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

Interim update prepared for 2013 IMCC Annual Meeting, April 14th-17th by Ohio State University, Dept. of Civil and Environmental Engineering and Geodetic Science and the DMRM (in cooperation with DMRM and B&N Coal Co.)

Purpose of the Study

- Evaluate and characterize the long – term effects that mining and reclamation practices have had on stream resources 5 to 20 years following reclamation
  - to evaluate and document how effective reclamation of previously disturbed areas through remining has been with respect to improvements in water quality, mitigation of hazards and watershed restoration
  - to make recommendations for improvements to mining and reclamation program areas

Objectives and Outcomes

- Evaluate the physical, biological and chemical characteristics of reconstructed streams and impacts to buffer zones, and compare with similar natural system standards (unmined streams*)*

- Results and data will be useful to Ohio's mining program and will be used to evaluate how effective our regulations and mining practices have been over a long period of time and whether programmatic changes should be made

Scope of Study

- Selection of sub watersheds:
  - A sub-watershed that has not been disturbed by mining
  - At least one sub-watershed that contains per-1972 mining without remining or reclamation
  - At least one sub-watershed that contains post 1972 remining of pre- 1972 mining disturbance
  - At least 2 sub - watersheds with post 1972 that was not previously disturbed by mining practices

Project Schedule and Participants

- October 1st 2012 through January 31st, 2014
- Participants- OSU researchers & students, DMRM hydrologists and interns, OSMRE staff, and input from the coal industry
- Funded by the OSMRE

Task 1- Study Area Locations

- Review of six (6) reconstrutced streams:
- Representative of extraction activities of various coal seams and dissimilar lithologies
- If possible include both Primary Headwater Habitat (PHWH) and non PHWH streams
- Mixture of gradients (no steep rock channels)
- Most streams will be PHWH watershed < 1 square mile
- Compare to control streams where possible

Task 2- DMRM Support

- Collaborative project; background information, file data, shape files, and field assistance
- Use of past biological, chemical, and sediment data from previous studies, ODNR, USGS, OSU, OEPA, watershed groups, or coal companies

Task 3- Hydrology and Floodplain Soils analysis

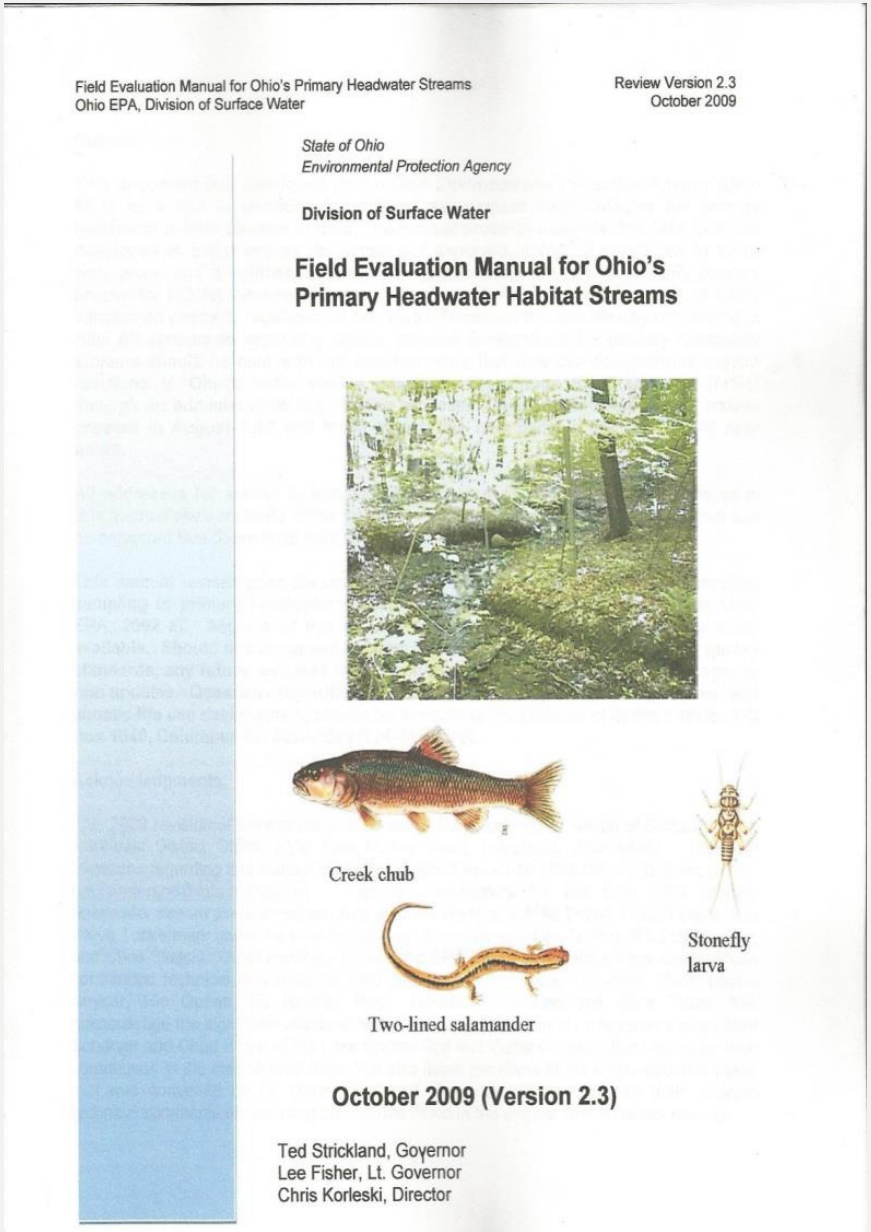
- Evaluate changes in peak flow and runoff volumes for 1 or 2 watersheds, ie. forested to grass cover
- Where reconstructed floodplain soils on low gradient streams are encountered perform laboratory testing of soil quality

OEPA is a national leader

using biological indicators to assess overall stream ecological integrity

established indices of habitat quality (QHEI, HHEI, etc).

Methods are designed specifically to predict and evaluate biology in natural streams and really have not been reconfigured for reconstructed streams



Summary of steps to use to assign and aquatic life use designation to a PHWH stream

- The Headwater Habitat Evaluation Index (HHEI) rapid assessment to determine potential of
    - aquatic life use
    - based entirely on physical measurements

    - by design high probability of over-classifying a stream (class I-III)
- Increased confidence when the HHEI is accompanied with a biological evaluation of the stream
- HHEI should not be used solely for indicator for overall physical integrity for reconstructed streams (based on study and evaluation completed by OEPA and ODNR, Division of Soil and Water Resources, 2010

Ohio EPA Primary Headwater Habitat Evaluation Form

HHEI Score (sum of metrics 1, 2, 3) : ☐

SITE NAME/LOCATION _____

_____ SITE NUMBER _____ RIVER BASIN _____ DRAINAGE AREA (mi²) _____

LENGTH OF STREAM REACH (ft) _____ LAT. _____ LONG. _____ RIVER CODE _____ RIVER MILE _____

DATE _____ SCORER _____ COMMENTS _____

NOTE: Complete All Items On This Form - Refer to "Field Evaluation Manual for Ohio's PHWH Streams" for Instructions

STREAM CHANNEL MODIFICATIONS: ☐ NONE / NATURAL CHANNEL ☐ RECOVERED ☐ RECOVERING ☐ RECENT OR NO RECOVERY

HHEI Metric Points

1. **SUBSTRATE (Estimate percent of every type of substrate present.** Check *ONLY* two predominant substrate *TYPE* boxes (Max of 40). Add total number of significant substrate types found (Max of 8). Final metric score is sum of boxes A & B.

TYPE		PERCENT	TYPE		PERCENT
☐☐	BLDR SLABS [16 pts]	_____	☐☐	SILT [3 pt]	_____
☐☐	BOULDER (>256 mm) [16 pts]	_____	☐☐	LEAF PACK/WOODY DEBRIS [3 pts]	_____
☐☐	BEDROCK [16 pt]	_____	☐☐	FINE DETRITUS [3 pts]	_____
☐☐	COBBLE (65-256 mm) [12 pts]	_____	☐☐	CLAY or HARDPAN [0 pt]	_____
☐☐	GRAVEL (2-64 mm) [9 pts]	_____	☐☐	MUCK [0 pts]	_____
☐☐	SAND (<2 mm) [6 pts]	_____	☐☐	ARTIFICIAL [3 pts]	_____

Total of Percentages of Bldr Slabs, Boulder, Cobble, Bedrock _____ (A) ☐ (B) ☐

SCORE OF TWO MOST PREDOMINATE SUBSTRATE TYPES: **TOTAL NUMBER OF SUBSTRATE TYPES:**

Substrate Max = 40 ☐ **A + B**

2. **Maximum Pool Depth** ***(Measure the maximum pool depth within the 61 meter (200 ft)*** evaluation reach at the time of evaluation. Avoid plunge pools from road culverts or storm water pipes) (Check *ONLY* one box):

☐ > 30 centimeters [20 pts] ☐ > 5 cm - 10 cm [15 pts]
☐ > 22.5 - 30 cm [30 pts] ☐ < 5 cm [5 pts]
☐ > 10 - 22.5 cm [25 pts] ☐ NO WATER OR MOIST CHANNEL [0 pts]

COMMENTS _____ **MAXIMUM POOL DEPTH (centimeters):** ☐

Pool Depth Max = 30 ☐

3. **BANK FULL WIDTH (Measured as the average of 3-4 measurements)** **(Check *ONLY* one box):**

☐ > 4.0 meters (> 13') [30 pts] ☐ > 1.0 m - 1.5 m (> 3' 3" - 4' 8") [15 pts]
☐ > 3.0 m - 4.0 m (> 9' 7" - 13') [25 pts] ☐ ≤ 1.0 m (≤ 3' 3") [5 pts]
☐ > 1.5 m - 3.0 m (> 4' 8" - 9' 7") [20 pts]

COMMENTS _____ **AVERAGE BANKFULL WIDTH (meters)** ☐

Bankfull Width Max=30 ☐

This information must also be completed

RIPARIAN ZONE AND FLOODPLAIN QUALITY ☆NOTE: River Left (L) and Right (R) as looking downstream☆

RIPARIAN WIDTH L	R	(Per Bank)	FLOODPLAIN QUALITY L	R	(Most Predominant per Bank)	L	R	
☐	☐	Wide >10m	☐	☐	Mature Forest, Wetland	☐	☐	Conservation Tillage
☐	☐	Moderate 5-10m	☐	☐	Immature Forest, Shrub or Old Field	☐	☐	Urban or Industrial
☐	☐	Narrow <5m	☐	☐	Residential, Park, New Field	☐	☐	Open Pasture, Row Crop
☐	☐	None	☐	☐	Fenced Pasture	☐	☐	Mining or Construction

COMMENTS _____

FLOW REGIME *(At Time of Evaluation)* (Check *ONLY* one box):

☐ Stream Flowing ☐ Moist Channel, isolated pools, no flow (Intermittent)
☐ Subsurface flow with isolated pools (Interstitial) ☐ Dry channel, no water (Ephemeral)

COMMENTS _____

SINUOSITY (Number of bends per 61 m (200 ft) of channel) (Check *ONLY* one box):

☐ None ☐ 1.0 ☐ 2.0 ☐ 3.0
☐ 0.5 ☐ 1.5 ☐ 2.5 ☐ >3

STREAM GRADIENT ESTIMATE

☐ Flat (0.5 ft/100 ft) ☐ Flat to Moderate ☐ Moderate (2 ft/100 ft) ☐ Moderate to Severe ☐ Severe (10 ft/100 ft)

June 20, 2008 Revision

Stream Channel Modifications

a. none/ natural channel
b. Recovered
c. Recovering
d. Recent or no recovery

HHEI score in 200 ft reference reaches

- Sum of metrics
  - 1- substrate
  - 2- maximun pool depth
  - 3- bank full width
- Other data
  - riparian width , floodplain quality,
  - flow regime, and stream gradient
  - stream channel: natural, recovered, recovering, or recent or no recovery

ADDITIONAL STREAM INFORMATION (This Information Must Also be Completed):

QHEI PERFORMED? - ☐ Yes ☐ No QHEI Score _____ (If Yes, Attach Completed QHEI Form)

DOWNSTREAM DESIGNATED USE(S)

☐ WWH Name: _____ Distance from Evaluated Stream _____
☐ CWH Name: _____ Distance from Evaluated Stream _____
☐ EWH Name: _____ Distance from Evaluated Stream _____

MAPPING: ATTACH COPIES OF MAPS, INCLUDING THE ENTIRE WATERSHED AREA. CLEARLY MARK THE SITE LOCATION

USGS Quadrangle Name:_____ NRCS Soil Map Page:_____ NRCS Soil Map Stream Order _____

County: _____ Township / City:_____

MISCELLANEOUS

Base Flow Conditions? (Y/N):_____ Date of last precipitation:_____ Quantity:_____

Photograph Information: _____

Elevated Turbidity? (Y/N): _____ Canopy (% open): _____

Were samples collected for water chemistry? (Y/N): _____ (Note lab sample no. or id. and attach results) Lab Number:_____

Field Measures: Temp (°C)_____ Dissolved Oxygen (mg/l) _____ pH (S.U.) _____ Conductivity (µmhos/cm) _____

Is the sampling reach representative of the stream (Y/N)_____ If not, please explain:_____

_____

Additional comments/description of pollution impacts:_____

_____

BIOTIC EVALUATION

Performed? (Y/N): _____ (If Yes, Record all observations. Voucher collections optional. NOTE: all voucher samples must be labeled with the site ID number. Include appropriate field data sheets from the Primary Headwater Habitat Assessment Manual)

Fish Observed? (Y/N)_____ Voucher? (Y/N)_____ Salamanders Observed? (Y/N)_____ Voucher? (Y/N)_____
Frogs or Tadpoles Observed? (Y/N)_____ Voucher? (Y/N)_____ Aquatic Macroinvertebrates Observed? (Y/N)_____ Voucher? (Y/N)_____

Comments Regarding Biology:_____

_____

_____

DRAWING AND NARRATIVE DESCRIPTION OF STREAM REACH (This must be completed):

Include important landmarks and other features of interest for site evaluation and a narrative description of the stream's location

FLOW ➜

3. Macroinvertebrate Scoring Sheet:

THE HEADWATER MACROINVERTEBRATE FIELD EVALUATION INDEX (HMFEI) SCORING SHEET

Indicate Abundance of Each Taxa Above each White Box.

Record HMFEI Scoring Value Points Within each Box.

For EPT taxa, also indicate the different taxa present.

Key: V = Very Abundant (> 50); A = Abundant (10 -50); C = Common (3 -9); R = Rare (< 3)

Sessile Animals (**Porifera, Cnidaria, Bryozoa**) (HMFEI pts = 1)	Crayfish (**Decapoda**) (HMFEI pts = 2)	Fishfly Larvae (**Corydalidae**) (HMFEI pts = 3)
Aquatic Worms (**Turbellaria, Oligochaeta, Hirudinea**) (HMFEI pts = 1)	Dragonfly Nymphs (**Anisoptera**) (HMFEI pts = 2)	Water Penny Beetles (**Psephenidae**) (HMFEI pts = 3)
Sow Bugs (**Isopoda**) (HMFEI pts = 1)	Riffle Beetles (**Dryopidae, Elimidae, Ptilodactylidae**) (HMFEI pts = 2)	Cranefly Larvae (**Tipulidae**) (HMFEI pts = 3)
Scuds (**Amphipoda**) (HMFEI pts = 1)	Larvae of other Flies (**Diptera**) Name: (HMFEI pts = 1)	EPT TAXA* Total No. EPT Taxa = _____
Water Mites (**Hydracarina**) (HMFEI pts = 1)	Midges (**Chironomidae**) (HMFEI pts = 1)	Mayfly Nymphs (**Ephemeroptera**) Taxa Present: [HMFEI pts = No. Taxa (x) 3]
Damselfly Nymphs (**Zygoptera**) (HMFEI pts = 1)	Snails (**Gastropoda**) (HMFEI pts = 1)	
Alderfly Larvae (**Sialidae**) (HMFEI pts = 1)	Clams (**Bivalvia**) (HMFEI pts = 1)	Stonefly Nymphs (**Plecoptera**) Taxa Present: [HMFEI pts = No. Taxa (x) 3]
Other Beetles (**Coleoptera**) (HMFEI pts = 1)	Other Taxa :	
Other Taxa:	Other Taxa:	Caddisfly Larvae (**Trichoptera**) Taxa Present: [HMFEI pts = No. Taxa (x) 3]
Other Taxa:	Other Taxa	

*Note: EPT identification based upon Family or Genus level of taxonomy

Voucher Sample ID_____ Time Spent (minutes):_____

Notes on Macroinvertebrates: (Predominant Organisms; Other Common Organisms; Diversity Estimate)

_____

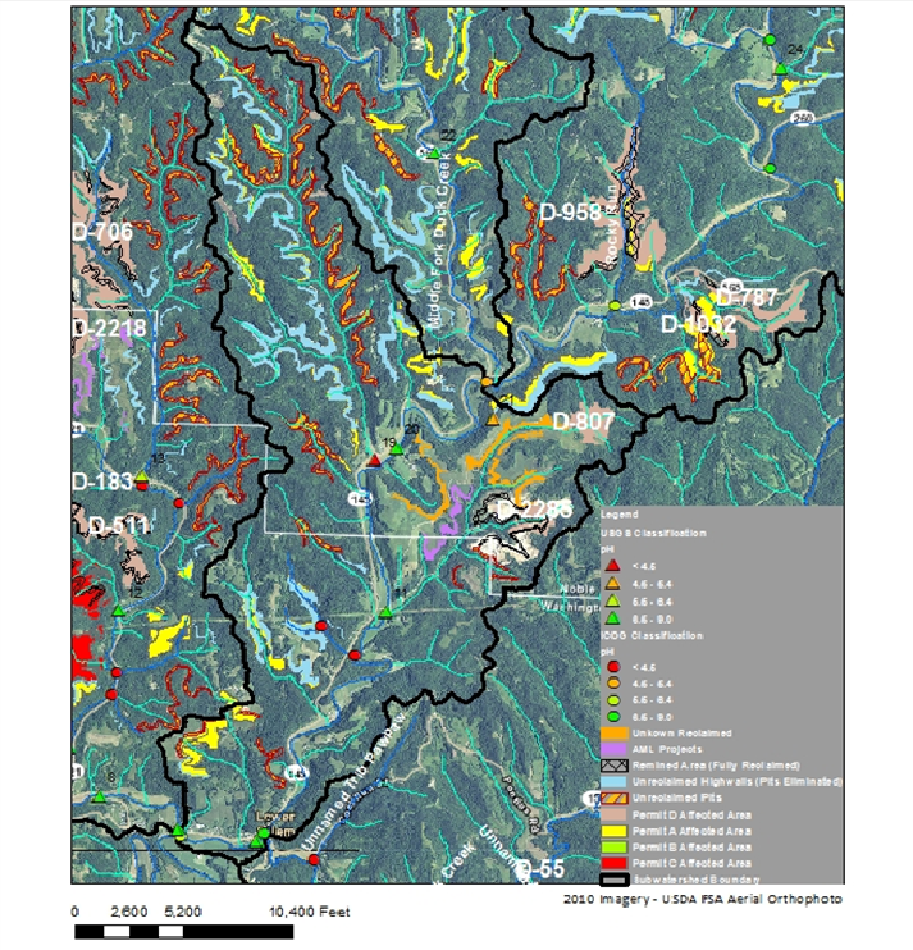
_____

_____

Final HMFEI Calculated Score (Sum of All White Box Scores) = ☐

IF Final HMFEI Score is > 19, Then CLASS III PHWH STREAM
IF Final HMFEI Score is 7 to 19, Then CLASS II PHWH STREAM
IF Final HMFEI Score is < 7, Then CLASS I PHWH STREAM

Study Area location sites # 1 and # 2 – East Fork Duck Creek B&N Coal Co. Inc.
D-0958 and D-0807



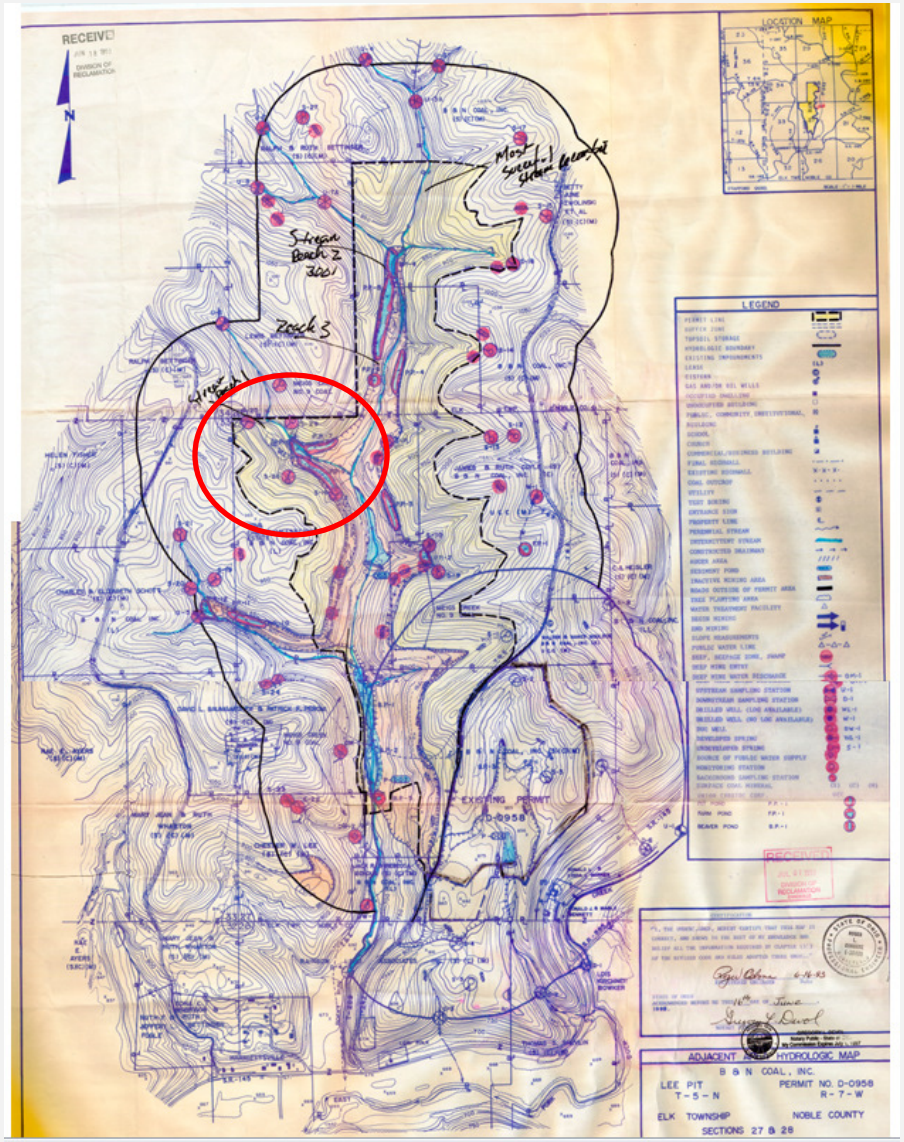
B&N Coal- D-0958 Stream Reach 1

Total Acreage – approx. 235.7

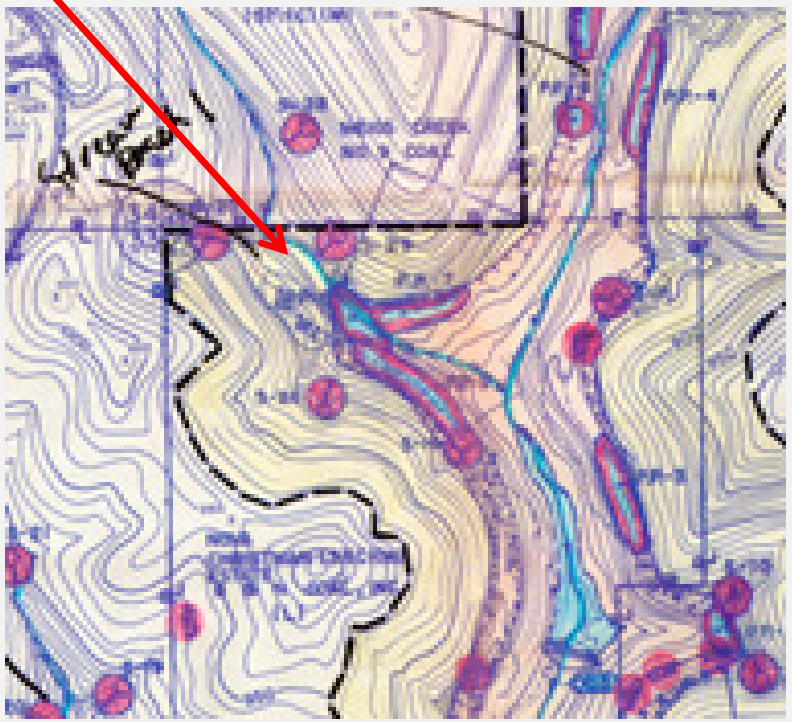
1951 Imagery

2010 Imagery

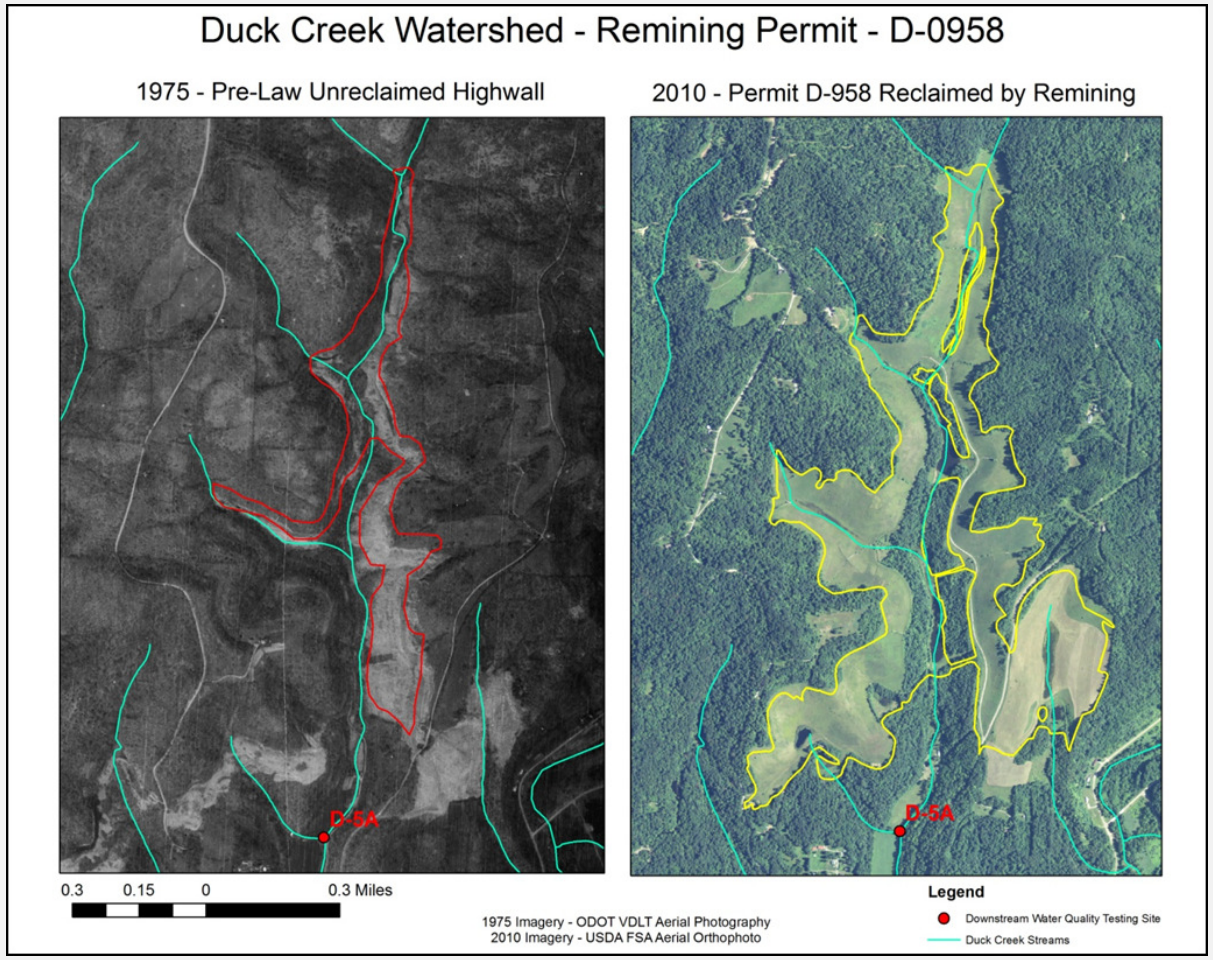
Permit D-0958 issued 2003



Stream reach 1



Remined Acreage – approx. 80.886
Highwall length eliminated – approx. 3.127 miles



B&N D-0958 Stream Reach 1

2010 Imagery

1951 Imagery

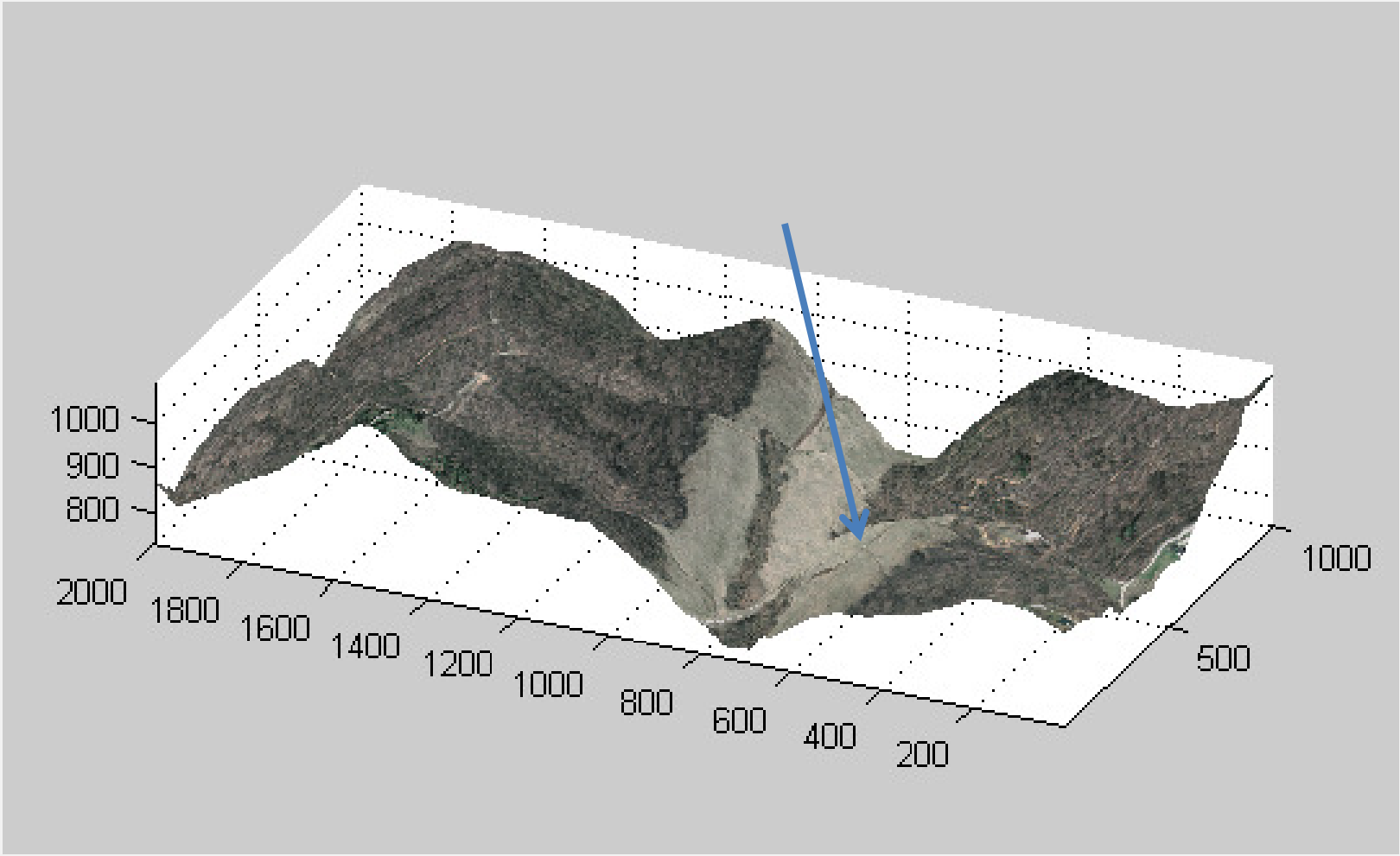
B&N Coal D-0958 Stream Reach # 1

Total Acreage – approx. 68

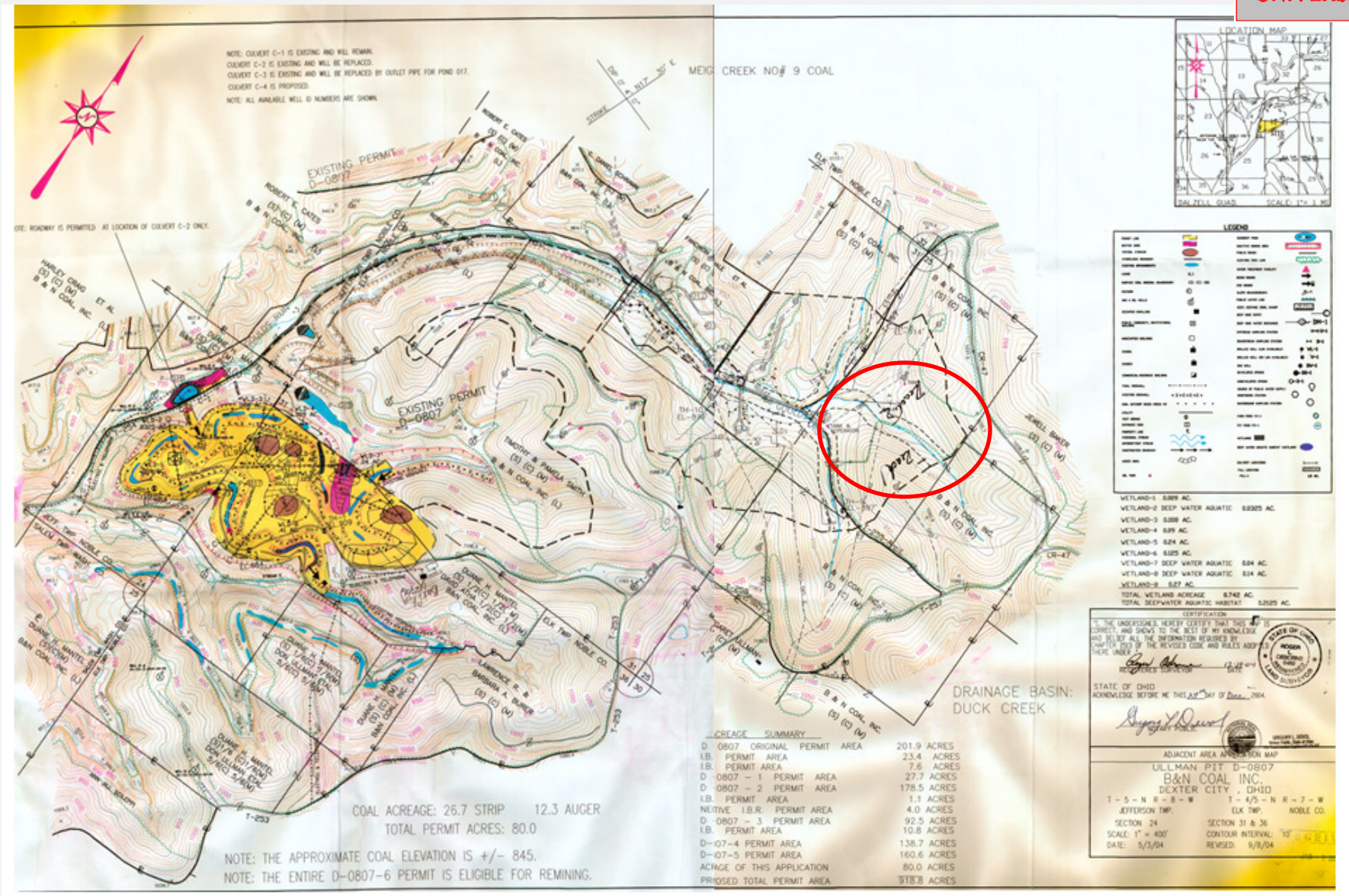
Year 6 was planted on 12-4-98 and was released on 8-19-03

Physical measurements

D-0958 LiDAR 3-D Image



Permit D-0807 issued 2010



B&N D-0807 Stream Reach 1

Year 12 was planted on 11-17-01 and was released on 5-1-07.

D-807 Stream Reach 1 & 2

Work to be accomplished at stream segment sites

- seasonal sampling for water chemistry
- flows
- at least one biological evaluation
- physical profile

Regulatory Perspective

Roger Osborne, P.E. Vice President
of B&N Coal Co.

Preliminary Findings for the Study:

Evaluating the Ecological Lift Provided by Remining

Presented by Roger Osborne
B&N Coal, Inc.

With Research provided by

Kleski Environmental Services

Introduction

- B&N is working with scientists from Kleski Environmental Services and Ohio University to provide the scientific research necessary to meet the goals of this study.

- In addition, B&N is working cooperatively with OSU/ODNR-DMRM in providing research for their study titled “Assessment of Stream Resources at Regulated Coal Mining and Remining Sites in Ohio”.

- Today’s presentation is divided into four Parts and is being presented by Roger Osborne of B&N Coal, Inc.

    1. Introduction/Study Objective/Study Methods
    2. Preliminary Study Data
    3. Preliminary Statistical Analysis
    4. Results and Conclusions

Part I

Background /Study Objectives/
Time Line/Site Selection/Methods

Background and Objectives

(All Mining is not equal)

- The EPA determined:
  - Mining activities impair benthic communities downstream of mining activities.
- Results of literature search show:
  - Few long term studies have been conducted on changes in aquatic communities down stream of mine sites.
  - Even fewer long term studies address changes in aquatic communities downstream of remine sites.
- Focus of study:
  - To evaluate both temporal and spatial changes in aquatic communities downstream of undisturbed sites and remine sites in small headwater streams.
- Principal goal of study:
  - To measure the ecological lift provided to a stream's aquatic community as a result of the remining activity.
- Secondary goal of study:
  - To anticipate the ecological lift provided to an aquatic community by remining.

Time Line of Study Plan Development and Initiation of Study

- Summer 2010: Initial look at aquatic communities on current mined sites; remine sites; and sites where no mining has taken place.
- Summer 2011: Expansion of assessment into additional remine sites and mine sites of varying age of completion.
- 2012: Statistical analysis of the data collected in 2010 and 2011
  - Four significantly different macroinvertebrate communities are present within the data sets. (p <.05)
  - Four distinct groups of chemical water quality are present within the data sets, three are significantly different. (p <.05)
- Spring 2013: Develop study plan to be initiated during field season 2013 to meet the goals of the study
- Summer 2013: Initiate sampling for study
- Spring 2014: Report initial findings and formalize outline of long term study.

Site Selection

- Stream Criteria
  - Stream meets OEPA's definition of Primary Headwater stream.
    - Watershed <1.0 mi2
    - Pools <40 cm.
  - Stream falls within the Duck Creek Watershed

- Streams meet one of three categories of mining
  - Permitted for mining
  - Permitted for remining/AML site
  - No Mining (may have other disturbances)

Sampling Methods: Hydrology/Chemistry

- Qualitative (Continuous)
  - Determine ionic composition of streams
  - Determine concentration/loading of key constituents
  - Evaluate spatial and temporal trends
  - Perform comparative analysis between ionic composition, loading and macroinvertebrate communities

- Quantitative (Continuous)
  - Volumetric (smaller flows)
  - Cutthroat Flume (moderate flows)
  - Electromagnetic Flow Meter (larger flows)
  - Define hydrologic regime/flow permanence
  - Perform comparative analysis between hydrologic regime and macroinvertebrate communities

Sampling Methods: Biological

- Macro Invertebrate Sampling (June 15 through October 30)
  - HMFEI (OEPA Primary Headwater)
    - Qualitative to family level
    - 200 foot reach
    - Dip net/Substrate Collection
  - Modified Bucket (Fritz, et. al., 2006. Moore, 2010.)
    - Quantitative to genus/species level
    - 100 meter reach
    - 4 pools/4 riffles within confines of bucket

- Vertebrate Sampling
  - VES for Salamanders
    - 30 foot reach
    - Dip net/Substrate Collection
  - Fish
    - Observations within study reach
    - Dip net/Seining

Sampling Methods: Physical

Dimensional Analysis
(Rosgen Techniques)

- Longitudinal Profile
  (Slope; Riffle/Run/Pool/Glides)
- Cross Sections
  (Bkf Width; Bkf Depth (Mean & Max); Wetted width; Active channel width)
- Plan Form
  (Meander length; Amplitude; Radius of Curvature)
- Substrate
  (Wohman Pebble Count; Wet Sieve Analysis)

Habitat Evaluation

- Ohio EPA HHEI (Three metrics)
  - Substrate (Observed)
  - Depth of Water in Pool
  - Bankfull Width
- Riparian Condition
  (Composition/Density/Light)

Primary Study Data

PART II

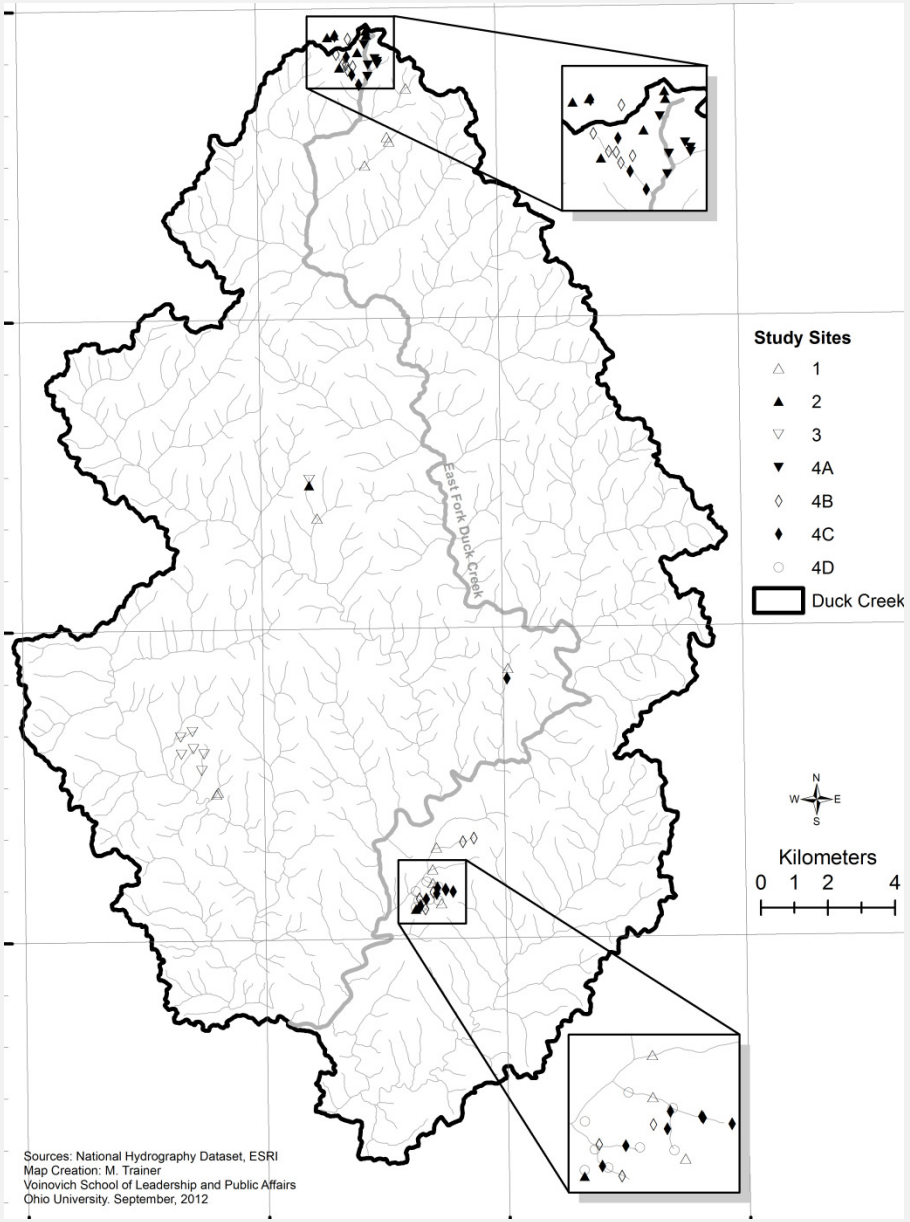
Preliminary Study
Duck Creek Watershed

- Preliminary data was taken from Study Segments that cluster around 10 different surface coal mining sites.

- HMFEI Protocol Used (family level)
- 65 Study Segments were sampled and the data used within the preliminary study.

- Results from five mine sites totaling 14 study segments are presented , all representing different ages of mining or remining:

Lee Pit	West Fork I/II
Barnesridge	Estadt V
Ullman V	



Estadt V

AML Reclamation 15 yrs. old

- Remine Site
- Grading and resoiling; drainage control; under drains
- Three sites monitored
  - #1 on the fill
  - #2 outfall of pond
  - #3 down stream of project

Site	#1	#2	#3
HHEI	63	74	76
HMFEI	5	25	37
Taxa Richness (family level)	3	14	17
EPT Taxa Richness (family level)	0	5	9
pH	3.8	7.92	8.26
Acidity	181	4.54	2.42
SC	1146	813	762
Iron	54.70	1.60	.56

Barnesridge

Reclamation 13 yrs. old

- Undisturbed Area
- Reconstructed using SMCRA criteria
- Three sites monitored
  - #1 and #2 on the fill
  - #3 down stream of pro

Post Mining Quality	Site #1	Site #2	Site #3
HHEI	44	63	77
HMFEI	17	33	25
Taxa Richness (family level)	14	27	14
EPT Richness (family level)	3	4	3
pH	7.85	7.95	8.08
Acidity	6.19	4.04	7.07
Conductivity	1386	1225	1487
Iron	.17	.17	.35

Lee Pit

Reclamation 12 yrs. old

- Remine Site
- Steam reconstructed using NCD
- Two sites monitored
  - #1 on the fill
  - #2 below the fill

Site	Site #1	Site #2
HHEI	57	57
HMFEI	24	43
Taxa Richness (family level)	14	25
EPT Richness (family level)	2	10
pH	8.26	7.95
Acidity	.64	7.16
SC	435	857
Iron	1.91	.46

Ullman V

Reclamation 4 yrs. old

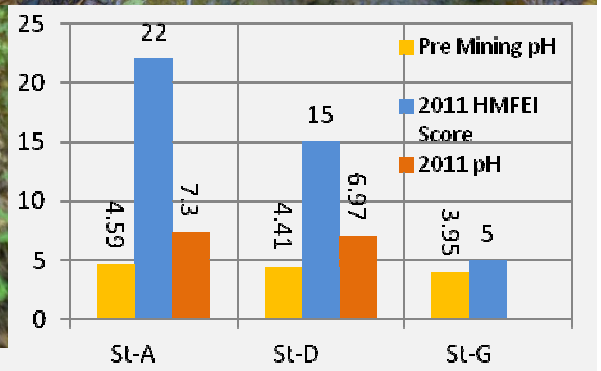
- Remining Site
- Stream reconstructed using NCD
- Three sites monitored
  - #1 and #2 on the fill
  - #3 downstream of project

Site	#1	#2	#3
HHEI	NA	72	68
HMFEI	17	22	23
Taxa Richness (family level)	11	10	11
EPT Richness (family level)	4	6	4
pH	NA	7.81	8.02
Acidity	NA	11.16	11.45
SC	NA	1522	1907
Iron	NA	.15	.28

West Fork I/II

Remining Current (<1yr)

- Remine Site
- Phase I reclamation remining site
  - #1 downstream
- Active remining
  - #2 downstream
- Unreclaimed Remine Site
  - #3 downstream



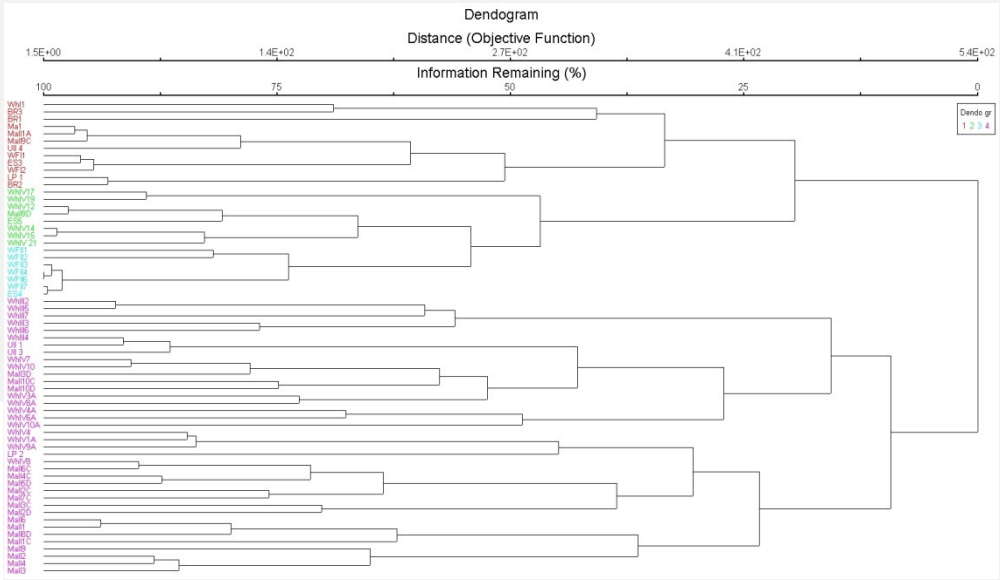
Site	#1	#2	#3
HHEI	66	57	60
HMFEI	22	15	5
Taxa Richness (family level)	12	12	5
EPT Taxa Richness (family level)	2	1	0
pH	7.3	6.97	3.95
Acidity	17.97	2.87	139.68
SC	1368	1272	1430
Iron	.05	.07	2.31

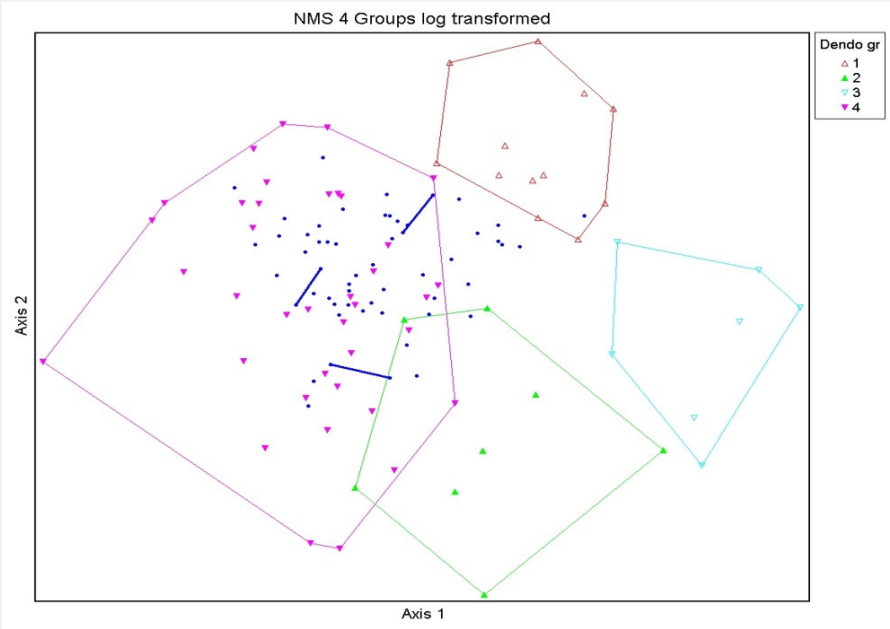
Preliminary Results of Statistical Analysis

PART III

Preliminary Results Statistical Analysis Macroinvertebrate Community and Water Chemistry

- Cluster analysis preformed first
  - Included all sites sampled in 2010/2011
  - A total of 65 sites were included in analysis
  - Four distinct macroinvertebrate communities were identified





- Multidimensional Scaling Performed Next
  - All taxonomic data and all water chemistry data collected for each site were analyzed.
  - Four groups were defined correlating with the four macroinvertebrate communities.

(Stress = 18.9%.)

Preliminary Results Statistical Analysis
Factor of Significance

Multi-response permutation procedures (MRPP) used to determine significance:

- The 4 groups of macroinvertebrate communities were significantly different ($p \leq 0.05$)
- 3 out of 4 groups representing different water chemistries were significantly different ($p \leq 0.05$) (Groups 2 and 4 were not found to be significantly different)

Table 2. Results of multiple-response permutation procedure test by water chemistry variables ($p \leq 0.001$).

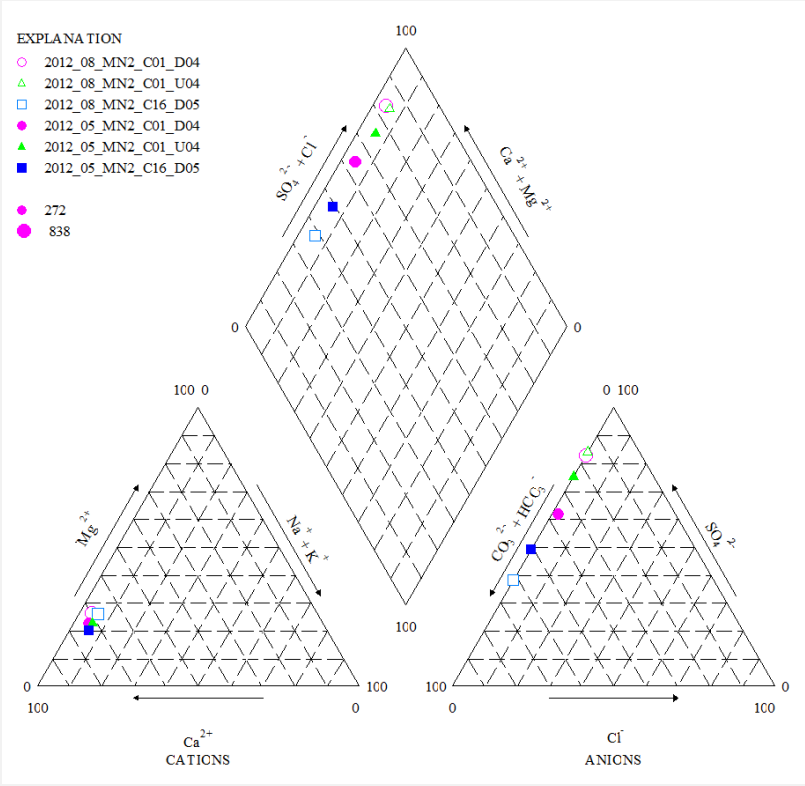
Cluster analysis group	T	Within Group Agreement	P Value
1 v 4	-7.396	0.087	< 0.001
1 v 2	-5.515	0.208	< 0.001
1 v 3	-5.579	0.141	< 0.001
4 v 2	-0.207	0.002	0.33
4 v 3	-11.17	0.118	< 0.001
2 v 3	-7.324	0.271	< 0.001
Group	Avg. Within-Group Distance		
1	0.342		
2	0.423		
3	0.285		
4	0.712		

Table 1. Results of multiple-response permutation procedure test by taxa ($p \leq 0.001$).

Cluster analysis group	T	Within Group Agreement	P Value
1 v 4	-11.169	0.137	< 0.001
1 v 2	-7.223	0.201	< 0.001
1 v 3	-5.602	0.141	< 0.001
4 v 2	-6.433	0.089	< 0.001
4 v 3	-7.012	0.101	< 0.001
2 v 3	-3.706	0.137	< 0.001
Group	Avg. Within-Group Distance		
1	0.311		
2	0.550		
3	0.135		
4	0.384		

Preliminary Results Statistical Analysis Chemical Water Quality

- Tri-linear Plots Define Sites based on Ionic composition.
  - A range of ionic composition is defined along a continuum as shown on the tri-linear plot.
  - This range corresponds with degree of chemical impairment associated with reclaimed surface mining
  - Based on this evidence further comparative analysis is to be performed between ionic composition and the macroinvertebrate community at the study sites.



Conclusion

PART IV

Conclusion

- It is evident from the preliminary data that water quality within mine sites and remine sites vary widely and that macroinvertebrate communities group according to a range of chemical water quality.

- It is also evident from the statistical results that other variables may be influencing the macroinvertibrate communities.
  - One group of macroinvertebrates dominated the other three totaling more than half the study segments.
  - Two cluster groups based on chemistry were not significantly different.

Long Term Study is Needed

- By linking the structure of macroinvertebrate communities to varying water chemistry from mine and remine sites, mining companies and the regulatory community can begin to anticipate changes in macroinvertebrate community structure.
- Water chemistry and macroinvertebrate sampling needs to continue.
- A comprehensive study plan as presented has been developed to do just that.
- Additional stream characteristics identified as influencing the quality of macroinvertebrate communities have been targeted for data collection.
- By including these additional key features in the statistical analysis, a clearer structure of the macroinvertebrate communities may emerge.