

Assessment of Stream Resources at Regulated Coal Mining and Remining Sites in Ohio

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Abstract

The long-term effects of mining and reclamation practices on five selected stream resources in the state of Ohio 5 to 30 years following reclamation were evaluated and characterized. The focus of the study is on reconstructed streams in the primary headwater areas of selected sub watersheds. This study evaluates the physical, biological, and chemical characteristics of reconstructed streams and compares these respective characteristics with known natural system standards or characteristics for the associated region. Results and data obtained from this study will be useful to Ohio's mining program and will be used to evaluate how effective regulations and mining practices have been over a long-term period of time and whether programmatic changes should be made. The study will also be used to determine whether the state regulator needs to refine and make improvements in reclamation methodologies, and best management practices (BMPs). It is important to evaluate the effectiveness of current mining regulations and the restoration of streams that were disturbed both through previous pre-law mining and current mining activities.

1. Introduction

Since the passage of modern day coal mining laws over 38 years ago in Ohio, mining through headwater streams is very prevalent and has played an important role in obtaining valuable coal reserves. However the reconstruction and restoration of streams at these mine sites have not been well documented in the state. Studying the impact mining and subsequent reconstruction of headwater streams can serve as valuable background information for regulators involved to effectively administer the mine permitting and reclamation programs. The information will promote a more seamless permitting system facilitating mining of coal reserves and restoring impacted streams back to productive ecological systems.

In this study, the effects of mining and reclamation practices on stream resources 5 to 30 years following reclamation were evaluated and characterized. The results and data obtained from this study were used to assess how effective the Ohio's mining regulations and practices have been on restoring impacted streams over a long period of time. The goal is to make recommendations for improvements to the mining and reclamation programs.

To the end, this study investigated the impacted streams located in the primary headwater areas with drainage areas less than one square mile. The study evaluated the physical, biological and chemical characteristics of these streams. The primary scope is to assess the current fluvial-geomorphic post-mining conditions of these streams and their recovery with respect to stream habitat, stability, channel or flow patterns, and vegetation in comparison to target values.

2. Stream Evaluation Approaches

The evaluation of stream conditions was carried out following the protocols described in the "*Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams*" published by the Ohio Environmental Protection Agency (OEPA), Division of Surface Water. The manual provides a standardized assessment for primary headwater habitat (PHWH) in the state of Ohio, which allows impacts to be evaluated with similar natural system standards. The manual uses both physical and biological indicators to assess overall streams ecological integrity based on established indices of habitat quality such as Qualitative Habitat Evaluation Index (QHEI), Headwater Macroinvertebrate Field Evaluation Index (HMFEI), and Headwater Habitat Evaluation Index (HHEI). HHEI is used to score physical habitat features that have been found to be statistically important determinants of biological community structure in PHWH streams. There is an increased confidence when the HHEI is accompanied with a biological evaluation of the stream. A combination of two rapid field bioassessment methods, i.e., Macroinvertebrate Aggregate Index for Streams (MAIS), and Headwater Macroinvertebrate Field Evaluation Index (HMFEI) scoring systems, was used in this study to perform the biological resources assessment.

Five reclaimed mine sites in Eastern Ohio (Figure 1a) containing reconstructed headwater streams were selected for scoring Headwater Habitat Evaluation Index (HHEI) on 200 foot reaches. These reconstructed streams ranged in type from ephemeral to intermittent streams and were representative of extraction activities of various coal seams with dissimilar lithology and a mixture of stream gradients. In addition, in the drainage area of reconstructed channels, five sites were selected in unmined streams to conduct HHEI and biological HMFEL/MAIS scorings on 200 foot reaches. The drainage areas were obtained using the USGS Streamstats website. A spreadsheet developed by Ohio Department of Natural Resources (ODNR) Division of Water was utilized to process data collected from field investigation.

In addition, the chemical water quality in comparison to target values, as well as floodplain soil tests were also conducted. At both the reconstructed and biological stream reaches, seasonal water samples were collected and submitted to the ODNR-DMRM certified laboratory for analysis of typical mining parameters. Results are compared to the coal mining NPDES Technology Based Limits.

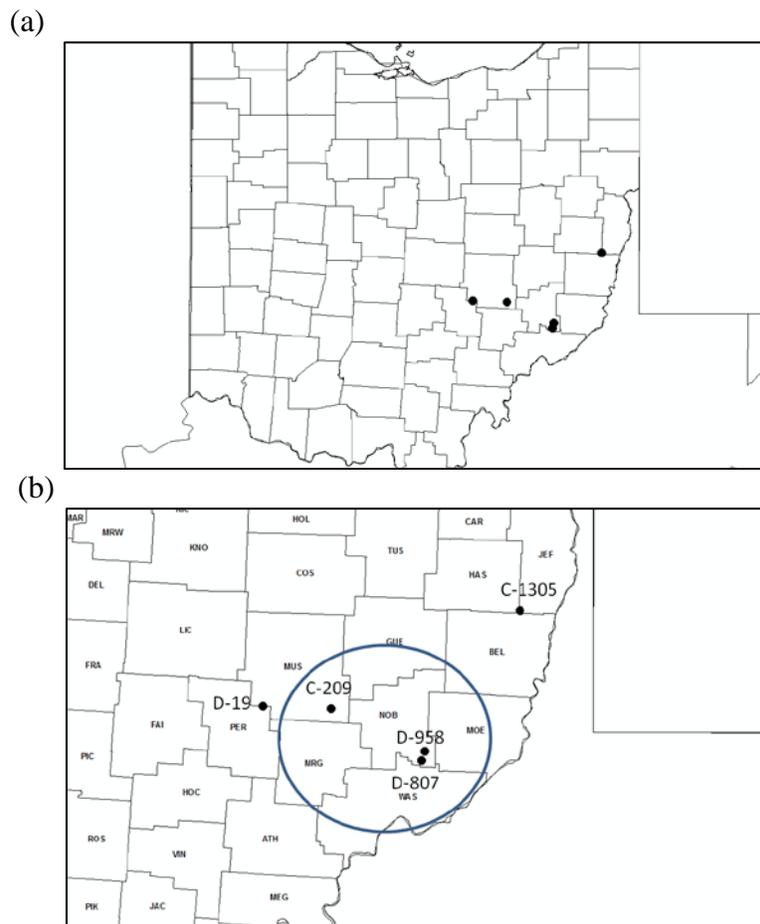


Figure 1. Relative locations of (a) the five selected sites and (b) the three sites reported in this study

3. Results and Discussions

The following results of the three selected sites; i.e., Central Ohio Coal Co. permit C-0209, B&N Coal Co. permits D-0958, and D-0807 (Figure 1(b)) are discussed;

- 1) Current fluvial-geomorphic conditions in comparison to approved stream reconstruction plans or actual reconstruction dimensions;
- 2) Post-mining stream recovery (e.g. stream habitat, stability, channel or flow patterns, and vegetation) in comparison to target values;
- 3) Biological resources in comparison to target values;
- 4) Chemical water quality in comparison to target values;
- 5) Bankfull width compared to calculated flows; and
- 6) Stream classification

3.1 Central Ohio Coal, C-0209

The mining in the area was conducted in 1970's. After mining was completed in 1979, spoil was graded to approximate original contours and covered with 8 inches of resoiling material. A total of 683 acres were affected on the permit. The stream segment investigated for this site is located in Muskingum County within the Meigs creek watershed. The tributary watershed is depicted in Figure 2. The turquoise area represents the stream reach that only HHEI was studied (reconstructed stream reach) and the red spot represents the stream segment where biological assessment was carried out (bio assessment site).

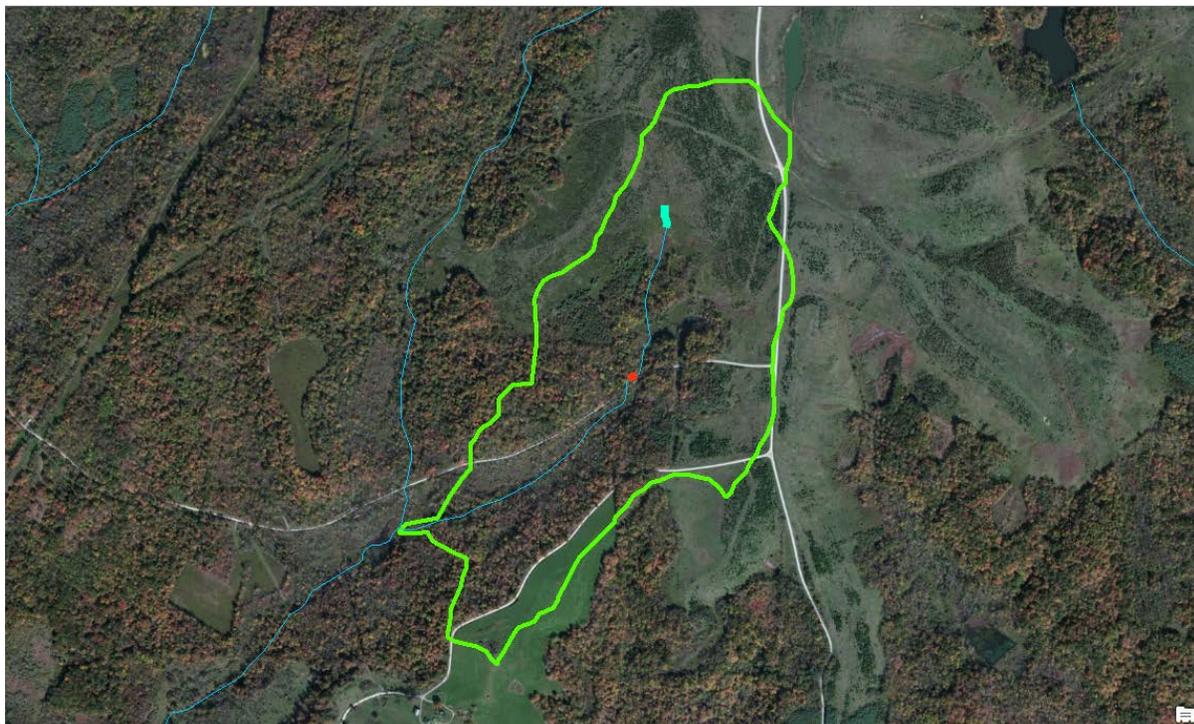


Figure 2. Reconstructed stream reach (turquoise area) and biological assessment site (red spot) locations at C-0209

Reconstructed Stream Reach

The reconstructed stream reach has a drainage area of .12 square miles based on its location within the tributary watershed. However the overall drainage area depicted above has a drainage area of .26 square miles that includes the watershed encompassing the reconstructed channel and the biological site. This number was attained through the use of the StreamStats Ohio website. The reconstructed stream reach has a slope of 13% and an annual mean precipitation of 37.4 inches. The HHEI score for the reconstructed stream reach was 32, and therefore, according to Ohio's PHWH classification, this stream segment is a Class II modified warmwater habitat.

For this stream reach there was a large amount of tree growth observed in riparian zone. There was marginal tree growth near the head of the stream reach, however, in the lower two thirds downstream there were trees that had circumferences of 25, 29, 32, 38, and 44 inches showing substantial growth and vitality.

Biological Assessment Site

The HHEI was also calculated at this stream segment, which is located 1,700 feet downstream of the reconstructed stream segment. The HHEI score of 88 is higher than the one of reconstructed stream reach. The higher HHEI score depicts the increase of biological diversity downstream from the reconstructed stream subsequent to mining of the site. In the riparian zone, there was extensive tree growth with trees surrounding the entirety of the biological stream reach. A riparian width of greater than 10 meters on the left bank and a riparian width of 5-10 meters were observed. On both banks of the biological stream reach there was a floodplain quality of a mature forest or wetland. At the time of the reach observation the stream regime was stream flowing. The stream had an observed sinuosity of greater than 3 and had an observed stream gradient of between 2 ft/100 ft and 10 ft/100 ft, which indicates the gradient of this stream segment is moderate to severe. Using the HHEI score, combining with the PHWH classification system, the biological stream segment can be classified as a Class 3 PHWH (Perennial).

Biological sampling in the stream below drainage of C-209 was completed on July 23rd, 2013. The stream had a fair to good flow located a short distance downstream from the mined areas and the habitat also appeared to be good. Macroinvertebrate sampling was conducted on the headwater stream reach where had suitable habitat for sampling, with riffles present. All organisms collected were preserved in a solution of 70% alcohol. Voucher specimens of crayfish, fish, and salamanders were collected and preserved in separate jars. In addition, Creek Cubs and Black Nosed Dace were also found. The samples were analyzed for identification down to the family level for all the macroinvertebrates.

Water Quality Data for C-0209 stream reaches

Low flow sampling was conducted on 8/15 2003 and all parameters were found to be within the EPA's Coal Mining Technical Based Limits (Figure 3).

Summary

The Ohio EPA's HMFEL scoring metric score of 25 exceeds the minimum of 20 as a Class III headwater stream. Using the "Weight of Evidence" approach, the combination of HHEI score of 88 and the HMFEL score of 25 indicate that the stream segment is a Class III stream, which is considered suitable for cool to cold water adapted aquatic species.

The biological stream segment is located 1,700 feet downstream of the reconstructed stream channel and shows no or minimal impacts from mining and reclamation at the C-0209 permit. After over 30 years following reclamation the tree growth in this reconstructed channel is excellent.

The original design of this reconstructed stream was a typical trapezoidal design, which is predominantly used in the mining industry to convey drainage over steep slopes. It is concluded that this reconstructed stream is in equilibrium and has recovered, which might contribute the excellent growth in the riparian zone of the reconstructed stream channel. However, it is not conclusive whether the trees were volunteers or planted by Central Ohio Coal Co (COCO). American Electric Power, the COCO's parent company, had conducted numerous carbon sequestration tree planting projects in the general area since the permit had been released by ODNR.

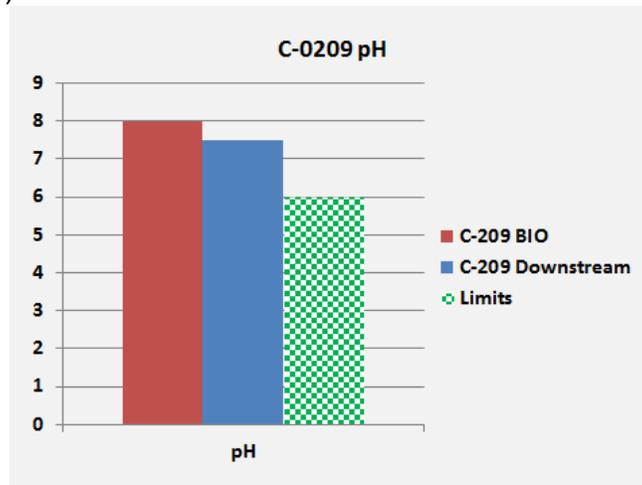
3.2 B&N Coal Co. D-0807

B&N Coal Company conducted strip mining operations at this site in Noble County, where contour mining was conducted with pans and dozers using the block cut approach. The site was reclaimed with 8 inches of resoiling material and the Year 12 segment containing the reconstructed stream was planted in 2001 and released in 2007.

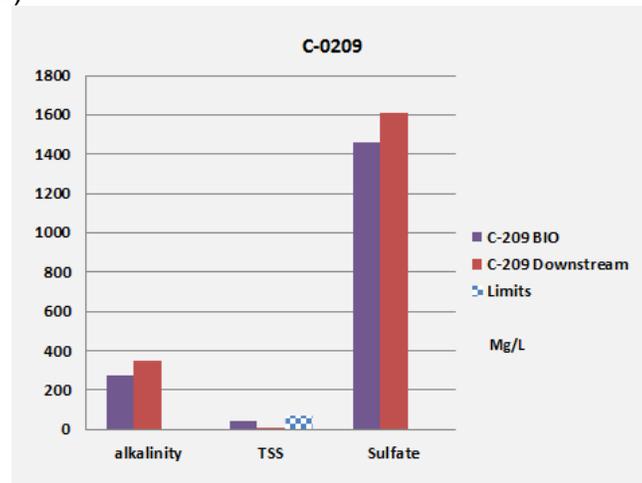
Reconstructed Stream Reach

This reconstructed stream segment is located within the East Fork Duck Creek watershed. The tributary watershed is depicted in Figure 4. The turquoise area represents the reconstructed stream reach and the red area represents the stream segment where biological assessment was conducted. The reconstructed reach has a drainage area of 0.15 square miles based on its location within the tributary watershed. According to StreamStats, the overall drainage area depicted above is about 0.58 square miles. The reconstructed stream reach has a slope of 1% and an annual mean precipitation of 39.6 inches. The HHEI score for the reconstructed stream reach was 35.

(a)



(b)



(c)

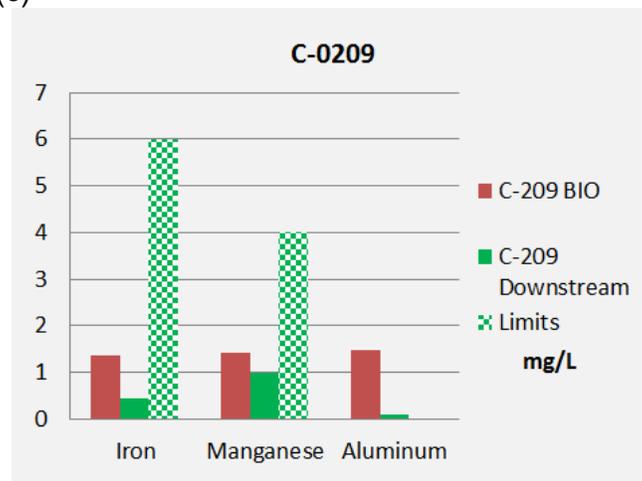


Figure 3. The water quality of the C-0209 Bio and Reconstructed stream reaches stream. (a) pH; (b) concentrations of alkalinity, total suspended solids, and sulfate; (c) Fe, Mn, and Al.

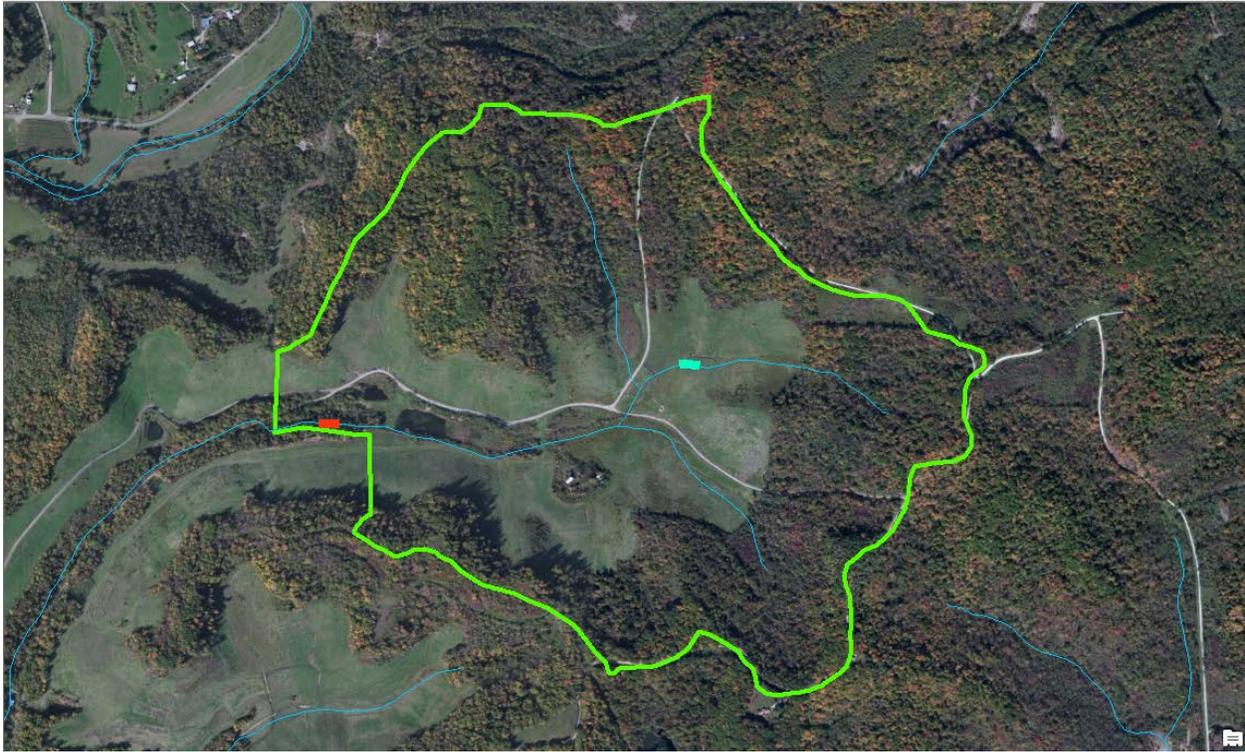


Figure 4. Reconstructed stream reach (turquoise area) and biological assessment site (red area) and biological assessment site locations at D-0807

In addition to acquiring field information to complete the reconstructed stream reach HHEI form, the reach's cross section and bankfull width (BFW) at various locations of this stream segment were also measured. Figure 5 depicts the banks of the channel, the bankful (bkf) elevation, the flood plain elevation (fpa) of Cross Section #2.

According to StreamStats Ohio, the 2 year peak flow for this reach was 87.3 cfs, which is very similar to the a peak 1-2 year bankful flow of 82.08 cfs observed in this study. Table 1 contains detailed hydraulic information of Cross Section #2.

Biological Assessment Site

The summary HHEI score for the stream segment where the biological assessment was carried out is 73. This biological stream segment is located 4,120 feet downstream of the reconstructed stream channel. According to Ohio's PHWH classification, this stream segment can be classified as a Class 3 PHWH (Perennial). A riparian width of greater than 10 meters on the left bank and a riparian width of less than 5 meters on the right bank was observed. On both banks of the biological stream reach there was a floodplain quality of a mature forest or wetland. At the time of the reach observation the stream regime was stream flowing. The stream had an observed sinuosity of 2 and had an observed stream gradient of 2.5 ft/100 ft which is between 2 ft and 10 ft per 100 ft meaning the stream reach has a gradient of moderate to severe.

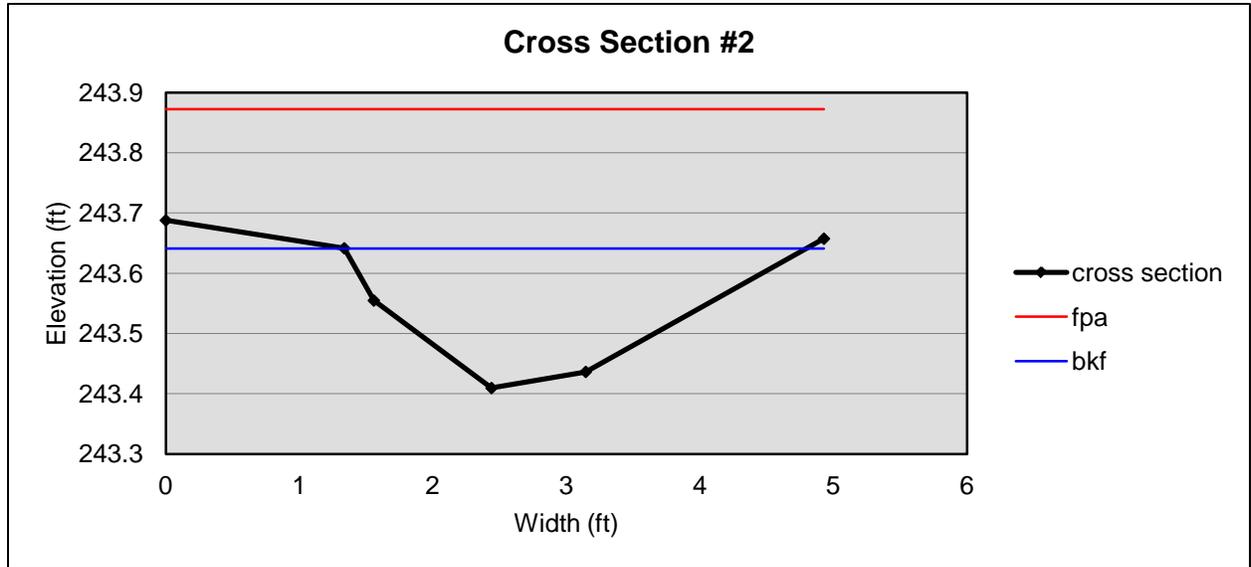


Figure 5. D-0807 Reconstructed Stream Reach

Table 1. D-0807 Cross Section #2 Hydraulic Information

Bankfull Dimensions	
0.5	x-section area (ft.sq.)
3.5	width (ft)
0.1	mean depth (ft)
0.2	max depth (ft)
3.5	wetted parimeter (ft)
0.1	hyd radi (ft)
25.3	width-depth ratio

Biological sampling in the segment downstream of D-0807 was conducted on 6/19, 2013. It was found that the lower two thirds of the 200 foot sample reach consisted of cobble to boulder sized rocks embedded in clay hardpan. This yielded few specimens. The upper third had a good amount of loose shale substrate which yielded the vast majority of the specimens collected. Sample ML-13-001 was taken and later analysis using Ohio EPA's HMFEI scoring metric showed a score of 24, which meets the minimum of 20 for a Class III headwater stream. The abundance of all taxa was low, with the exception of Tricoptera, Caddisflies. Class III streams are considered suitable for cool to cold water adapted aquatic species. In addition, Creek Cubs, Black Nosed Dace present, crayfish, and a larval Northern Two-lined Salamander were also found.

Particle Size Analysis and Water Quality Data for D-0807 stream reaches

When comparing the particle size percent sand, silt and clay there is a consistent correlation between the unmined natural flood plain soils and the soils tested at the reconstructed flood plain. The resoiling materials at the reconstructed site (i.e., D-0807 SR1 and SR2) appear to have excellent properties with respect to particle size (Figure 5 (a)). Low flow sampling was conducted on 6/25, 2013 at the site and all parameters are within EPA's Coal Mining Technical Based Limits Figures 5(b), (c), and (d).

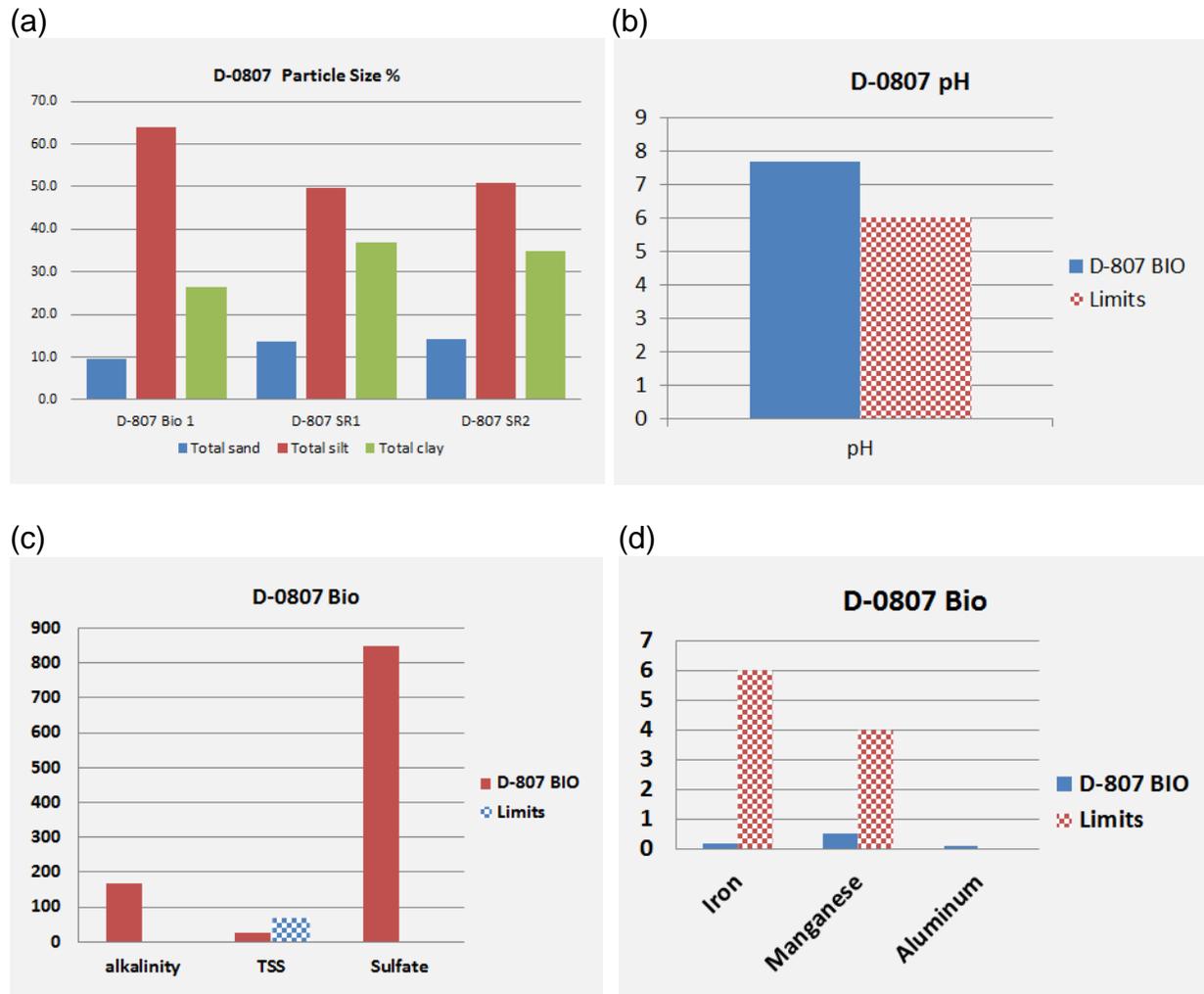


Figure 6. The soil particle size (a) and water quality ((b)-(d)) of the D-0807 Bio and Reconstructed stream reaches stream. (b) pH; (c) concentrations of alkalinity, total suspended solids, and sulfate; (d) Fe, Mn, and Al

Summary

At certain times during the summer low flow season water was not flowing in the channel, but several pools are present and measurable. This intermittent stream is in a state of quasi-equilibrium recovering from the reconstruction period post 7 years.

Using the “Weight of Evidence” approach, the combined HHEI score of 73 and the HMFEI score of 24 indicate that the stream segment where biological assessment was carried out, i.e., biological stream segment, is a Class III stream, which is considered suitable for cool to cold water adapted aquatic species.

This biological stream segment is located 4,120 feet downstream of the reconstructed stream channel and shows no apparent or only minimal impacts from mining and reclamation at the D-0807 permit. The downstream biological assessment site is a class III stream with a diverse biologic community. Additional biological sampling of the reconstructed stream reach will be conducted soon.

3.3 B&N Coal Co. D-0958

This permit was a remining secondary coal recovery operation utilizing pan & dozers to advance and eliminate approximately 12,840 linear feet of unreclaimed highwall and extract the #9 and 9a coal reserves. The site was resoiled with eight inches of suitable alternative resoiling material. Figure 7 depicts the location of the stream segment reconstructed which also reconnected the stream segment with the unaffected drainage area. The natural drainage system was interrupted by past mining practices that left an unreclaimed highwall and pit complex. The Year 6 segment containing the reconstructed stream was planted in 1998 and released in 2003 by ODNR.

Reconstructed Stream Reach

This stream segment is located in Noble County within the East Fork Duck Creek watershed. The tributary watershed is depicted in Figure 8. The turquoise line represents the reconstructed stream reach and the red line represents the biological stream that was analyzed.

The reconstructed reach has a drainage area of .14 square miles based on its location within the tributary watershed. However the overall drainage area depicted above has a drainage area of .7 square miles. This number was attained through the use of the StreamStats Ohio website. The reconstructed stream reach has a slope of 1.5% and an annual mean precipitation of 39.8 inches. The HHEI score for the reconstructed stream reach was 47.

Similarly to D-0807, a survey was conducted at B&N D-0958 to depict various cross sections along the 200 foot stream reach. Cross Section #2 is depicted below in Figure 9. The channel bank is represented by the black line, the bankful (bkf) elevation blue, and the flood plain (fpa) elevation red. The hydraulic information for this particular cross section in stream reach can be found in Table 2.

The peak 1-2 year bankful flow of this stream segment was calculated to be 77 cfs, which is approximate 22% lower than the 2 year peak flow of 98.1 cfs obtained from StreamStats.

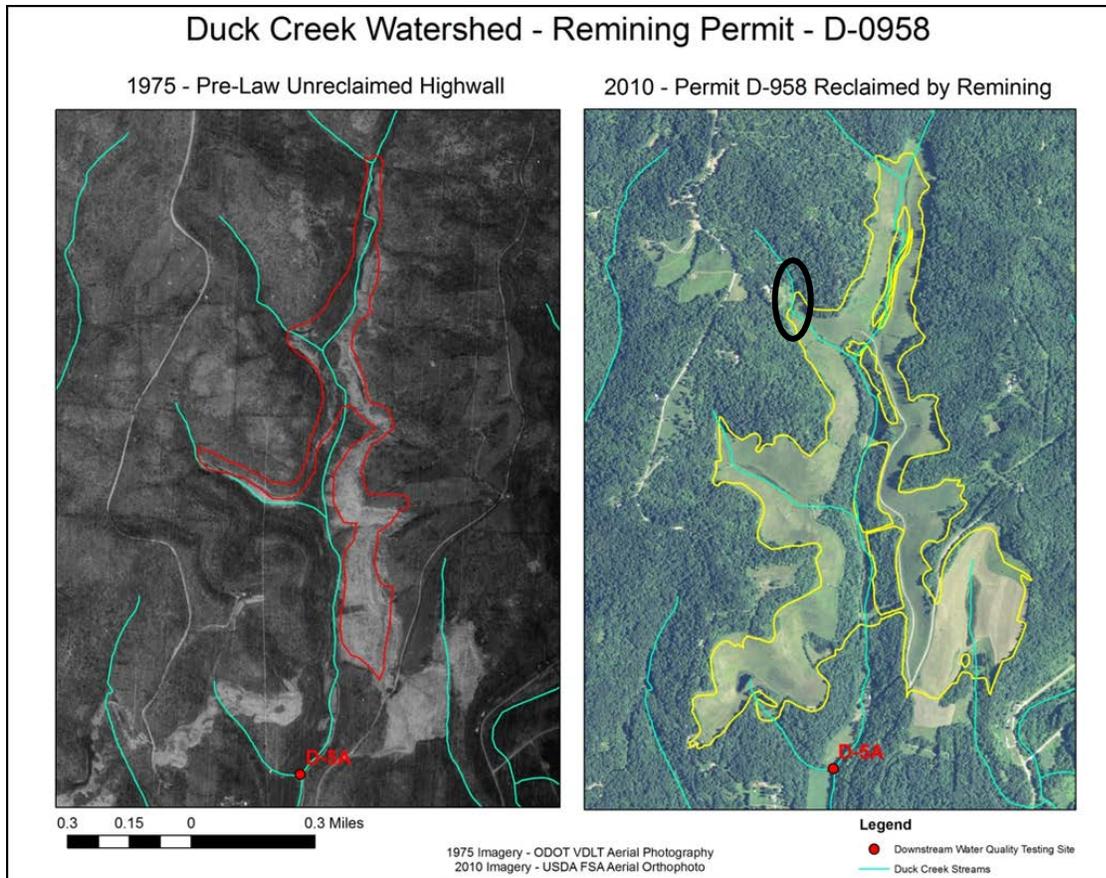


Figure 7. Remining, highwall elimination, and reconnected stream (black oval) D-0958

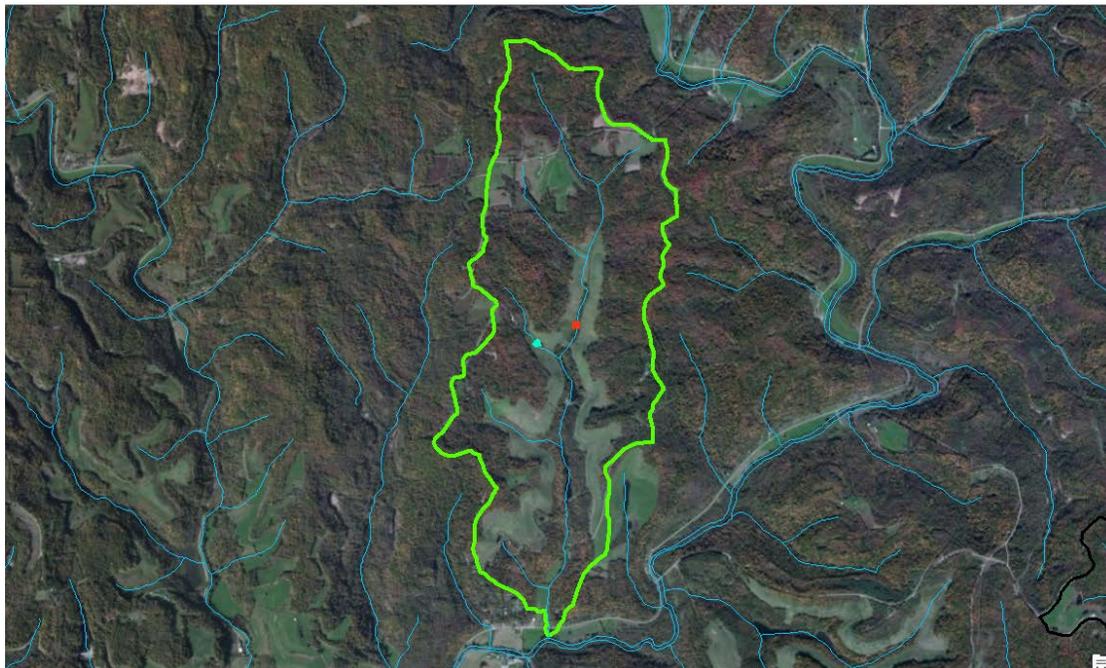


Figure 8. Reconstructed stream reach (turquoise area) and biological assessment site (red area) and biological assessment site locations at D-0958

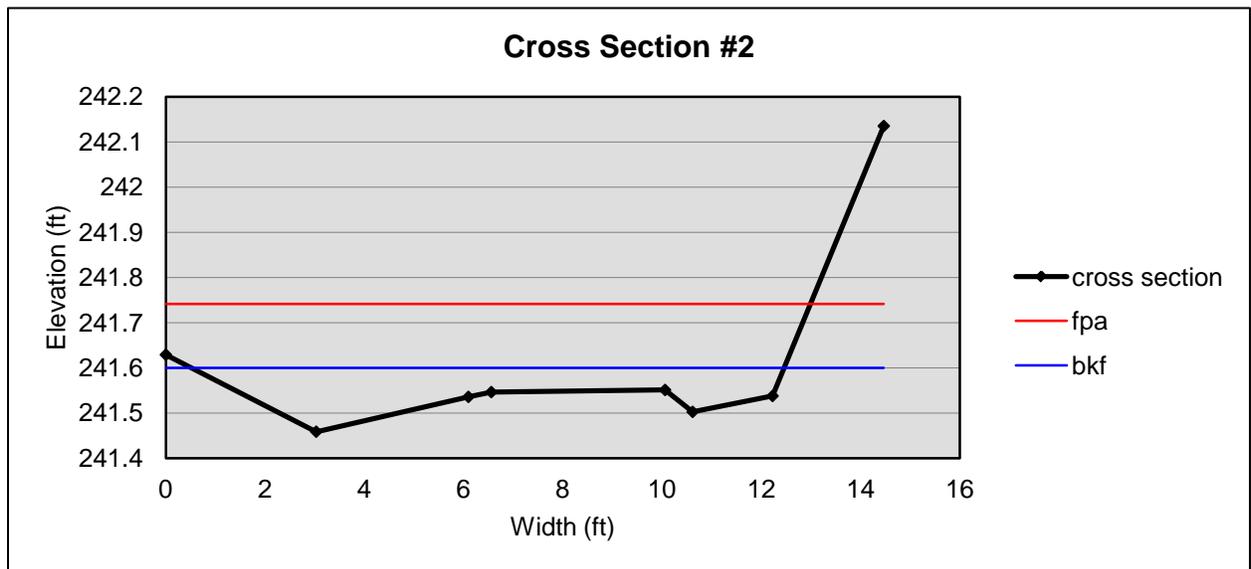


Figure 9. D-0958 Reconstructed Stream Reach Cross Section #2

Table 2. D-0958 Cross Section #1 Hydraulic Information

Bankfull Dimensions	
0.9	x-section area (ft.sq.)
11.9	width (ft)
0.1	mean depth (ft)
0.1	max depth (ft)
12.0	wetted parimeter (ft)
0.1	hyd radi (ft)
162.5	width-depth ratio

Biological Assessment Site

The biological diversity downstream from the reconstructed stream subsequent to remining of the site was evaluated. The summary HHEI score for the D-0958 biological site is 64. A riparian zone of width of 5-10 meters on both left and right sides was observed. On both banks of the biological stream reach there was a floodplain quality of a mature forest or wetland. At the time of the reach observation the stream regime was stream flowing. The stream had an observed sinuosity of 2 and had an observed stream gradient of between 2 ft/100 ft and 10 ft/100 ft meaning the gradient is moderate to severe. Using the HHEI score, combined with PHWH classification flow chart, this

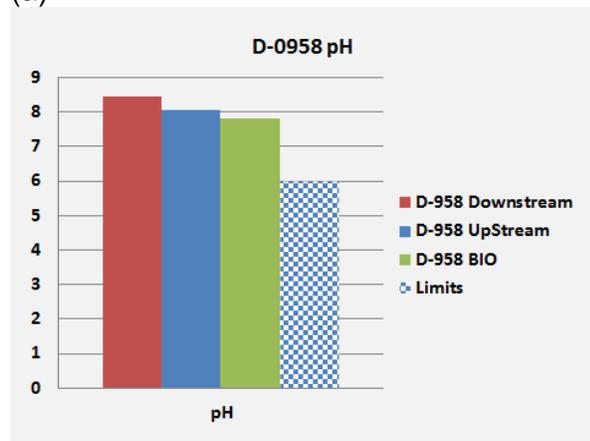
stream segment can be classified as a Class 3 PHWH (Perennial). Biological sampling in the stream adjacent to D-0958 was conducted on 6/19, 2013.

Sample ML-13-002 was taken and later analysis using Ohio EPA's scoring metric showed a score of 28, which indicates the stream is a Class III headwater stream. There were three mayfly families represented with four different taxa, which is unusual in streams coming from mined areas. However, this stream starts upstream of the mined area which may dilute and impacts that sulfates might have on Mayflies. Class III streams are considered suitable for cool to cold water adapted aquatic species. In addition, crayfish and a larval Northern Two-lined Salamander were also found in the stream.

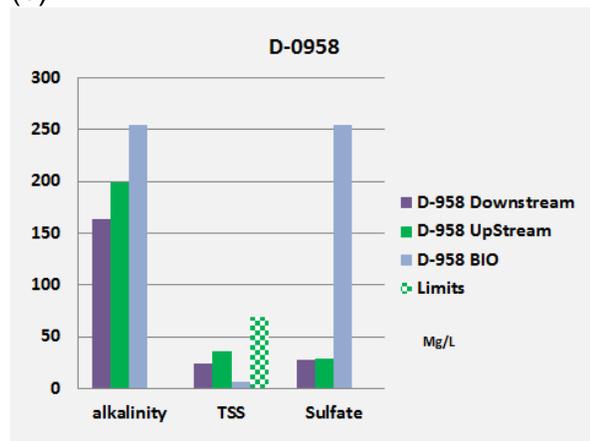
Water Quality Data for D-0958 Bio and Reconstructed stream reaches

Low flow sampling was conducted on 6/25, 2013. All measured parameters were within USEPA's Coal Mining Technical Based Limits shown in Figure 10.

(a)



(b)



(c)

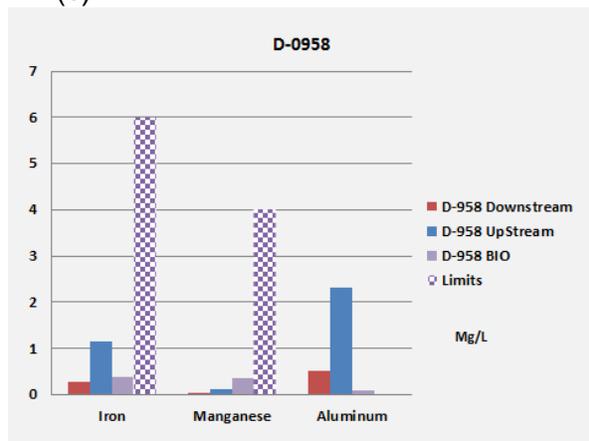


Figure 10. The water quality of the D-0958 Bio and Reconstructed stream reaches stream. (a) pH; (b) concentrations of alkalinity, total suspended solids, and sulfate; and (c) Fe, Mn, and Al

Remining Water Quality

The D-5A sampling point depicted in Figure 11 captures the water quality in the main stem of Rocky Run, below drainage of remining permit D-0958. The water quality data extracted from DMRM permitting shows broad improvements in pH (S.U) and acidity (mg/L as CaCO₃).

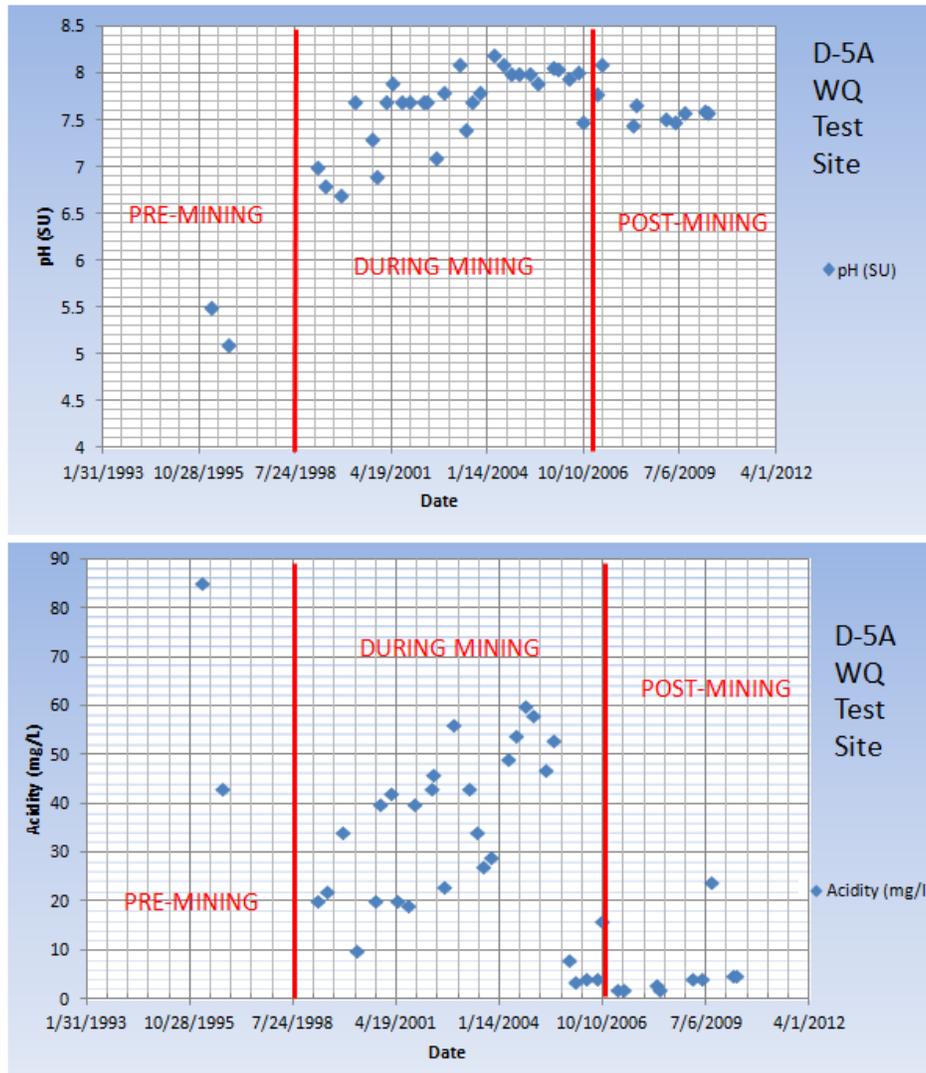


Figure 11. pH and alkalinity of stream water collected from D-5A within the D-0958 remining permit

Summary

The reconstructed stream segment HHEI Score was 47, and is classified as a Modified Class II PHWH intermittent stream. At certain times during the summer low flow season water is not flowing in the channel, but isolated shallow pools are still present and measurable. The intermittent stream is in a state of quasi-equilibrium recovering from

the reconstruction period post 11 years. Using the “Weight of Evidence” approach the combined HHEI score of 64 and the HMFEI score of 28 indicate the biologic stream segment is a Class III stream considered suitable for cool to cold water adapted aquatic species. This biologic stream segment is located 1,320 feet adjacent to the reconstructed stream channel and shows no apparent or only minimal impacts from mining and reclamation at the D-0958 permit. The downstream biological site indicates a class III stream with a diverse biologic community. Additional biological sampling of the reconstructed stream reach will be conducted in the near future. The results will be compared with the biological studies undertaken by B&N coal at this permit.

The results obtained from the stream evaluations of the three sites are summarized in Table 3.

Table 3. Summary of the Stream Evaluation

Permit	Site type	HHEI score	HMFEI score	Stream type	Stream Classification
C-0209	reconstructed	32*	n/a	ephemeral	Class I
C-0209	biological	88	25	perennial	Class III
D-0958	reconstructed	47	n/a*	intermittent	Class II
D-0958	biological	64	25	perennial	Class III
D-0807	reconstructed	35*	n/a*	intermittent	Class II
D-0807	biological	73	21	perennial	Class III

*To be re-evaluated or new evaluations to be conducted

4. Preliminary Conclusions and Recommendations

4.1 Preliminary Conclusions

- 1) The downstream and adjacent biological sites of reconstructed stream segments exhibit Class III bio diversity characteristics and water quality standards are met at all sites.

- 2) The “weight of evidence” suggests stream segments located at D-0958 and D-0807 permits are in a state of quasi equilibrium while C-0209 permit is in equilibrium.

4.2 Recommendations based on current available data

- 1) Consider construction of Two Stage Channels at mine sites. This practice is gaining traction in the agriculture industry, and may have applicability in the mining sector.
- 2) For reconstructed channels increase emphasis and incentives for tree planting in the riparian corridor perhaps in exchange for mitigation credits i.e. per linear foot of stream planted with suitable tree species
- 3) Increase awareness of Ohio coal operators to follow DMRM guidelines for natural channel design and two stage channels where appropriate. Coal Operators and DMRM staff should receive training in this area.



Figure 12. Example Two Stage Channel Cross Section

A typical drainage channel is designed to have a single stage trapezoidal cross section. This channel design is great for efficient downstream water travel; however, with lacking flood plains the channel can experience side bank erosion and sediment buildup. Two Stage channels are designed as such to activate the flood plain and minimize these occurrences. At the first stage, or main channel, a smaller bankful width allows for water velocities high enough to reduce the amount of sediment deposition and promote transport. This sediment transport allows for heterogeneous sedimentation which increases biodiversity. The second stage allows for greater flood control in high storm event flows and an increased stability of the overall channel. For greater stability, the first stage of the channel will be lined with a rock material to counteract bank erosion. Also, two stage channels allow for nutrient removal to occur. With a large channel surface area, denitrification can occur more rapidly. This in turn results in a higher bio-assimilation, or plant growth, allowing for peak flow attenuation. Figure 14 depict a typical two stage channel cross section and an example how a two stage channel would look in the field.

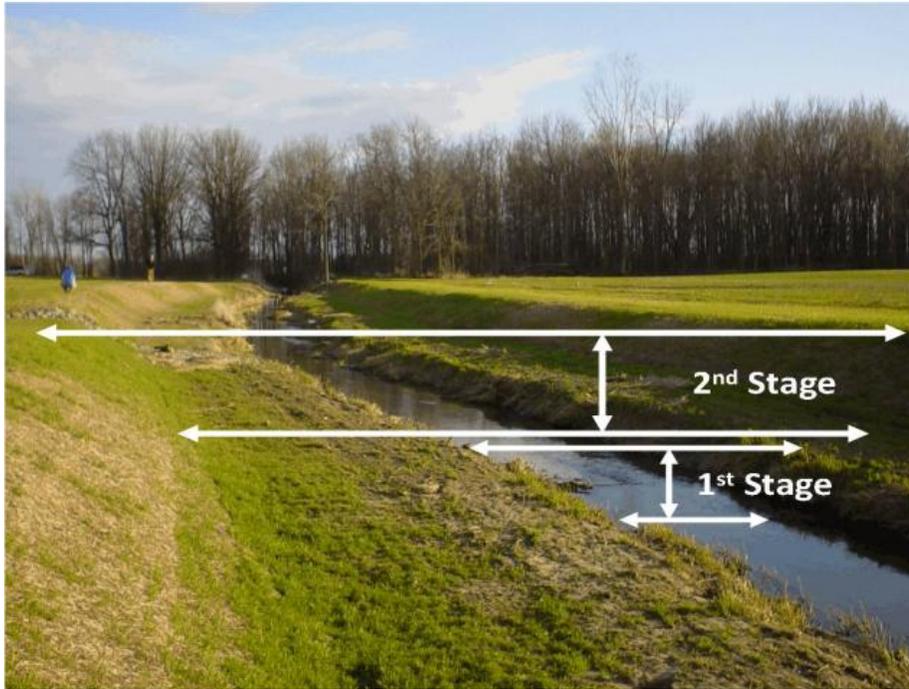


Figure 14. Example Two Stage Channel

5. Works In Progress

Seasonal water quality sampling for all stream segments are to be carried out to provide more chemical properties background of the streams. In addition, additional HMFEI biological evaluations will be carried out at the reconstructed stream sites. The physical profiles of the streams at the segments where biological assessments were carried out will be established. Data collected from this study will be further analyzed to develop final conclusions and recommendations.

Glossary

Bankfull channel	the portion of the channel that is most effective at maintaining itself
Bankfull cross sectional area	the channel area that corresponds to the bankfull flow
Bankfull flow	the discharge at which channel maintenance is most efficient
Bankfull width	the surface width of the stream measured at the stage of the bankfull discharge
w/d ration	the ratio of the bankfull width to the mean depth at bankfull
HHEI	Headwater Habitat Evaluation Index
PHWH	Primary Headwater Habitat
HMFEI	Headwater macroinvertebrate Field Evaluation Index
Weight of evidence	HHEI and HMFEI scores, and BFW compared to streamstats

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