ESTABLISHMENT OF VEGETATION IN CONSTRUCTED WETLANDS USING BIOSOLIDS AND QUARRY FINES

by

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Abstract. A common problem with constructing wetlands on abandoned mine sites is the lack of adequate soil needed to establish vegetation. One component of a full-scale passive treatment system, built at Jennings Environmental Education Center in Brady Township, Butler County, PA, addressed this issue through the development of a "field trial" to find an inexpensive alternative substrate for wetland plants. A simple soil substitute "recipe" was followed which called for the mixing of an inorganic material with a nutrient-rich organic material. The inorganic constituent used was silt-size pond cleanings from a sand and gravel operation. The organic material used was a composted product made from exceptional quality biosolids. Both components were obtained from local sources (less than 16 kilometers [12 miles] from the site) and mixed on site with a Caterpillar 943 track loader. The soil was used to construct a channel wetland 3 meters (10 feet) wide by 60 meters (190 feet) long. A seed mixture which contained 22 different wetland plant species was added to the substrate prior to directing the partially treated abandoned mine drainage into the wetland. After one year, the vegetation was studied to determine the percent cover and species composition in order to document the effectiveness of this method of wetland construction. The preliminary results of this study indicate that this is an effective means to establish and sustain wetland vegetation. The addition of a fabricated substrate consisting of composted biosolids and silt can be a very effective method to establish dense and diverse vegetation in a constructed wetland.

Introduction

This project was conducted as part of an on-going restoration effort at the Jennings Environmental Education Center (Jennings), PA Department of Conservation and Natural Resources, located in Brady Township, Butler County, PA. Jennings is affected by acid mine drainage (AMD) that issues from an abandoned deep mine on the Middle Kittanning coalbed (Allegheny Group; Kittanning Formation). This deep mine, known as the Brydon Mine, was active from 1935 to 1944.

The development and execution of this project are part of a joint effort of the Slippery Rock Watershed Coalition and Jennings Water Quality Improvement Coalition.

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Restoration efforts at this site span a period of more than 30 years. These efforts include: mine seals installed in the 1970s, which subsequently failed in 1984; installation of a 4-cell wetland-type passive treatment system in 1989 that improved the water quality but did not produce the desired circumneutral pH and low metals concentrations; an anoxic limestone drain installed in 1993 that plugged in less than one year due to the precipitation of aluminum hydroxide within the drain; and installation of a vertical flow pond utilizing a mixture of spent mushroom compost and limestone aggregate followed by a channel wetland, open-water wetland and settling pond in 1997, that successfully treat the drainage. (See Figure 1.)

The Vertical Flow System is a Demonstration Project funded by the PA Department of Environmental Protection (PADEP), Bureau of Watershed Conservation through an US Environmental Protection Agency Fiscal Year 1996 Section 319 Grant. Due to the unique nature of this project, many new and innovative passive treatment techniques were applied to abate the dissolved aluminum-bearing discharge at Jennings. One of these techniques allowed members of the Jennings Water Quality Improvement Coalition (JWQIC) to investigate the use of a mixture of composted exceptional quality biosolids and quarry fines as a fabricated substrate for the establishment of vegetation in a constructed wetland.

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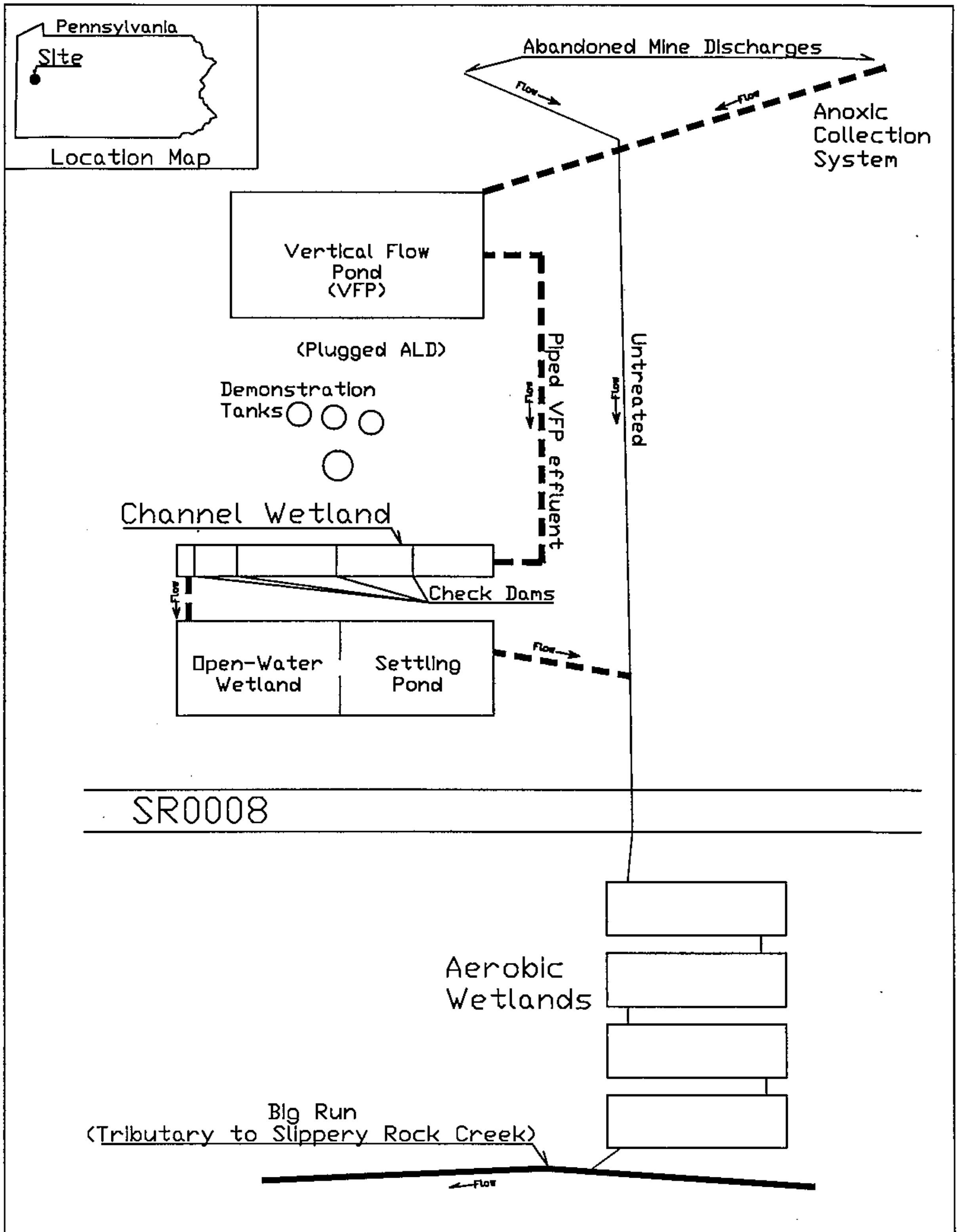

Figure 1. Schematic of Jennings Site (Not to scale.)

Substrates Considered

Common Wetland Substrates

As with many passive treatment systems constructed at abandoned mine sites, the supply of an appropriate on-site substrate can be extremely scarce or nonexistent. In order to encourage the establishment of vegetation, an off-site source of material is commonly needed. Two commercially available options, topsoil and spent mushroom compost, were evaluated based on purchase, delivery, and installation costs.

Topsoil is generally available from most landscape or garden suppliers with varying qualities and costs. Two types of topsoil were locally available including raw and enriched. Raw topsoil is an un-screened product usually derived from the stripping of soil from land development projects. Enriched topsoil products are usually a screened and nutrient enhanced material. Spent mushroom compost is a by-product of the mushroom industry and is widely used in the construction of passive treatment systems. The cost of these materials was prohibitive (See Table 1.); therefore, a more economical alternative was investigated.

Fabricated Substrate

A collaborative effort of JWQIC participants investigated a potential alternative substrate to be utilized in wetland construction. This alternative follows a simple substitute "recipe" where both inorganic and organic materials are mixed in order to fabricate a substrate for wetland vegetation. In order to be cost effective, local sources of inexpensive materials were used.

The local source for the inorganic constituent of the substitute "recipe" was a sand and gravel operation about 6 miles from the site. This operation extracts materials from a glacial deposit near Slippery Rock, PA. The product used for this trial is referred to as quarry fines or pond-sand. It is primarily composed of silt-sized particles and has few economically important uses. The material was obtained at about $2.50/ton plus hauling costs.

Organic material was obtained from a local municipal wastewater treatment facility located about 12 miles from the site in Butler, PA. The Butler Area Sewer Authority currently produces an exceptional quality composted biosolids product. (See Table 2.) This material is available to the general public as a soil-amendment at a cost of $2.00/ton plus hauling.

Table 1. Cost Comparison of Fabricated Substrate with Commercially Available Materials

	Fabricated Substrate				
Material	**Silt (Quarry Fines)**	**Composted Biosolids**	**Topsoil (enriched)**	**Topsoil (raw)**	**Spent Mushroom Compost**
Bulk Density	3000lb/CY	850lb/CY	2500lb/CY	2500lb/CY	1100lb/CY
Volume Amount	15 CY	15 CY	30 CY	30 CY	30 CY
Weight Amount	23.0 T	6.4 T	37.5 T	37.5 T	16.5 T
Cost per ton (Loaded)	$2.50	$2.00	$18.00	$12.00	$15.00
Cost per ton (Delivered)	$4.02	$5.47	$21.30	$13.50	$18.30
	$4.75 (avg.)				
Total Cost	$92.46	$35.00	$798.75	$506.25	$301.95
Comparable Totals	**$127.46**		**$798.75**	**$506.25**	**$301.95**

Table 2. Representative Analysis - Composted Biosolids

Sample Date		9/9/93	3/10/94	6/2/94	8/24/94	12/22/94	2/23/95	3/28/95	Maximum and Minimum Range of Values	Average Values	EPA Part 503 Conc. Limits for EQ biosolids (mg/kg)	PA DER Maximum Class I biosolids concentrations allowed for land application (mg/kg)
Sample ID		Cell 8 Compost	Finished Compost	Compost Cell 17	Finished Compost Cell	Finished Compost	Finished Compost Cell 8	Finished Compost				
Components (reported on a dry weight basis)												
NH_4-N	%	0.008	0.003	0.100	0.006	0.010	0.010	0.01	0.003 - 0.01	0.008	-	-
TKN	%	0.461	1.100	1.000	1.000	1.000	1.200	0.990	0.461 - 1.200	0.960	-	-
Plant Available Nitrogen	%	0.140	0.330	0.300	0.300	0.300	0.360	-	0.140 - 0.360	0.290	-	-
Phosphorous	mg/kg	45.500	8420.000	106.000	2400.000	36.000	140.000	14200.00	36 - 14200		-	-
Potassium	%	720.000	1040.000	996.000	984.000	889.000	1190.000	1000.000	720 - 1190	974.000	-	-
Total Solids	%	68.200	59.400	76.600	83.300	77.100	73.200	69.200	59.4 - 83.3	72.400	-	-
Volatile Solids	%	37.200	44.300	47.200	43.100	51.300	50.800	50.630	37.2 - 51.3	46.400	-	-
Total Organic Carbon	%	20.700	24.600	26.200	23.900	28.500	28.200	28.130	20.7 - 28.5	25.700	-	-
C:N Ratio		44.800	22.400	26.200	23.900	28.500	23.500	28.400	22.4 - 44.8	28.200	-	-
pH		7.800	8.200	9.000	8.800	8.000	7.800	6.900	6.9 - 9.0	8.100	-	-
Arsenic (As)	mg/kg	4.000	2.900	2.300	<6.000	28.000	9.000	2.500	2.3 - 28.0	7.800	41.0	41.0
Barium (Ba)	mg/kg	396.000	NA	NA	NA	NA	NA	NA	396.000	396.000	-	-
Cadmium (Cd)	mg/kg	3.000	<2.000	2.000	1.000	1.000	<1.000	0.800	0.8 - 3.0	1.500	39.0	25.0
Chromium (Cr)	mg/kg	10.000	20.000	30.000	13.000	13.000	10.000	12.100	10.0 - 30.0	15.400	1200.0	1200.0
Lead (Pb)	mg/kg	40.000	30.000	<12.000	17.000	34.000	21.000	33.600	<12.0 - 40.0	26.800	300.0	300.0
Nickel (Ni)	mg/kg	40.000	34.000	32.000	20.000	21.000	14.000	16.500	14.0 - 40.0	25.400	420.0	420.0
Silver (Ag)	mg/kg	25.000	13.000	16.000	30.000	26.000	29.000	NA	13.0 - 30.0	23.200	-	-
Copper (Cu)	mg/kg	130.000	397.000	145.000	182.000	178.000	252.000	167.500	130.0 - 397.0	207.000	1500.0	1500.0
Zinc (Zn)	mg/kg	378.000	862.000	280.000	435.000	497.000	865.000	529.300	280.0 - 865.0	549.000	2800.0	2800.0
Molybdenum (Mo)	mg/kg	10.000	<20.000	10.000	<10.000	<10.000	<10.000	2.100	2.1 - <20.0	10.300	-	18.0
Sodium (Na)	mg/kg	368.000	611.000	519.000	465.000	514.000	661.000	NA	368.0 - 661.0	523.000	-	-
Selenium (Se)	mg/kg	1.100	<0.800	0.200	<6.000	<6.000	<7.000	<0.38	0.2 - <7.0	3.100	36.0	36.0
Mercury (Hg)	mg/kg	1.000	0.840	0.930	1.100	1.200	1.200	1.120	0.84 - 1.2	1.050	17.0	17.0
PCB's	mg/kg	<0.100	<0.200	<0.400	<0.100	<0.300	<0.100	NA	<0.1 - <0.4	<0.200	-	2.0

- = Not Applicable
NA = Not Analyzed

Wetland Installation

Channel Construction

The original purpose of the channel, where this field trial was conducted, was to convey treated mine drainage from the full-scale Vertical Flow Pond at Jennings to an open-water wetland and settling pond. This channel conveys 30 gpm of effluent from the Vertical Flow Pond which discharges through an aeration device at the southern edge of the site to the inlet of the open-water wetland at the northern edge of the site. The channel as constructed was 190 ft long by 10 ft wide at the bottom.

Substrate Placement

The materials were delivered to the site and stockpiled separately. A Caterpillar 943 track loader (Bucket capacity ~1.75 CY) was used to place and to mix the materials in the channel. A bucket of quarry fines was placed and spread with a bucket of biosolids placed and spread on top. The materials were added 1:1, by volume, with the teeth of the bucket used to mix the materials by back-dragging. Placement of a total of 30 CY of material took about 2 hours. The average thickness of the substrate as placed was about five inches.

Water Depth Control Structures

Once the substrate was in place check dams were installed. The check dams divide the channel wetland into four cells or "steps" of varying lengths with equal amounts of fall in each cell. Pressure-treated boards (2X10), 12 feet in length, with a 10-foot wide by 0.2-foot deep trapezoidal weir notched into the top, were utilized. These "steps" helped to create micro-topographic relief and varying flow paths while controlling velocity. Within each of these cells a variety of small channels and pools was created. Water depths from the channel wetland and open-water wetland are shown in Tables 3 and 4.

Seeding Procedures

The channel wetland was seeded in mid-August 1997. Prior to allowing the effluent from the Vertical Flow Pond to enter the channel wetland, the substrate was saturated using the effluent from the pilot-scale systems at the site (Approx. 3 gpm flow of treated and untreated water). The substrate was allowed to be completely saturated for a period of about 24 hours before being seeded. The saturated substrate was hand-raked and seeded. (See tables 5a & 5b.) The obligate wetland seed mixture was applied mainly in the center portions of the channel and where greater water depths were anticipated. The Jennings Mix containing a higher number of facultative species was primarily applied along the edges of the wetland and where shallower water depths were anticipated. Vegetation was observed within the first week after seeding.

The wetland was allowed to establish after seeding for approximately two weeks before the effluent from the full-scale Vertical Flow Pond was introduced to the wetland. After initial introduction of the treated effluent some erosion of the substrate occurred due to lack of vegetation and significant precipitation events.

System Monitoring

Wetland Surveys

On three occasions the channel wetland was surveyed to determine plant type composition and percent coverage. On 10/26/1998, the wetland was surveyed by undergraduate students from Slippery Rock University under the direction of Dr. Gerald Chmielewski, Department of Biology. Twenty-nine transects of the wetland were surveyed to determine the species present and visually estimate the percent coverage. The results of this survey are presented in Table 6.

The second and third surveys were completed between 3/15-17/1999 by Michael Enright and 6/16-21/1999 by Charlene Wick, respectively. (Both undergraduate interns studied under Dr. Fred Brenner, Department of Biology, Grove City College.) A portable 1 m^2 grid divided into 400 5 cm^2 blocks was placed at each meter along the length of the wetland and moved across the wetland. The wetland consists of a gently sloping saturated channel with 2:1 side slopes. (See Table 3.) The upper portions of the side slopes are generally not saturated.

The percent coverage was estimated by counting the number of 5 cm^2 blocks in which each plant type was found and converting this number into square meters. If more than one plant type was found within a 5 cm^2 block, the plant type with the most stems was given that block. The results of these surveys are shown in Table 6.

The 10/26/98 survey yielded a coverage of 113.8%. This is attributed to the visual method of estimation used. This allows for multiple levels of coverage to be counted. One species that is representative of obtaining greater than 100% coverage by this method is *Lemna minor* which was estimated to cover 26.55% of the entire wetland. This is in comparison to the grid method which did not count *Lemna minor*. This example is one reason for the difference in percent coverage between the two method. The first survey method differs significantly from the method used for subsequent surveys. The first survey should be used for documentation purposes only and not used as a direct comparison to the grid-method surveys.

Comparison of Water Depths: Channel Wetland vs. Large Wetland

Table 3. Water depth measured in Channel Wetland 7/17/99

Row #	Distance from final Check Dam (m)	West Depth (ft)	Center Depth (ft)	East Depth (ft)	Avg. Depth (ft)	Avg. Depth (cm)	
1	0	0.10	0.05	0.00	0.05	1.52	Check dam
2	2	0.14	0.04	0.20	0.13	3.86	
3	4	0.21	0.41	0.39	0.34	10.26	
4	6	0.20	0.02	0.22	0.15	4.47	
5	8	-0.08	0.35	0.00	0.09	2.74	Check dam
6	10	0.38	0.05	0.02	0.15	4.57	
7	12	0.12	0.00	0.19	0.10	3.15	
8	14	0.00	0.50	0.00	0.17	5.08	
9	16	0.15	0.09	0.14	0.13	3.86	FLOW ↑
10	18	0.10	0.05	0.15	0.10	3.05	
11	20	0.06	0.50	0.25	0.27	8.23	
12	22	0.03	0.35	-0.05	0.11	3.35	
13	24	0.10	0.03	0.08	0.07	2.13	
14	26	0.08	0.40	0.10	0.19	5.89	
15	28	0.01	0.07	-0.03	0.02	0.51	Check dam
16	30	0.18	0.15	0.03	0.12	3.66	
17	32	0.01	0.12	0.00	0.04	1.32	
18	34	0.10	0.10	0.24	0.15	4.47	
19	36	0.03	0.32	0.08	0.14	4.37	
20	38	0.00	0.15	0.07	0.07	2.24	
21	40	0.01	0.30	0.08	0.13	3.96	
22	42	-0.15	0.02	0.14	0.00	0.10	Check dam
23	44	0.23	0.00	0.16	0.13	3.96	
24	46	0.00	0.05	0.10	0.05	1.52	
25	48	0.03	0.15	-0.05	0.04	1.32	
26	50	-0.10	0.28	0.05	0.08	2.34	
Avg. Depth in ft		0.07	0.18	0.10	0.12		
Avg. Depth in cm		2.27	5.33	3.00	3.54		

Range: 0.15 ft above WL to 0.50 ft deep
Range: 4.47 cm above WL to 15.24 cm deep

Average Water Depth: 0.12 ft
Average Water Depth: 3.54 cm

Table 4. Water depth measured in Open-Water Wetland 7/17/99

	Row	West Depth (ft)	Center Depth (ft)	East Depth (ft)	Avg. Depth (ft)	Avg. Depth (cm)	
	1	0.55	0.65	0.72	0.64	19.51	
	2	0.73	0.83	0.63	0.73	22.25	FLOW ↑
	3	0.62	0.70	0.83	0.72	21.84	
	4	0.81	0.84	0.73	0.79	24.18	
	5	0.72	0.80	0.80	0.77	23.57	
	6	0.65	0.80	0.55	0.67	20.32	
Avg. Depth in ft		0.68	0.77	0.71	0.72		
Avg. Depth in cm		20.73	23.47	21.64	21.95		

Range: 0.55 ft deep to 0.84 ft deep
Range: 16.76 cm deep to 25.60 cm deep

Average Water Depth: 0.72 ft
Average Water Depth: 21.95 cm

Table 5a. Obligate Wetland Mix

Species	Botanical Name	Percent*
Arrow Arum	*Peltandra virginica*	20.00%
Giant Bur-Reed	*Sparganium eurycarpyum*	20.00%
Green Bulrush	*Scirpus atrovirens*	18.00%
Button Bush	*Cephalanthus occidentalis*	10.00%
Soft-Stem Bulrush	*Scirpus validus*	6.00%
Cosmos Sedge	*Carex comosa*	5.00%
Pickerel Weed	*Pontedera cordata*	5.00%
Lake Bank Sedge	*Carex lacustris*	4.50%
Hard-Stem Bulrush	*Scirpus acutus*	4.00%
Nodding Bur Marigold	*Bidens cernua*	3.00%
Monkey Flower	*Mimulus ringens*	2.00%
Turtlehead	*Chelone glabra*	1.00%
Rough Leaved Goldenrod	*Solidago patula*	1.00%
Virgins Bower	*Clematis virginiana*	0.50%

Table 5b. Jennings Mix

Species	Botanical Name	Percent*
Meadow Foxtail	*Alopecurus pratensis*	33.30%
Virginia Wild Rye	*Elymus virginicus*	33.30%
Rice Cut Grass	*Leersia oryzoides*	10.80%
Nodding Bur-Marigold	*Bidens cernua*	6.70%
Lesser Bur-reed	*Sparganium americanum*	5.30%
Green Bulrush	*Scirpus atrovirens*	2.70%
Blue Vervain	*Verbena hastata*	2.70%
Squarestem Monkey Flower	*Mimulus rigens*	1.30%
Wool Grass	*Scirpus cyperinus*	1.30%
Small Seeded Bulrush	*Scirpus microcarpus*	1.30%
Many Leaved Bulrush	*Scirpus polyphyllus*	1.30%

*Percent by weight. Each seed mix: net weight one pound

One other factor in considering the percent coverages is the increased vegetated area between the March and June surveys. This increased the total area surveyed due to the expansion of the wetland vegetation beyond the channel bottom. An additional $1m^2$ per row was used as the base to calculate the percent coverage. By including this area which was not part of the substrate amended channel, a lower percent coverage was realized even though the actual coverage area increased.

Of the 22 species in the seed mixtures only 10 were observed between 14 and 22 months after being planted; therefore, 12 species were planted and not observed. In contrast, 21 different plants were observed in the wetland which were not included in the seed mixture. The species with the highest estimated percent coverage (53.31%) was *Alopercurus pratensis*. Overall, the plants most observed belonged to the grass family with percent total coverage ranging from 37.00% to 65.00%.

Although not part of the original seed mixture, *Lemna minor* was the plant observed with the next highest documented total percent coverage (26.55%). This species dominates the open-water wetland below the channel wetland (estimated coverage is about 100%). The reason for the high populations of duckweed in both of these wetlands is not known; however, very high *Lemna minor* populations have been observed in other vertical flow-type passive treatment systems. This may be attributed to the elevated nutrient levels of water treated with organic materials.

The reason for the successful invasion of volunteer plants is not known. The establishment of these plants may be attributed to natural distribution processes, an impure seed mix, the placement of hay bales below check dams, and upgradient site stabilization. A variety of wildlife has been observed within the channel wetland, even during the winter months, which may contribute to the introduction of non-planted species.

Table 6. Establishment of Vegetation.

Percent coverage of wetland observed on three occasions.
Visual estimation technique used for 10/26/98 survey.
Portable 1 m^2 grid used to estimate coverages during 3/16/99 & 6/20/99 surveys.

	Seeding Rate lb/ac	Common Name	Family	Genus	Species	% COVERAGE OBSERVED 10-26-98	3-16-99	6-20-99
1		Maple Trees	Aceraceae	Acer	rubrum	0.02%		
2		Yarrow	Asteraceae	Achillea	millefolium	0.09%		
3		Grey Goldenrod	Asteraceae	Solidago	nemoralis	0.03%		
4		Flat-topped Goldenrod	Asteraceae	Euthamia	graminifolia	0.07%		
5	2.2	Nodding Bur Marigold	Asteraceae	Bidens	ceruna	2.52%		
6	4.8	Green Bulrush	Cyperaceae	Scripus	atrovirens		observed	4.41%
7	1.4	Soft-Stemmed Bulrush	Cyperaceae	Scripus	validus			3.95%
8		Marsh Straw Sedge	Cyperaceae	Carex	hormathodes			
9	1.2	Cosmos Sedge	Cyperaceae	Carex	comosa	0.34%	observed	2.50%
10	1	Lake Bank Sedge	Cyperaceae	Carex	lacustris			
11		Flatsedge	Cyperaceae	Cyperus	sp.	1.69%		
12		Three way sedge	Cyperaceae	Dulichium	arundinaceum	0.19%	1.00%	0.00%
13		Soft Rush	Juncaceae	Juncus	effuses	3.31%	2.00%	5.39%
14		Lesser Duckweed	Lemnaceae	Lemna	minor	26.55%		
15		Wild Onion	Lileaceae	Allium	sp.	0.19%		
16		Purple-leaved Willow herb	Pimulaceae	Epilobium	coloratum	1.90%		
17	7.6	Virginia Wild Rye	Poaceae	Elymus	virginicus	11.66%		
18	2.5	Rice Cut Grass	Poaceae	Leersia	oryzoides			
19		Crown Vetch	Poaceae	Coronilla	varia	0.03%		
20		Reed Grass	Poaceae	Phragmites	maximus		37.00%	45.87%
21		Kentucky Bluegrass	Poaceae	Poa	pratensis			
22		Bentgrass	Poaceae	Agrostis	sp.			
23		Cord Grass	Poaceae	Spartina	pectinata			
24	7.6	Meadow Foxtail	Poaceae	Alopecurus	pratensis	53.31%		
25		Docks	Polygonaceae	Rumex	sp.	0.17%		
26		Smartweed	Polygonaceae	Polygonum	sp.	6.66%		
27		Meadowsweet	Rosaceae	Spiraea	sp.	0.03%		
28		Aspen Trees	Salicaceae	Poplus	sp.			observed
29	0.8	Monkey Flower	Scrophlariaceae	Mimulus	ringens	0.09%		
30		Cattails	Typhaceae	Typha	sp.	3.52%	7.00%	12.82%
31	0.6	Blue Vervain	Verbanaceae	Verbena	hastata	1.43%		
32	0.2	Turtlehead	Scrophlariaceae	Chelone	glabra			
33	0.1	Virgins Bower	Ranuncluaceae	Clematis	virginiana			
34	0.9	Hard-Stem Bulrush	Cyperaceae	Scirpus	acutus			
35	2.3	Button Bush	Rubiaceae	Cephalanthus	occidentalis			
36	0.3	Wool Grass	Cyperaceae	Scirpus	cyperinus			
37	0.3	Small Seeded Bulrush	Cyperaceae	Scirpus	microcarpus			
38	1.2	Pickerel Weed	Ponteriaceae	Pontederia	cordata			
39	1.4	Soft-Stem Bulrush	Cyperaceae	Scirpus	validus			
40	0.2	Rough Leaved Goldenrod	Asteraceae	Solidago	patula			
41	1.2	Lesser Bur-reed	Sparganiaceae	Sparganium	americanum			
42	4.6	Giant Bur-reed	Sparganiaceae	Sparganium	eurycarpum			
43	4.6	Arrow Arum	Araceae	Peltandra	virginica			
					Total Percent Coverage Observed:	113.80%	47.00%	74.94%

Number of Planted Species Observed: 10
Number of Non-Planted Species Observed: 21
Number of Planted Species Not Observed: 12

Wetland surveys performed by the following groups and inviduals:
10-26-98 by Slippery Rock University students under the direction of Dr. Jerry Chmielewski Dept. of Biology.
3-16-99 by Michael Enringht, Grove City College under the direction of Dr. Fred Brenner, Dept. of Biology.
6-20-99 by Charlene J. Wick, Biologist, with assistance from Dr. Fred Brenner, Dept. of Biology, Grove City College.

Some information from the above table was revised according to USDA NRCS on-line database *http://plants.usda.gov/plants/fr_scilist.cgi*

Cattails, purposefully excluded from the original seed mix, were observed in increasing numbers throughout the three surveys. It is anticipated that the percentage of cattails will continue to increase over time. The dominant nature of cattails is one of the reasons they were excluded from the seed mixtures.

Unsuccessful establishment of planted species may be due to erosion, competition, consumption by wildlife, and less than favorable conditions, relating to water quality and depth, and substrate composition.

Water Quality Monitoring

One concern with the use of biosolids is the presence of metals. The composted product used in this trial exceeds all of the federal and state requirements for exceptional quality biosolids (See Table 2.); however, grab samples were collected in the winter, spring, and summer of 1999 and analyzed for standard mining parameters and a suite of metals. (See table 7.) Monitoring stations included: (1) RAW - untreated mine drainage sampled before entering the Vertical Flow Pond. (2) VFP - effluent from the Vertical Flow Pond equal to influent of the channel wetland. (3) WL - effluent of the wetland prior to entering the open-water wetland.

In general, there was a decrease in all metals (except Mn, Se, and Ca) from the RAW water to the VFP effluent. A minor decrease in all metals was observed from the channel wetland influent compared to effluent, with no significant increases noted.

Monitoring of standard mining parameters demonstrated the effectiveness of the vertical flow pond in treating the acid mine drainage. The channel wetland had very little affect on the standard mining parameters as expected based on its small surface area. A slight increase in pH was observed probably due to the release of carbon dioxide gas. A slight decrease was seen in aluminum, iron, and manganese. It appears that the expected increase in alkalinity with temperature due to microbial activity was also observed within the wetland. Except for iron, manganese, aluminum, and sulfate, the effluent of the channel wetland met EPA drinking water standards for the parameters monitored.

Summary

Preliminary results, based on this field trial, indicate that addition of a substrate fabricated from exceptional quality composted biosolids and quarry fines is economical, safe and effective for successful establishment of vegetation in a constructed wetland.

These results were obtained by monitoring a wetland receiving treated, net-alkaline mine drainage from a Vertical Flow Pond. Based on the preliminary findings, this mixture appears to be a promising alternative substrate for this and other types of constructed wetlands. The vegetative growth observed even during winter months is attributed to the relatively warm water received from the Vertical Flow Pond coupled with significant water velocities relative to those velocities that would be present in larger and broader wetlands (i.e., the open-water wetland which did freeze during winter months).

Table 7. Water Monitoring Data.

(1) RAW - untreated mine drainage sampled before entering the Vertical Flow Pond. (2) VFP - effluent from the Vertical Flow Pond equal to the influent of channel wetland. (3) WL - effluent of the wetland prior to entering the open-water wetland.

PARAMETER	15-Mar-99			29-Apr-99			22-Jun-99			EPA DRINKING WATER STANDARDS[1]
	RAW	VFP	WL	RAW	VFP	WL	RAW	VFP	WL	
FLOW (LPM)		95.54			118.67			84.37		NA
FLOW (GPM)		25.24			31.35			22.29		NA
FIELD pH	4.0	6.6	7.2	4.0	6.5	7.3	4.0	6.4	7.1	6.5-8.5
LAB pH	3.27	6.79	7.50	3.00	7.05	7.40	3.36	6.63	6.95	6.5-8.5
FIELD TEMPERATURE (°C)	7	7	7	11	14	14	12	19	21	NA
ACIDITY (mg/L $CaCO_3$)	289	0	0	213	0	0	269	0	0	NA
ALKALINITY (mg/L $CaCO_3$)	0	152	133	0	166	157	0	143	146	NA
CONDUCTIVITY (umhos/cm)	1344	1397	1385	1201	1254	1264	1124	1274	1275	NA
SULFATE (mg/L)	1385	741	756	551	601	551	738	652	640	250
TOTAL IRON (mg/L)	42.0	4.8	0.2	35.1	3.6	0.5	43.6	17.8	15.2	0.3
MANGANESE (mg/L)	18.5	15.1	7.1	16.7	14.9	14.2	15.9	15.9	15.6	0.05
ALUMINUM [<0.04]* (mg/L)	21.4	0.5	0.0	20.0	0.4	0.1	17.2	0.4	0.4	0.05
TOTAL SUS. SOLIDS (mg/L)	29	12	7	1	3	3	5	9	6	NA
ARSENIC (mg/L)	0.0488	0.0049	0.0035	0.0411	0.0061	0.0048	0.0419	0.0035	0.008	0.05
CADMIUM [<0.001]* (mg/L)	0.008	0.001	0.002	0.005	0.002	0.001	0.007	0	0	0.005
CHROMIUM [<0.0019]* (mg/L)	0.0089	0	0	0.0076	0	0	0.0092	0	0	0.1
CALCIUM (mg/L)	108.23	266.22	258.14	97.06	231.55	231.33	92.13	231.98	228.98	NA
COPPER (mg/L)	0.024	0.019	0.16	0.016	0.02	0.019	0.009	0.011	0.009	1.3
MERCURY [<0.0001]* (mg/L)	0.0002	0	0	0	0	0	0.0001	0	0	0.002
MOLYBDENUM (mg/L)	0.0046	0.0047	0.0033	0.0033	0.0035	0.003	0.0058	0.0043	0.003	NA
NICKEL [<0.01]* (mg/L)	0.62	0.13	0.11	0.55	0.09	0.08	0.52	0.09	0.07	NA
LEAD (mg/L)	0.0095	0.0108	0.0088	0.0019	0.0018	0.0019	0.0012	0.0012	0.0017	0.015
SELENIUM [<0.003]* (mg/L)	0	0	0	0	0.0004	0	0	0.008	0.0017	0.05
ZINC [<0.001]* (mg/L)	0.793	0.042	0.038	0.694	0.026	0.017	0.655	0.013	0.007	5

* A value of 0 represents a sample with a concentration below the detection limit as noted to the right of the parameter.

[1]Current Drinking Water Standards from EPA web site, http://www.epa.gov/OGWDW/wot/appa.html