 0.05 level. The trend for the borehole is not significant.

Impact of Jamison Mine Discharges on Wolford Run

The impact of the Jamison Mine discharges on Wolford Run was assessed on February 12, 2015. The sampling included Wolford Run upstream (immediately downstream of the SR 981 culvert), a tribuatary from the west, the airshaft discharge, the borehole discharge, and Wolford Run downstream. Stream flows were measured with a velocity meter. Airshaft and borehole flows were estimated from mesurements gpm. The borehole valve was opened to allow a 30 gpm flow. The airshaft was estimated at 410 gpm, which is based on repeated flow measurements made when the borehole valve was closed and all water was flowing through a flume. Chemical parameters were measured by G&C Laboratory (Summerville PA).

The sampling results are shown in Table 4. Wolford Run upstream had pH 6 and was marginally acidic. This is a substantial improvement over the highly acidic conditions observed a decade ago. According to Ron Hornansky (New Stanton District Mining Office Watershed Manager), an upstream remining project is reclaiming an AML site that produced severe AMD in the past. The benefits of the project are significant.

A large flow of water enters Wolford Run from the west between the SR 981 culvert and the airshaft inflow. The "West Trib" is clean alkaline water. The airshaft and borehole had chemical characteristics in line with previous measurements. Wolford Run downstream was marginally acidic and contained elevated concentrations of Fe and Al.

Table 5 shows loading calculations made from the Feb 12, 2015 data. The downstream flow rate was 91% of the sum of upstream flow rates. This good correspondance provides confidence in loading evaluations. Fe, Mn, and sulfate loads also showed good capture (89-113%). Downstream acidity loadings below were much lower than the sum of upstream. This is likely an artifact of the hot acidity measurement procedure which is not accurate at low concentrations as exist in Wolford Run above and below. (If the upstream acidity vaule is only 10 mg/L higher, the acidity loadings balance.)

The sampling results provide a good assessment of current conditions. The Jamison Mine discharges double the instream Fe loading. The iron staining visible in the Kiskiminetas River below Wolford Run is largely due to the Jamison Mine discharges. If the Jamison Mine discharges were removed from Wolford Run, the stream would be net alkaline with low concentrations of particulate Fe and Al. The stream could support fish and the impact of Worford Run on the Kiskiminetas River would be minimal. If the Jamison Mine discharges were treated to an net alkaline condition, Worford Run downstream would be strongly net alkaline. If the Jamison Mine discharges were treated to an alkaline condition with less than 10 mg/L Fe, Wolford Run downstream would be alkaline with less than 5 mg/L Fe. While the stream would still be stained with iron precipitates, this chemistry would support fish. The stream's deleterious inpact on the Kiskiminetas River would be minimized.

Table 4. Results from Feb 12, 2015 sampling of Wolford Run

	Flow	pH	Alk	Acid	Fe	Al	Mn	SO4
	gpm		*mg/L $CaCO_3$*		*mg/L*	*mg/L*	*mg/L*	*mg/L*
WR upstream	5,219	6.5	6	4	4.7	3.0	1.3	100
West Trib	1,501	6.7	31	-24	0.1	0.3	<0.1	23
Airshaft	410	5.9	55	93	76.2	3.6	2.3	768
Borehole	30	5.8	17	148	89.3	2.7	3.0	960
WR downstream	7,889	6.5	5	10	6.6	2.5	1.1	106

Table 5. Loading calculations from Feb 12, 2015 sampling.

	Flow	Acid	Fe	Mn	SO4
	gpm	*ppd $CaCO_3$*	*ppd*	*ppd*	*ppd*
WR upstream	5,219	251	293	84	6,258
West Trib	1,501	-426	2	1	415
Airshaft	410	456	375	11	3784
Borehole	30	53	32	1	346
WR downstream	7,889	989	623	109	10,019
SumUp/Down	91%	34%	113%	89%	108%

Treatment Alternatives

Several treatment options are presented in this section. Throughout the project passive treatment has been a preferred alternative because the KWA does not have the financial resources to operate a chemical system. The recommended passive approach is an anoxic limestone drain followed by oxidation/settling ponds followed by constructed wetlands. Anoxic limestone drains are buried beds of limestone where calcite dissolution raises the pH to 6-7 and generates alkalinity. Under anoxic conditions Fe will not precipitate and passes through the bed. This feature avoids plugging of the bed with iron solids. ALDs generate 150-250 mg/L alkalinity. This is sufficient alkalinity to assure that the ALD discharge would be net alkaline.

The presence of 3 mg/L Al in the raw water creates a concern because the Al will precipitate in the limestone bed. It is recommended that this problem be minimized by building two parrallel ALDs and plan on periodically cleaning the stone.

The net alkaline discharge from the ALDs would discharge to a series of ponds where aerobic processes would precipitate the dissolved ferrous iron as particulate iron oxide. Empirical observations at existing passive systems indicate that property sized ponds readily decrease the Fe concentration of aerated water to 10-15 mg/L. Beyond this point, Fe removal is slowed by less efficient solids settling. Wetlands are effective for removal of 10-15 mg/L Fe. The final polishing of the mine water would occur within a constructed vegetated wetland.

Table 6 shows design assumptions and sizes of the treatment units. The flow rate of the borehole averages 370 gpm and has ranged as high as 443 gpm. A design flow rate of 440 gpm is assumed. The calculations assume that the discharge would flow from the airshaft and contain the average chemistry measured 2013-2105.

- The ALD sizing assumes that the ALD discharge contains 275 mg/L alkalinity, that the system provides 20 years of full treatment at the design flow, and 90% $CaCO_3$ limestone. The calculated sizing is 7,821 tons. If the bed is 8 ft deep with vertical sidewalls, the surface area of ALD is 19,553 ft^2.
- The ponds and wetlands are sized based on performance of the Lowber passive treament system where an 1,800 gpm discharge containing 70 mg/L Fe is treated to to 1 mg/L Fe. The 4 foot deep ponds are are assumed to decrease Fe to 15 mg/L at a rate of 25 gFe per m^2 per day ($g\ m^{-2}day^{-1}$). The total surface area of the ponds is 74,341 ft^2 (1.71 acres).
- The 0.5 ft deep wetlands are assumed to decrease Fe from 15 mg/L to 1 mg/L at a rate of 4 $g\ m^{-2}day^{-1}$. The total surface area of the wetlands is 90,345 ft^2 (2.07 acre).

The surface areas provided above are for treatment units and do not account for roads and berms. The footprint of passive treatment system is geneally 1.5-2.0 times larger than the sum of the units. Assuing a ratio of 1.75, then the total passive treatment will have a footprint of about 7.4 acres.

Three passive treatment options were developed and evaluated: 1) make full use of the current site; 2) pipe the AMD to the closest site suitable for full scale passive treatment, and 3) pump to a site suitable for full scale passive treatment. The options are presented below.

<u>1) Passive Treatment on Existing Property</u> The first alternative considered is to construct a gravity-driven passive system that utilizes the existing treatment ponds and adjacent property as fully as possible. The amount of suitable property around the Jamison Borehole is limited and there is not enough property for construction of a full-size passive system. The best use of the property is to treat the water with an ALD and settle as much iron as possible in ponds. Map 1 shows a possible layout for this alterative. The plan assumes that the following.

- The elevation of the discharge is raised to 880 ft;
- The discharge is piped to an 8,000 ton anoxic limestone;
- The ALD discharge is treated by the existing settling ponds and another series of ponds constructed on an AML site across Wolford Run.

The ALD should be constructed in two cells that operate in parallel. The presence of particulate Al in the Jamison Mine discharges makes it likely that the limestone aggregate will become plugged with Al solids after a period of several years. The solids can be removed by cleaning the aggregate at much less cost than limestone replacement. The parallel arrangement will allow continued treatment of the AMD during ALD cleaning operations.

Iron removal would occur in two sets of ponds arranged in parallel. The effluent of the ALD would be split with one portion flowing to the existing ponds and the remaining water flowing across the creek to the new ponds.

Table 6. Assumptions and Passive System Calculations

Design Assumptions	**quantity**	**units**
Flow rate, average	370	gpm
Flow rate, high	443	gpm
Flow rate, design	440	gpm
Untreated acidity	128	mg/L $CaCO_3$
Untreated Fe	87	mg/L
Anoxic Limestone Drain		
Influent alkalinity	85	mg/L $CaCO_3$
Effluent alkalinity	275	mg/L $CaCO_3$
Life	20	years
Limestone	7,821	tons
Surface area at 8 ft depth	19,553	
Oxidation/Settling Ponds		
Influent Fe	87	mg/L
Effluent Fe	15	mg/L
Fe removal rate in ponds	25	grams Fe per m^2 per day
Total pond surface area	74,341	ft^2
Constructed Wetland		
Influent Fe	15	mg/L
Effluent Fe	1	mg/L
Fe removal rate in wetland	4	grams Fe per m^2 per day
Total wetland surface area	90,345	ft^2
Full Treatment System		
Total surface area of units	184,238	ft^2
Footprint factor	1.75	
Footprint of system	322,417	ft^2
Footprint of system	7.4	acre

The existing ponds currently have a total surface area of 42,500 ft^2. The first pond (closest to the Jamison borehole) could be expanded toward the borehole (through the existing undersized ALD) which would increase the size of the ponds to 45,500 ft^2. The existing ponds have very little gradient. The flow of water through the ponds would be reversed so that the final discharge is located near the borehole.

The AML property on the opposite side of Wolford Run includes an abandoned access road and coal refuse. If the site was graded to a flat condition approximately 2.0 acres could be created that was lower than 880 ft (discharge elevation of the ALD). The cut produced from the current coal refuse would be used to fill on top of the road. However, excess cut will be likely be produced that will require off-site disposal. The two ponds shown on Map 1 have a total surface area of 41,000 ft^2.

Table 7 shows the components of the passive system. The system would, on average, discharge pH 6.5-7.5 alkaline water with 10-15 mg/L Fe. The four-foot-deep ponds have a volume of approximately 2.4 million gallons. Fe sludge (50% Fe solids, 15% solids sludge, 10 lb/gal) production would be about 160,000 gallons per year. This is equivalent to 7% of the pond volumes. Sludge removal would be needed every 6-7 years to maintain treatment effectiveness. The iron sludge produced by the system would be very pure and would have potential resource recovery value.

An advantage of this alternative is that the property is owned by a single individual, Charles Anderson. Mr. Anderson allowed the original treatment system to be built on the property and has supported the efforts completed through this project. This portion of the Anderson property is predominantly AML and has little value for farming or development.

Table 7. Assessment of the feasibility of the current site to achieve treatment parameters defined in Table y.

Requirement	**System**
Raise discharge to 880 ft	Achievable with restored borehole and valve
ALD, 7,800 tons	Achievable on site in concrete tank
Settling Ponds, 74,341 ft^2	Existing expanded ponds: 45,500 ft^2 New ponds on north side of WR: 41,000 ft^2 Total pond surface area: 86,500 ft^2
Wetlands, 90,345 ft^2	Property not available
Fe loading at 370 gpm, 87 mg/L Fe Fe loading at 370 gpm, 101 mg/L Fe	22.6 gFe/m^2/day 25.6 gFe/m^2/day

2) Gravity Pipeline to Alternative Site Because the borehole and airshaft are both located high above the Kiskiminetas River flood plain, it is possible to pipe the flow to a suitable site. A gravity piping system would have no annual costs other than periodic pipe cleaning. A suitable location was identified that is along the Kiskiminetas River upstream of the Wolford Run inflow. Map 2 shows a potential layout. The 20 acre site is undeveloped and much of the property is located on a bench above the floodplain and below an active Norfolk Southern railroad. There is more than enough room to fit a full-size passive treatment system. Access to the property requires a 5,800 ft pipeline that would parallel the railroad for 2,000 ft. A PA1 Call request revealed that the railroad right-of-way contains buried fiber optic transmission lines (Windstream Corporation) and gas lines (Shelly Oil & Gas and Peoples Gas). The presence of these buried utilities on the ROW makes the placement of an AMD pipeline highly unlikely (or very expensive). Installation of the pipeline outside of the ROW requires hanging the pipeline on a very steep hillside above the railroad. This would be cost prohibitive.

The potential treatment site is currently owned by the Kotulak family. After an initial discussion about the potential project with Hedin Environmental, the family indicated that they were not interested in proceeding. Subsequent efforts by the KWA personnel to discuss the project with the Kotulak family were not successful. The difficulty of placing a pipeline along the active railroad and the uncooperative stance of the property owner resulted in rejection of this alternative.

3) Pump and Passive Treat The Jamison discharge could be pumped to a location that is suitable for a full-size passive treatment system. A model for this approach is the Holiday Construction reclaimed surface mine in the Jacobs Creek watershed where 125 gpm of pumped groundwater has been successfully treated with a passive treatment system for 25 years. The costs to operate the pump are paid by the company that conducted the mining.

Land suitable for a full-size passive treatment is located above the discharge site at ~1000 ft elevation. Table 8 shows pumping cost calculations. An annual cost of approximately $25,000 per year is estimated.

Table 8. Pumping cost estimate.	
Flow rate, sustained wet weather, gpm	440
Head, ft	150
Pump efficiency	77%
Pump horsepower	22
Electricity cost, $/kwh	0.10
Pump electrical cost, $/yr	$14,000
Pump O&M estimate, $/yr	$10,000
Total pumping cost, $/yr	$24,000

Map 3 shows a potential treatment location that was selected because the land is not developed. HE met with the primary landowner, Patrick Calandrella. While Mr. Calandrella was supportive of the project, he cautioned that the property was also owned by several heirs and that an agreement with all the heirs for a mine water project was likely to be difficult.

PADEP does not currently provide long-term O&M funding for watershed associations. To be considered for DEP funding, the watershed association would need to fund pumping costs. The KWA does not currently have the capacity to fund these pumping costs. The financial liability arising from a continuous pumping program made this option infeasible.

Landowner Contacts

DEP requires landowner consent before it will proceed with a grant that would develop plans and permits for a treatment system. Landowners were contacted for each of the three treatment options developed. The Kotulak family owns undeveloped land along the Kiskiminetas River that would be appropriate for a full-size passive treatment system. After hearing about the potential treatment plans the family informed us that they were not interested in project involvement and refused all subsequent efforts at contact.

The property that is most convenient to a pump/treat system is owned by the Calandrella family. While local resident Patrick Calandrella was supportive of the project, we learned that the

Calandrella property is owned by multiple family members. Mr. Calandrella believed that working with all the family members would be difficult.

The current treatment system is on property owned by Charles Anderson. Mr. Anderson has been very cooperative throughout the project. Mr. Anderson also owns the AML site on the opposite side of Wolford Run that would be suitable for placement of ponds. Mr. Anderson is not inclined to donate more property for an enlarged passive treatment system. However, it may be possible to purchase the property. If expansion of the current treatment system is considered, the first step will be buying the property from the Anderson family.

Summary

This project advanced the concept of treating the Jamison Mine discharges so that water quality benefits would be realized in Wolford Run and the Kiskiminetas River. The borehole, which was in disrepair, was rehabilitated and pipe was installed that provides complete control of the flow. It was determined that the elevation of the discharge can be raised 17 ft, at which point it discharges from an airshaft. The chemistry of the flow from the airshaft is less contaminated than the borehole and was still improving at the conclusion of this project. The ability to raise the discharge makes passive treatment more feasible on the existing and adjacent site.

The existing sludge ponds were cleaned out. The iron sludge was pumped to a temporary sludge basin, dewatered, and removed from the site. The sludge produced was a high-Fe iron oxide which is currently being processed and considered for use in soil remediation projects.

The stream was sampled in February 2015. The sampling revealed that the quality of Wolford Run upstream of the project area is much improved, apparently due to remining activities. The stream was alkaline with modest concentrations of Fe and Al. The Jamison Mine discharges doubled the iron content of the stream. If the Jamison Mine discharges were treated to an alkaline condition with 80-90% removal of the iron, Wolford Run below the site would be alkaline with low concentrations of Fe and Al. The stream would probably support a fishery. The treatment would decrease the impact of Wolford Run on the Kiskiminetas River, eliminating most of the iron staining that currently visible.

Three treatment alternatives were developed.

1. The first option considered the largest treatment system feasible at the current site (including a refuse pile across the creek). Limited space only allows the installation of an anoxic limestone drain and oxidation/settling ponds. There is insufficient space for a constructed wetland. This treatment system would generate alkaline water and remove 80-90% of the Fe. Wolford Run would still be stained orange, but is chemistry would support a low-quality fishery. The impact on the Kiskiminetas River would be substantially decreased. This alternative is preferred by the KWA.

2. The second option considered installing a 5,800 ft gravity pipeline to an undeveloped site along the Kiskiminetas River upstream of the inflow of Wolford Run. The site is large enough to fit a full-scale passive system that would treat the flow to < 2 mg/L Fe. Accessing the site requires placing the pipeline in the ROW of an active rail line that contains buried fiber optic cables and gas/oil lines. It will be difficult and expensive to place an AMD pipeline on the ROW. The landowner of the property was contacted about the project and is unwilling to consider the project at this time.

3. The third option considered pumping the water to a site above the discharge where a full-size treatment system could be installed. The nearest potential site is located about 100 ft higher than the current mine discharge. The annual cost to pump the flow to this location was estimated at $24,000/yr. The burden for operating the pumping system would be on the Kiskiminetas Watershed Association. This option was rejected for financial reasons.

Photo 1. Perforated pipe and shale traps being lowered into the borehole

Photo 2. Solid pipe being lowered into the borehole

Photo 3. Finished pipework with grout injection

Photo 4: Wolford Borehole Improvements.

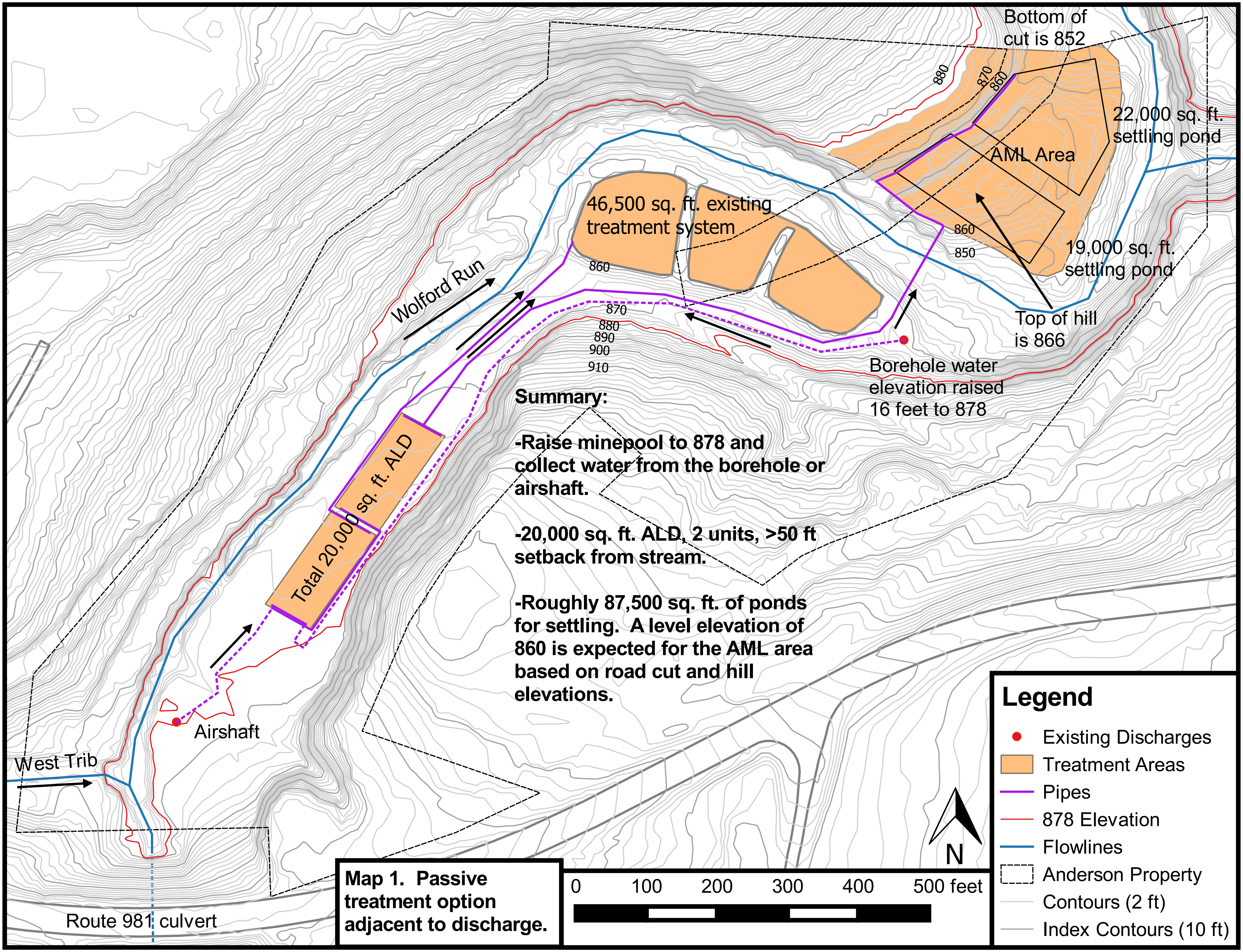
Photo 5: Concrete Vault Protection of Wolford Borehole Improvements.

Photo 6. Sludge pumping equipment used for the Wolford project. The pond has been drained down and much of the sludge already removed. The photo shows the pump being moved.

Photo 7. Sludge pump in operation at Wolford. The pump both mixes (spraying) and pumps. The photo shows mixing operation.

Photo 8. Sludge was pushed toward the pumping station using an excavator.

Photo 9. The sludge basin in December 2012. The sludge dewatered naturally in place (note the cracking) and then was stacked in small piles to promote drying.



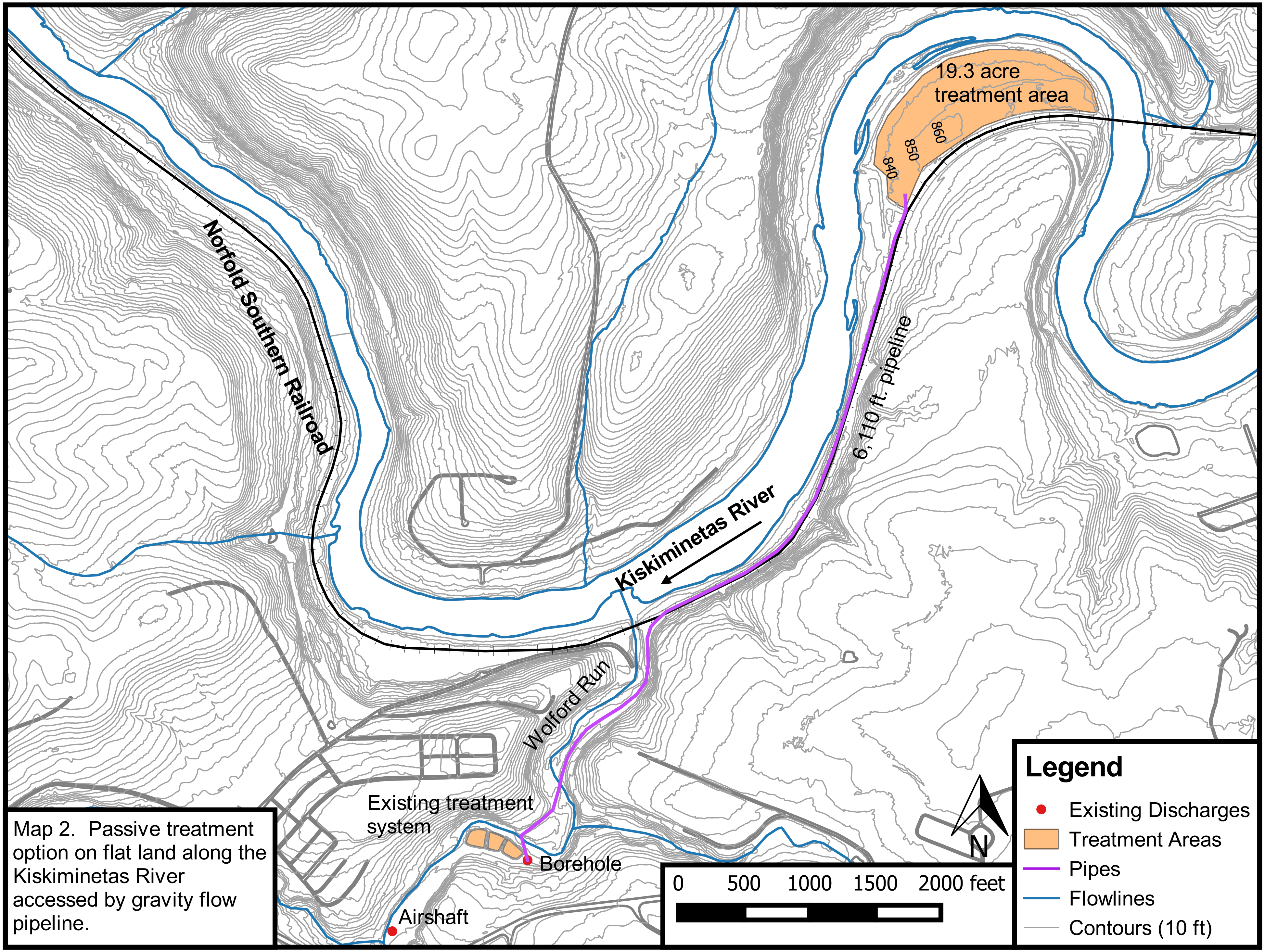
Summary:

-Raise minepool to 878 and collect water from the borehole or airshaft.

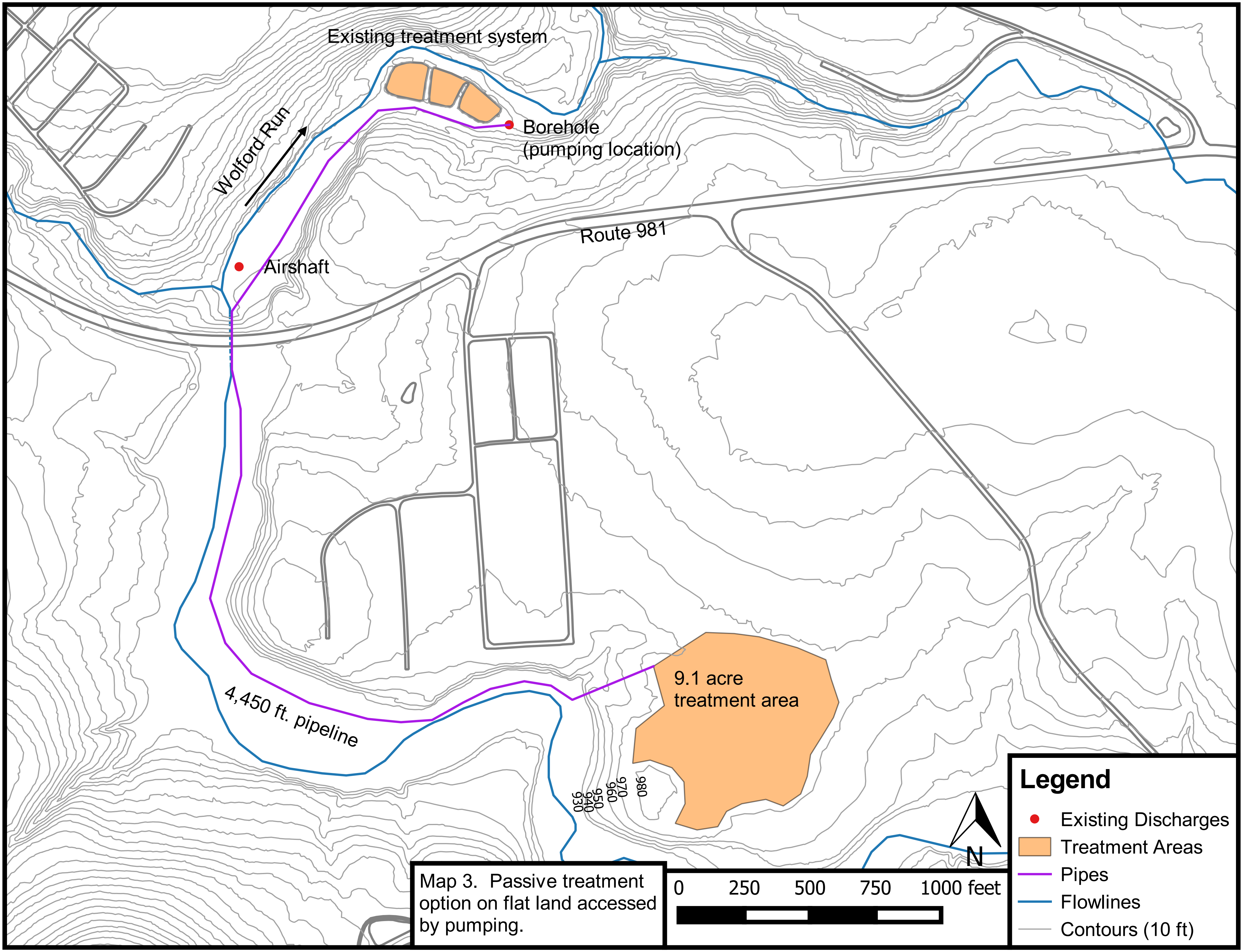
-20,000 sq. ft. ALD, 2 units, >50 ft setback from stream.

-Roughly 87,500 sq. ft. of ponds for settling. A level elevation of 860 is expected for the AML area based on road cut and hill elevations.

Map 1. Passive treatment option adjacent to discharge.



Map 2. Passive treatment option on flat land along the Kiskiminetas River accessed by gravity flow pipeline.



Map 3. Passive treatment option on flat land accessed by pumping.