Coal Tailings Reclamation Practices: Soil Cover Variances - The Ayrshire Alternative[1]

Jack R. Nawrot[2]

Abstract. Reclamation of potentially acid producing coal processing waste generally requires 4 feet (1.2 m) of soil cover to comply with most state and federal requirements (Surface Mining Control and Reclamation Act of 1977 (PL 95 - 87)). Soil cover variances for acid coal slurry (tailings) have included alkaline amendments (agricultural limestone) and reduced soil cover depths. Direct seeding of alkaline amended coal tailings substrates has been demonstrated on more than 1,800 acres throughout the midwest since the late 1970's. Slurry reclamation practices have included upland cool season grasses and legumes, warm season native prairie grasses, and emergent and open water wetlands. Direct seeded slurry demonstrations implemented by the Cooperative Wildlife Research Laboratory SIUC during the 1980's and 1990's have received regulatory approval (bond release), as well as state and national (OSM) reclamation awards. Reclamation monitoring has documented vegetative cover, water quality, and substrate geochemistry through the period up to bond release. This annual monitoring has established a > 25-year database supporting the principles and practices of acid coal tailings reclamation. A recent soil cover variance at the Amax Ayrshire Mine (southwest Indiana) incorporated the principles of pyrite aging and weathering, and incremental limestone amendment to establish warm season grasses and shallow water wetlands on a ~170 acre (70 ha) acid producing slurry basin. Pre-treatment (1995) and posttreatment (1996 - 1999, 2003) substrate monitoring identified differential pyrite oxidation in unsaturated surface, and saturated subsurface profiles within the Ayrshire slurry basin. Agricultural limestone amendment (~100 - 150 tons/ac (225 335 Mg/ha)) has restored and maintained a favorable (alkaline) acid-base balance for seven years since the initial (1995) application. Warm season grass establishment provided > 87% aerial coverage in the direct seeded upland zones. Pre-treatment acid (pH 2.6) surface water quality in the shallow wetland zone has been restored to post-treatment alkaline (pH 7.8) conditions.

Additional Key Words: pyrite oxidation, acid abatement, acid-base balance, limestone amendment, warm season grass, direct seeding

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Introduction

Direct vegetation establishment of limestone amended coal slurry areas has been demonstrated to be an environmentally effective and economically desirable alternative to soil covering. Direct seeding reclamation demonstrations, including both upland and wetland habitat establishment, have been implemented throughout the Midwest as Experimental Practices under the Federal Surface Mining Control and Reclamation Act of 1977 (PL 95-87), post-law state variances, pre-law alternatives, and Abandoned Mine Land (AML) reclamation projects. (Table 1). Successful reclamation projects have been based upon the incremental process of limestone amendment (2 to 3 years; 45-50 tons (100 - 112 Mg/ha) $CaCO_3$/acre/year)), and direct seeding using cover crops (years 1 and 2) followed by permanent cover establishment (year 3) of cool and warm season grasses and legumes; and/or, wetland plant establishment (Nawrot and Gray, 2000).

Aging and weathering of the oxidized surface zone in inactive slurry areas plays a significant role in pyrite depletion (Nawrot, 1981). Most midwest coal slurry is non-acid during active disposal and remains non-acid for ~ 14 - 18 months following inactivation and dewatering. Acidification begins after drawdown and dewatering when pyritic sulfur (~1-5 %) in exposed substrates begins to oxidize (Nawrot and Warburton, 1987). Generally, pyritic sulfur levels decrease to less than 1% following 2 to 3 years after dewatering. However, well-weathered (i.e. pyrite depleted oxidized zones) surface substrates will remain extremely acidic (pH <3.0) unless alkalinity is applied to restore a favorable acid-base balance (Nawrot, 1981). A well-weathered surface slurry profile is ideally suited to direct vegetation establishment following limestone amendment practices to neutralize acidity and restore alkalinity. Saturated substrates and seasonally inundated coal tailings surfaces can often be developed as wetland habitats (Nawrot et al., 1987). The Ayrshire Mine North Slurry Pond (active 1982 - 1992) had undergone several seasons of aging and weathering (pyrite oxidation). Therefore, geochemical analyses were conducted to evaluate the feasibility of a direct vegetation establishment alternative for the ~ 170 acre (70 ha) acid tailings basin. The Ayrshire North Pond tailings area is one of the many midwest tailings basins that has been monitored by the Cooperative Wildlife Research Laboratory (CWRL) Reclamation Program following initial limestone amendment and direct seeding. Similar to

Table 1. Slurry reclamation practices implemented in the Midwest as alternatives to soil covering[1].

Habitat Initiated Status Type ILLINOIS Monterey No. 1 1976 Post-Law Demonstration Wetland Slurry 2,4 Arch Captain 1982 Experimental Practice Upland/Wetland AMAX Sunspot 1986 Variance Wetland Peabody Little John 1984 AML Upland Staunton Sportsmans Club 1985 AML Upland/Wetland Burning Star 5 1986 Variance Wetland Arch Streamline 1993 Variance Wetland

Arch Denmark 1988 Variance Wetland Cells 1,2,3 Upland Inclines 3,4 1990 Variance Upland/Wetland

Peabody Will Scarlet Cell 9 1987 Variance Wetland IA/IB, IC3, IC4 1984 Pre-law Wetland Peabody River King 1 - Cell 1, 2, 3 1986 Variance Wetland/Upland Peabody Randolph Prep 1986 Variance Wetland Snake Den Hollow 1988 Variance Upland IDNR Fish and Wildlife Area Wetland INDIANA AMAX Ayrshire 1984 Experimental Practice Upland/Wetland AMAX Ayshire North Pond 1994 Variance Upland/Wetland AMAX Minnehaha 1986 Pre-law Upland

Table 1. Continued

abitat Initiated Status Type

AMAX Chinook 1998 Variance Upland Friar Tuck 1992 AML Upland Lynnville A-16 1995 Variance

Upland Lynnville A-17 1995 Variance Upland/Wetland Squaw Creek - West 1993 Variance

Upland/Wetland Hawthorne Cell 5 1993 Variance Upland Latta Ax Pond 1993 Variance Upland

KENTUCKY Gibraltar 2A, 2B, 3H 1993 Experimental Practice Upland/Wetland Camp 11 Complex

1992 Variance Upland/Wetland Ken Mine 1996 Variance Upland/Wetland

KANSAS Indian Creek 1987 AML Wetland MISSOURI Bee Veer EP1 1993 Variance Upland/Wetland

RDA2, RDA3

[1]This list includes those slurry reclamation practices in which the CWRL Mined Land Reclamation Program had involvement in site characterization, or reclamation plan development or implementation. Many additional operators have also used direct seeding and wetland development practices at pre- and post-law sites throughout the Midwest.

previous coal slurry experimental practices and reclamation variances, differential rates of pyrite oxidation and weathering were readily observed in the pre- and post-treatment substrate monitoring data. Initial slurry substrate sampling (12 July 1995) assessed the pre-treatment conditions. Subsequent sampling (1996 - 1999, 2003) identified post-treatment conditions of limestone amended portions of the slurry basin. Surface and shallow groundwater were also monitored between 1995 and 2003. This paper summarizes geochemical conditions of the pre- and post-treatment slurry substrate, vegetation establishment , and water quality trends over a nine year period beginning in July 1995.

Methods

Soils

To evaluate the pre- and post-treatment acid-base equilibrium within the oxidized surface (0-6" (0-15 cm)) and saturated subsurface (30-36" (76-91cm)) zones of the 172-acre (70 ha) Ayrshire tailings basin, substrate samples were collected from a grid (@600' X 600' (182 X 182 m)) established along a 3,300-foot (1003 m) centerline transect and 6 left and right perpendicular transects oriented from the slurry discharge zone (OCL) to the decant zone (~33CL) (Fig. 1). The substrate sample grid included 21 surface (0-6" (0-15 cm)) sample points. The six centerline sample points were also used for annual monitoring of subsurface (30-36" (76-91cm)) sample pairs in order to document differential pyrite oxidation in the saturated subsurface tailings profile. Substrate analyses included pH, pyritic sulfur, neutralization potential, soluble salts, potassium, magnesium, calcium, sodium, iron, manganese, phosphorus (P_1, P_2). This summary only addresses the acid-base equilibrium and immediate acidity relationships. Micro nutrient and fertility analyses are reported in the project annual summary reports (Nawrot, 1996; Nawrot, 2004). Substrate monitoring was conducted one year pre-treatment (12 July 1995), and 5 years post-treatment (25 July 1996, 13 May 1997, 1 September 1998, 5 May 1999, and 7 October 2003).

Water Water quality monitoring was also conducted post-treatment to assess conditions within the shallow inundated wetland zones and from three shallow (depth @ 10' (3 m) below surface)

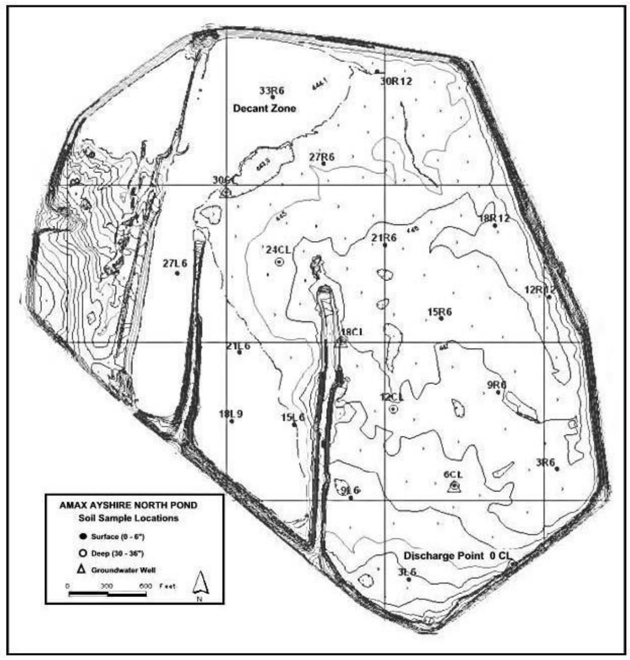


Figure 1. Site characterization and monitoring map.

groundwater wells located along the centerline transect at sample stations 6CL, 18CL, and 30CL (Fig. 1). Analyses of surface and groundwater included pH, conductivity, acidity, alkalinity, total ion, and sulfates. Samples were collected October 1995 through October 2003 to assess long-term trends associated within the inundated wetland zones and the shallow groundwater system within the confines of the tailings basin.

Vegetation

Vegetation cover assessments were conducted during annual site inspections following the first full growing season (July 1996) after the initial limestone amendment application and cover crop establishment (annual rye) in the upland zones (Fig. 1: OCL - 18CL). Final vegetative assessment during October 2003 was conducted along the centerline and parallel transect sampling points. Groundcover density and species composition within the principal upland and wetland plant communities was evaluated using a 0.5 X 0.5 m quadrat to sample 4 subplots at each of the sample grid points along the 6-centerline (CL), and 6 left and 6 right (L6, R6) parallel transect stations that occurred within the upland warm season grass, and moist soil wetland plant communities.

Vegetation assessment data were used to delineate the principal plant community zones within the slurry basin (Fig. 11).

Results and Discussion

Slurry Pre-treatment

Pre-treatment (12 July 1995) slurry samples illustrated the beneficial effects of aging and weathering within the surface (0-6" (0-15 cm)) oxidized zone (Table 2). Surface samples were generally well oxidized as indicated by low pH values (X = 2.7) and reduced surface pyrite values (X = 0.30%) compared to saturated sub-surface (30-36" (76-91cm)) pyrite values (X = 2.45%). Potential acidity values in the oxidized surface zone generally were well within the “treatable” range (i.e. less than 15 tons $CaCO_3$, eq/1000 tons (<34 Mg/ha))(Nawrot and Warburton, 1987) . Most surface samples supported potential acidity values of less than 10 tons $CaCO_3$ eq/1000 tons (22.4 Mg/ha) (Fig. 2). Similar to most single-point slurry discharge systems, pyritic sulfur values were greater in those samples associated with the coarser-grained pyritic materials of the discharge zone where sand-sized particles often exceed 80 percent (Bravo and Nawrot, 1996). A gradual shift from coarse textured (loamy sand) to finer textured silt-clay slurry materials occurred along the discharge (0 CL) to decant (30 CL) gradient. Sand-sized particles were less than 20 percent in the decant zone (30CL), while the clay-sized fraction was greater than 40 percent (clays). In contrast, discharge zone samples were characterized by >80% sand and < 10% clay sized soil particles (loamy sands). Similar to other midwest coal slurry reclamation alternatives, these coarse-textured zones are best suited for upland cover (warm season grass) establishment, while the silt-clay decant zones are ideally suited for moist soil and wetland development practices.

Depletion of pyrite in the surface zone resulted in generation of acid salts and subsequent depletion of naturally occurring calcareous slurry constituents. Therefore, most surface slurry samples exhibited neutralization deficits ranging from 10 to 30 tons $CaCO_3$ eq/1000 tons (22 - 67 Mg/ha). Neutralization deficits in the well-oxidized (i.e. acidified) surface zone contributed to extremely acidic (X pH - 2.7) substrates in the pre-treatment (1995) samples (Table 2). In contrast, most pre-treatment deep samples (30-36" (76-91 cm)) still supported neutralization potential values in excess of 100 tons $CaCO_3$ eq/1000 tons (224 Mg/ha) (Table 2, Fig. 3).

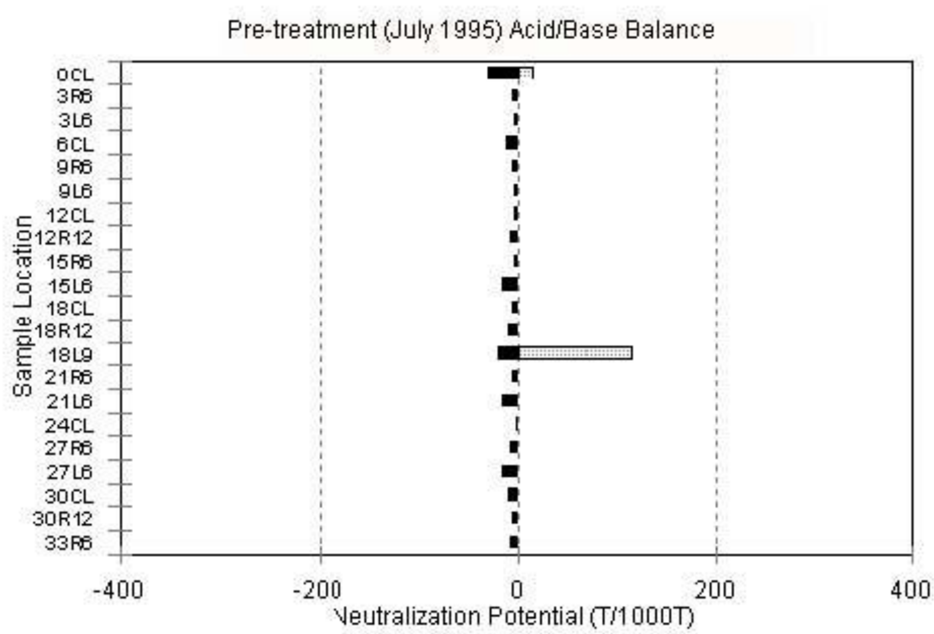
Saturated conditions in the pre-treatment (1995) subsurface (30-36" (76-91cm)) samples greatly decreased or precluded pyrite oxidation as evidenced by the circum-neutral pH values (X - 6.7), excess neutralization potential values, and residual pyritic sulfur (potential acidity) values ranging from 40 to > 160 tons $CaCO_3$ eq/1000 tons (90 to >358 Mg/ha)(Fig. 3). Similar to most other midwest coal tailings basins, unreacted naturally occurring neutralization potential in saturated subsurface zones of the Ayrshire tailings basin could be expected to maintain circum-neutral conditions for many (10 - 50+) years as acid runoff from other coal waste was not present within the tailings watershed.

In general, the oxidized surface zone of the Ayrshire North Slurry Pond was characterized by pre-treatment geochemical conditions ideally suited to limestone amendment and direct seeding. Therefore limestone amendment rates of approximately 50 - 100 tons/acre (112 - 224 Mg/ha) for a period of two to three years were recommended to restore alkaline conditions and support directly seeded vegetation.

Slurry: Post-treatment

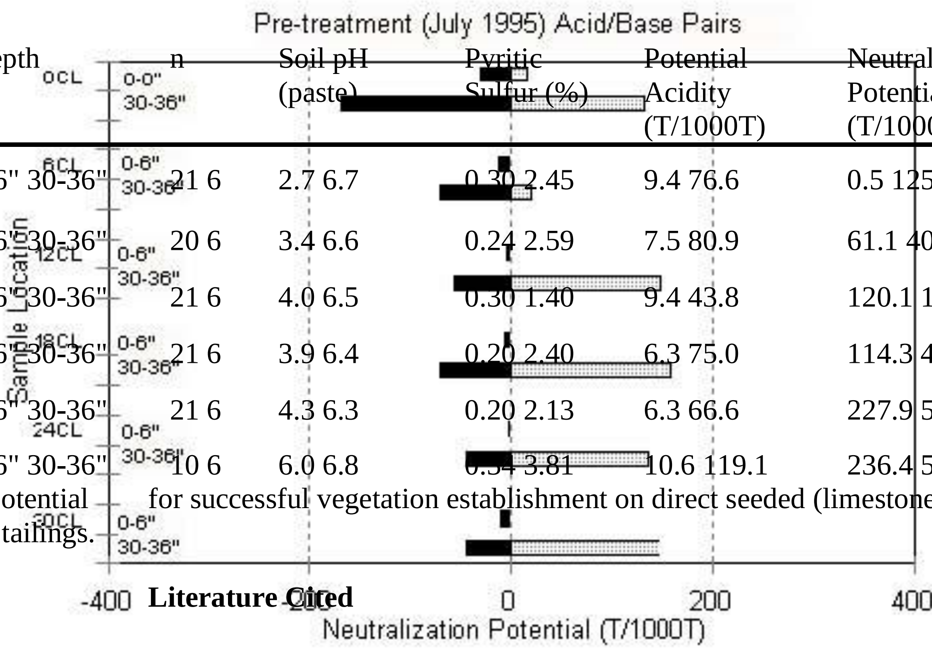
Initial limestone amendment (~ 50 to 100 tons/acre (112-224 Mg/ha)) in September 1995 began the restoration of alkaline conditions throughout the accessible upslope portions of the slurry pond (up to approximately 18CL, Fig. 1). Due to unstable surface conditions, a low ground pressure wide track (40" (102 cm)) spreader (Go Tract 1600) was used for agricultural limestone amendment applications. Subsequent limestone amendment applications (50 - 75 tons/acre (112-168 Mg/ha)) during 1996, 1997, and 1998 to previously untreated portions of the slurry basin restored excess neutralization potential (>60 - 230 tons $CaCO_3$ eq/1000 tons (>134-515 Mg/ha) to the oxidized surface zones as indicated by post-treatment surface samples collected in 1996 - 1999, and 2003 (Table 2). These enhanced levels of neutralization potential far exceed the overall neutralization requirements of the residual pyritic sulfur values in the oxidized zone during all five post-treatment monitoring periods. Residual pyritic sulfur values in the oxidized surface zone recorded in the final (October 2003) monitoring data averaged 0.34% compared to an average pyritic sulfur value of 3.81% in the saturated subsurface tailings zone (Table 2). Comparison of oxidized and unoxidized sample pairs (0-6" and 30-36" (0-15 cm and 76-91cm)) collected during the final substrate monitoring in October 2003 further illustrated that the tailings surface zone had undergone significant weathering and had responded successfully to excess alkaline amendments (Fig. 5). The final establishment of an average acid-base equilibrium of greater than 225 tons $CaCO_3$ eq/1000 tons (504 Mg/ha) throughout the previously acid surface zone of the Ayrshire North Pond tailings basin is a strong indication that non-acid conditions will persist and support successful vegetative cover in the permanently seeded upland prairie and moist-soil wetland zones.

Figure 2. Pre-treatment (July 1995) acid-base balance surface (0-6" (0-15 cm)) samples. Figure 3. Pre-treatment (July 1995) acid-base sample pairs (0-6" and 30-36" (0-15 and 76-91 cm)).



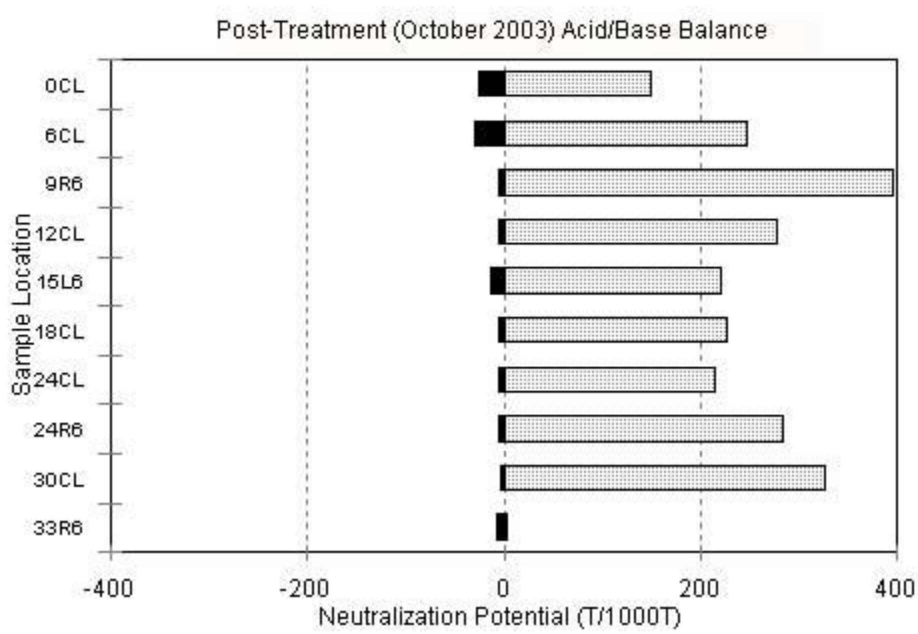
Year	Depth	n	Soil pH (paste)	Pyritic Sulfur (%)	Potential Acidity (T/1000T)	Neutralization Potential (T/1000T)
1995	0-6" 30-36"	21 6	2.7 6.7	0.30 2.45	9.4 76.6	0.5 125.1
1996	0-6" 30-36"	20 6	3.4 6.6	0.24 2.59	7.5 80.9	61.1 40.2
1997	0-6" 30-36"	21 6	4.0 6.5	0.30 1.40	9.4 43.8	120.1 15.1
1998	0-6" 30-36"	21 6	3.9 6.4	0.20 2.40	6.3 75.0	114.3 41.2
1999	0-6" 30-36"	21 6	4.3 6.3	0.20 2.13	6.3 66.6	227.9 50.8
2003	0-6" 30-36"	10 6	6.0 6.8	0.34 3.81	10.6 119.1	236.4 50.4

the long term potential for successful vegetation establishment on direct seeded (limestone amended) coal tailings.



Literature Cited

Figure 4. Post-treatment (October 2003) acid-base balance surface (0-6" (0-15 cm)) samples. Table 2.



Amax Ayrshire North Pond. Mean values by depth (0-15 cm and 76-91 cm): 1995 - 2003.

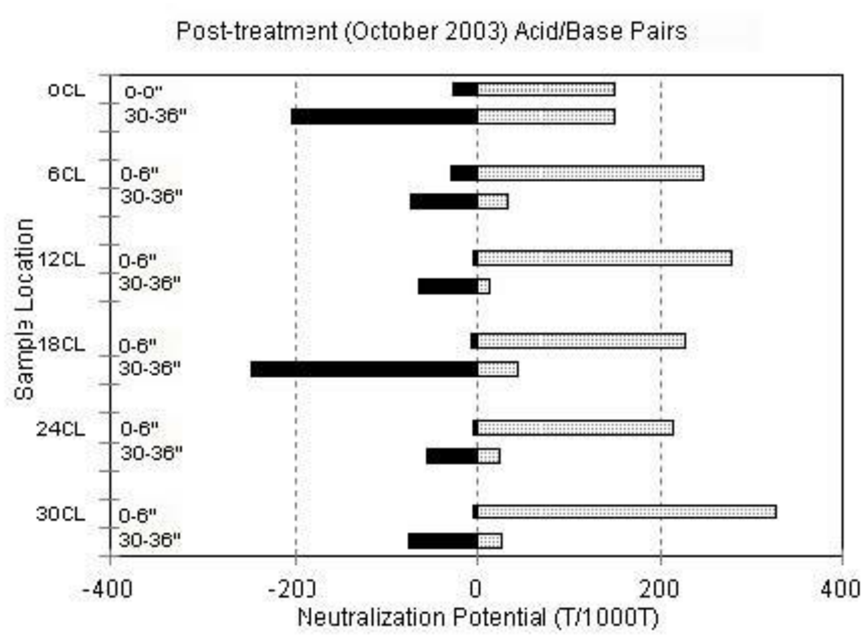


Figure 5. Post-treatment (Oct. 2003) acid-base sample pairs (0-6" and 30-36" (0-15 cm ,76-91

<u>Water Quality</u>

Surface and groundwater samples were collected between October 1995 and October 2003 (Fig. 6 - 10, and Table 5). Groundwater samples were obtained from shallow (10' (3 m)) peizometers (1 ½" (3.8 cm) diameter Tri Loc® slotted 0.001" (0.025 mm) well tips 2 ½' (0.7 m) long) installed at sampling stations 6CL, 19CL, and 30CL. Surface water quality was recorded from samples collected from the inundated wetland zone located in the northwest corner of the slurry area. Initial acid conditions (pH < 6.0) within the surface pool was affected by runoff from the untreated coarse refuse (gob) in the inside toe of the adjacent embankment; and, the untreated downslope portions of the slurry area. Prior to the influence of the initial limestone amendment applications, the runoff from exposed coarse refuse and the oxidized tailings surface had generated extremely acidic impounded water in the decant zone (Fig. 6). Surface water acidity exceeded 1,350 ppm $CaCO_3$ with total iron and sulfate values of 380 and 4,000 mg/l, respectively (Fig. 9, Fig. 10). Elevated concentrations of iron and sulfate in the surface water contributed to pre-treatment (1995) surface water conductivity values of 4.1 mmhos/cm.

Despite the acidic pre-treatment conditions in the shallow surface water zone, all three groundwater monitoring wells supported excess alkalinity values ranging from 356 to 376 ppm $CaCO_3$, with circum-neutral pH values ranging from 6.7 to 7.3 (Fig. 6, Fig. 8). Saturated substrates below the dewatered oxidized slurry surface sustained redox conditions unsuitable for pyrite oxidation, consequently groundwater monitoring results in the Ayrshire tailings basin reflected the valuable role of saturation (or inundation) in the prevention of pyrite oxidation. The differential pyritic sulfur values of the surface and subsurface substrate samples previously discussed (Table 2) represent typical depletion (>90%) of pyrite that occurs when dewatered coal tailings are allowed to oxidize.

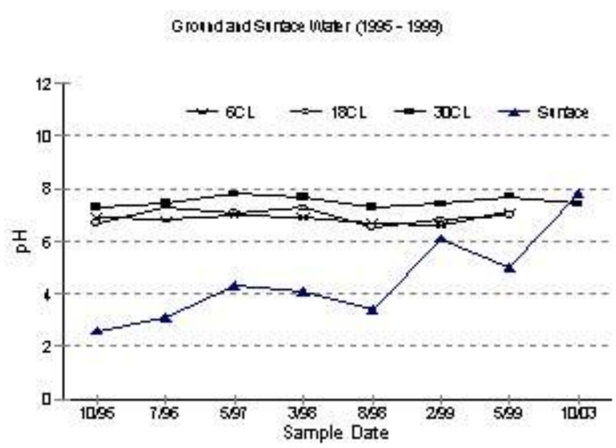
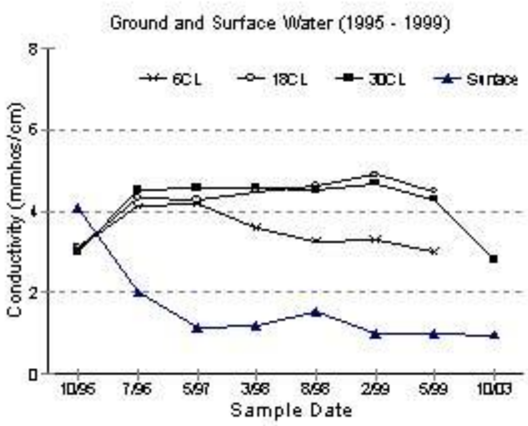


Figure 6. Groundwater and surface water pH values - 1995 - 2003.

Reductions of acidity in the surface water pool beginning between 1996 (Fig. 6) resulted from limestone amendment to the slurry surface and subsequent neutralization of acid salt deposits. Alkaline amendment and covering of the exposed coarse refuse embankment materials (gob) during fall 1996 further reduced the acid load. Restoration and maintenance of alkaline conditions within the inundated wetland zone was successful after all untreated portions of the slurry had received limestone amendment and the exposed coarse refuse embankment was treated with agricultural limestone and covered. Restoration of alkalinity in the oxidized slurry surface through limestone amendment application contributed to gradual declines in sulfates and iron in both surface and groundwater samples (Fig. 9, Fig. 10). Final surface water monitoring of the shallow wetland zone in October 2003 documented excess alkalinity (45 ppm $CaCO_3$) and favorable pH values (7.8) (Fig. 6, Fig. 8). Water quality within the shallow water wetland zone is expected to remain circumneutral with low total iron and sulfate due to increased alkalinity. Recent attainment of full pool water levels will also maintain saturated substrates and inhibit pyrite oxidation.

Figure 8. Alkalinity



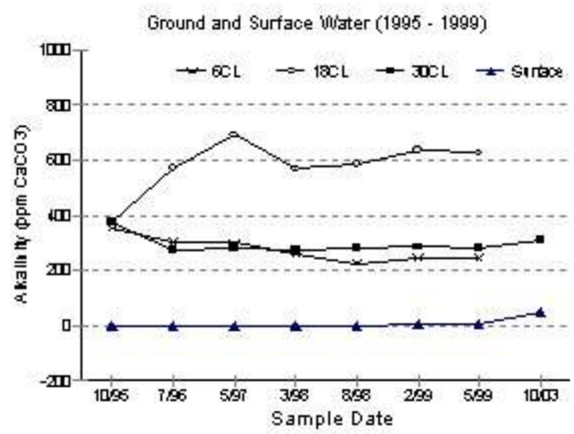
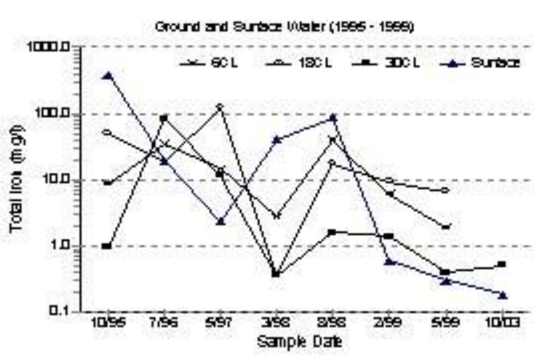


Figure 7. Conductivity



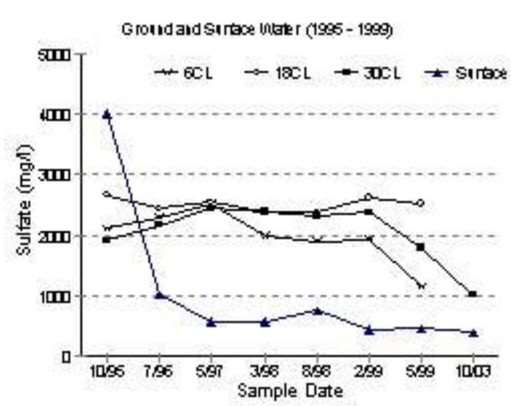


Figure 9. Total Iron

Figure 10. Sulfate

Vegetation Establishment

The principal factor affecting vegetation establishment in direct seeded coal tailings basins are soil texture and moisture transitions along the discharge to decant gradient (Nawrot 1981). The 172-acre (70 ha) Ayrshire North Pond tailings basin exhibited a typical distribution of upland and wetland plant communities associated with a single point discharge tailings system (Fig. 11). Plant community distribution was associated with the four topographic/hydrologic zones:

>447': Upland - Warm Season Grass 47.2 acres (19 ha)

446' - :447': Upland - Moist Soil Transition 31.4 acres (13 ha)

445' - :446': Moist Soil - Seasonally Inundated 23.8 acres (10 ha)

441' - :445': Seasonally Inundated - Shallow Wetland 69.2 acres (28 ha)

Initial limestone amendment application rates in the upland zones during fall 1995 and 1996 were targeted to reach minimum rates of 150 tons/acre (336 Mg/ha). A total of 3 years (1995-1997) of limestone amendment increased neutralization potential levels from initial pre-treatment levels of <1 ton $CaCO_3$ eq/1000 tons to post-treatment levels of more than 225 tons $CaCO_3$ eq/1000 tons (>500 Mg/ha) throughout the upland warm season grass and moist soil wetland zones (Table 2). Limestone amendments were disced into the slurry surface prior to seeding with annual rye and fertilizer application (Table 3).

Table 3. AMAX Ayrshire Mine-North Slurry Pond. Limestone, seed, and fertilizer rates.

CCE) Rate Fall 1995, 1996, 1997 100 & 50 tons/acre (total 150 tons/acre)

VEGETATION

Cover Crop (Cereal Rye (*Secale cereale*) 100 lbs/acre (112 kg/ha)

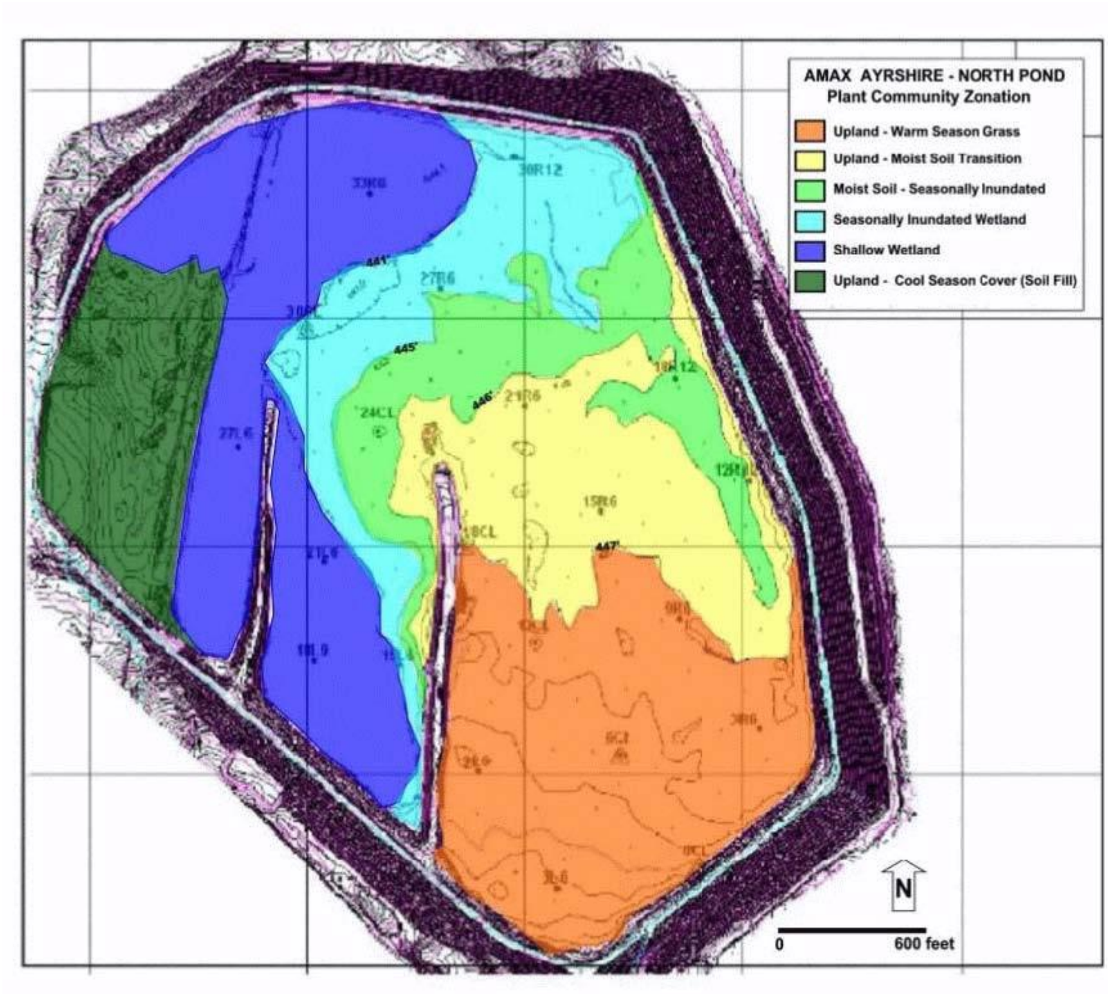
Fall 1995,1996,1997

Permanent - Upland Zones - Spring 1997

Blackwell Switchgrass (*Panicum virgatum*) 12 lbs/acre (13.4 kg/ha) Korean lespedeza (*Lespedeza stipulacea*) 8 lbs/acre (9.0 kg/ha) Redtop (*Agrostis alba*) 8 lbs/acre (9.0 kg/ha) Indiangrass (Cheyenne) (*Sorghastrum nutans*) 8 lbs/acre (9.0 kg/ha) Big bluestem (Kaw) (*Andropogon gerardi*) 5 lbs/acre (5.6 kg/ha) Little bluestem (Aldous) (*Schizachyrium scoparium*) 5 lbs/acre (5.6 kg/ha)

Moist Soil Zones - Spring 1998 Japanese Millet (*Echinchloa crus-galli*) 20 lbs/acre (22.4 kg/ha)

Figure 11. AMAX Ayrshire slurry basin. Plant community zonation.


AMAX AYRSHIRE - NORTH POND
Plant Community Zonation
Upland - Warm Season Grass
Upland - Moist Soil Transition
Moist Soil - Seasonally Inundated
Seasonally Inundated Wetland
Shallow Wetland
Upland - Cool Season Cover (Soil Fill)
N
0
600 feet

NUTRIENT AMENDMENT

Fall 1995, 1996, 1997

18-46-0 400 lbs/acre (448 kg/ha) 0-0-60 200 lbs/acre (224 kg/ha) 46-0-0 150 lbs/acre (168 kg/ha)

Spring 1997 46-0-0 150 lbs/acre (168 kg/ha)

Spring 1998 46-0-0 150 lbs/acre (168 kg/ha) 0-46-0 300 lbs/acre (336 kg/ha)

Figure 13. October 2003

Figure 12. July - 2000

Figure 13. October 2003

Figure 12. July - 2000

Limestone applications and "hot spot" re-treatment continued downslope in the moist soil zones during 1997 and 1998 until target neutralization amendment levels of ?150 tons $CaCO_3$ eq/1000 tons(336 Mg/ha) had been reached. Permanent vegetative cover was established in the upland warm season grass zones during May 1997 using a warm season grass drill. The principal prairie grass components in the seed mix included switchgrass (*Panicum virgatum*), Indian grass (*Sorghastrum nutans*) , big bluestem (*Andropogon gerardii*), and little bluestem (*Schizachyrium scoparium*) (Table 3). Native grass germination and growth during the first growing season (1997) was poor due to the drill settling too deep into the loose seed bed. Despite the excessive planting depths, switchgrass germination and growth contributed perennial cover in the compressed drill tracks in association with annual grasses (*Setaria* spp.) and forbs (*Solidago* sp.) during the first growing season. Germination and growth of the residual prairie grass seed continued to increase the density of the warm season grass stand through the subsequent growing seasons (1998-2000). By the summer of 2000, the three dominant prairie species included switchgrass, Indian grass, and big bluestem (Fig. 12). Switchgrass which accounted for >55 percent of the groundcover in the drier upland zones, increased to ?72 percent in

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Figure 14. Shallow water wetland zone

Figure 15. Seasonally inundated zone.

the mesic prairie grass zone adjacent to the moist of the 40-acre (16.2 ha) prairie grass zone during Spring 2002 resulted in increased density of big bluestem, Indian grass, and little bluestem throughout the upland portions of the direct seeded tailings basin. Vegetative assessments during October 2003 documented groundcover density ranging from 83 to >97 percent in the upland prairie grass zone. Indian grass and big bluestem were co-dominants in the upland zone collectively accounting for >75 percent of the groundcover occurring in sample quadrats 0CL through 12CL (Fig. 13). In the drier discharge zone (0CL through 9CL) switchgrass contributed ~10-15 percent of the prairie grass cover. Little bluestem was a minor component (:5-8 percent) in most sample quadrats.

Indian grass and big bluestem co-dominance decreased downslope as switchgrass increased in density and contributed 55 to >80 percent groundcover in the transition zone (12CL through 18CL) from upland to moist soil plant communities. The upland moist soil transition zone was also characterized by volunteer establishment of eastern cottonwood (*Populus deltoides*) seedlings that attained heights of 3.5 - 6.0 feet (1 -2 m) by the fourth growing season (October 2003) following their initial establishment (~June 2000).

The moist soil - seasonally inundated wetland zone adjoining the permanently inundated shallow water wetland was characterized by dense stands of reedgrass (*Phragmites australis*) interspersed with cattails (*Typha latifolia*) and willows (*Salix nigra*)(Fig. 14). Despite dense groundcover associated with reedgrass stands, moist soil annuals such as wild millet (*Echinochloa crus galli),* marsh smartweed (*Polygonum pennsylvanicum*) and nut sedge (*Cyperus strigosus*), contributed valuable herbaceous cover and waterfowl food associated with seeds and tubers. Seasonally exposed mudflats and the shallow inundated wetland zones were dominated by dense groundcover mats of spike rush (*Eleocharis* spp.) (Fig. 15). Floating aquatics in the open water wetland plant community included broad-leaved pondweed (*Potamogeton nodosus*) and narrow-leaved pondweed (*P. pectinatus*).

Summary

In general, plant community development within the 172-acre (70 ha) Ayrshire North Pond tailings basin reflects the successful establishment of a favorable acid-base balance in the previously acidified surface zone. The textural and moisture gradient between the discharge and decant portions of the tailings basin have influenced the distribution of and transitions between the upland and wetland plant communities. Although annual and seasonal rainfall effect water levels in the wetland zone and soil moisture in the upland zones of the tailings basin, the existing plant communities will continue to adapt to this microhabitat variability with future shifts in species composition and distribution along the soil moisture gradient. Future monitoring of this basin as well as the more than 30 other slurry basins (Table

Year	Depth	n	Soil pH (paste)	Pyritic Sulfur (%)	Potential Acidity (T/1000T)	Neutralization Potential (T/1000T)
1995	0-6" 30-36"	21 6	2.7 6.7	0.30 2.45	9.4 76.6	0.5 125.1
1996	0-6" 30-36"	20 6	3.4 6.6	0.24 2.59	7.5 80.9	61.1 40.2
1997	0-6" 30-36"	21 6	4.0 6.5	0.30 1.40	9.4 43.8	120.1 15.1
1998						

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