# Acid Mine Drainage Neutralization at Augusta Lake, Indiana

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## Abstract

Augusta Lake is a 52-acre acid lake (over 29,000,000 $ft^3$) that drains 932.3 acres of the Patoka River Watershed in Pike County, Indiana. Nearly 70% of this land area was previously mined prior to the 1977 Surface Mine Control and Reclamation Act (SMCRA). Consequently, sparsely vegetated acidic spoil piles contributed several tons of acid to the lake each year. Prior to reclamation, water exiting the lake was extremely acid, with a pH of 3.5 and 310 mg/L of acidity. In addition, biological surveys of Mill Creek, the receiving stream of Augusta Lake, indicated the stream was devoid of aquatic life. Beginning in 1999, the South Fork of the Patoka Watershed Steering Committee and Airgas Incorporated, began efforts to eradicate acidity within Augusta Lake by dumping alkaline materials into strategic locations within the lake and into alkaline recharge trenches. Since 1999, these efforts have reduced the acidity leaving the lake by 94%. In addition, treatment has reduced the acid load to Mill Creek by as much as 168 tons of acid per year and increased biological activity within the stream, as well as, in the lake itself.

## Background

The Augusta Coal Field in Pike County, Indiana has been heavily mined by draglines since prior to 1950. Visible signs of historic mining, such as spoil piles and pit lakes, still exist throughout the region. A 1949 study by the Indiana State Board of Health indicated that acid water from coal mining operations in the Augusta Coal Field area was polluting the Patoka River and degrading the water supply for the town of Winslow, Indiana. Augusta Lake was constructed during the fall of 1950 in an effort to reduce the acidity from these mines. The objective was to construct a reservoir large enough to impound sufficient water to dilute the acidity originating in the disturbed surface mine area above, thus reducing the acid load to Mill Creek and the Patoka River. However, dilution of the acid in the lake was insufficient and water leaving the lake remained acidic, pH 3.5 with 310 mg/L of acidity. Table 1 contains pre-treatment water quality data for several sample sites within Augusta Lake. Figure 1 shows the location of these numbered sampling sites.

**Table 1: Pre-treatment water quality of samples taken within Augusta Lake.** *Refer to Figure 1 for locations of numbered* sample stations.

| August 19,1997 | | | | September 12,1997 | | | | | October 10,1997 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Station | pH | Alk ppm | Acid ppm | Sample Station | pH | Alk ppm | Acid ppm | Flow gpm | Sample Station | pH | Alk ppm | Acid ppm |
| 1 | 3.49 | | 190 | 1 | 3.45 | | 310 | 291.74 | 1 | 4.29 | | 110 |
| 2 | 3.28 | | 280 | 2 | 3.3 | | 190 | | 2 | 3.97 | | 97 |
| 3 | xxx | | | 3 | 3.3 | | 710 | 129.17 | 3 | 4.58 | | 270 |
| 3 stp | xxx | | | 3 stp | 14 | 1400 | | 1 | 3 stp | 10.89 | 1300 | |
| 4 | 3.6 | | 240 | 4 | 3.2 | | 400 | | 4 | 3.73 | | 99 |
| 5 | 2.92 | | 430 | 5 | 2.6 | | 460 | 92.02 | 5 | 3.26 | | 230 |
| 6 | 7.88 | 200 | | 6 | 6.36 | 240 | | 11.23 | 6 | 6.38 | 240 | |
| 7 | 3.43 | | 250 | 7 | 3.33 | | 470 | | 7 | 4.12 | | 89 |
| 8 | 3.71 | | 480 | 8 | 3.39 | | 370 | | 8 | 4.2 | | 96 |
| 9 | 3.44 | | 310 | 9 | 3.34 | | 370 | | 9 | 4.22 | | 110 |
| 10 | 3.43 | | 330 | 10 | 3.33 | | 360 | | 10 | 4.11 | | 110 |

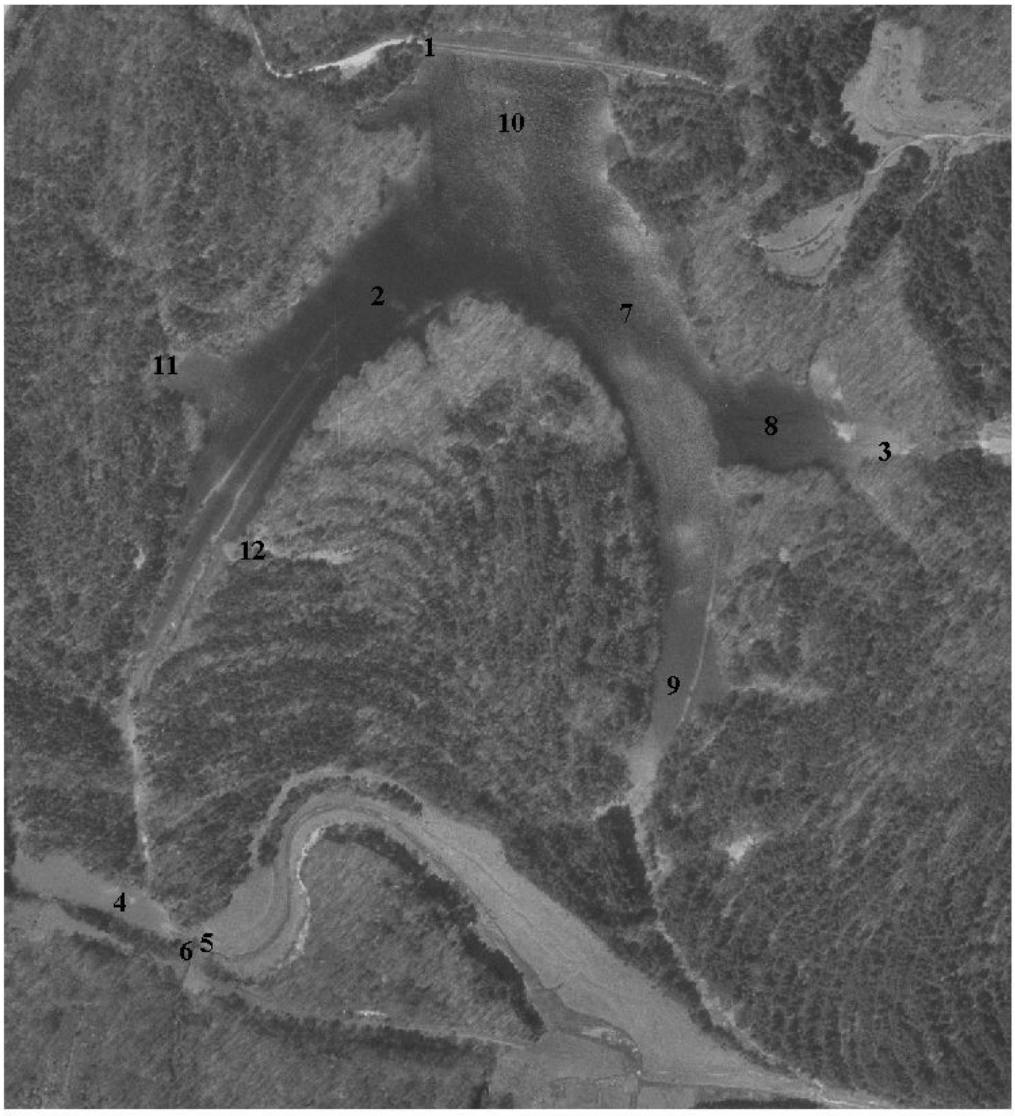



Figure 1. Locations of sample stations within the Augusta Lake watershed.

Early in 1996, the Patoka South Fork Watershed steering Committee was formed in response to the Office of Surface Mining's (OSM) Appalachian Clean Streams Initiative (ACSI). As a result of that meeting, a number of sites were selected for possible acid mine drainage remediation. Included in that list was Augusta Lake, which lies outside of the boundary of the South Fork of the Patoka watershed, yet within Pike County.

In the spring of 1997, a team comprised of the following representatives lent their assistance in considering a neutralization project for Augusta Lake: US Fish and Wildlife Service, US

Geological Survey, Office of Surface Mining, Indiana Department of Environmental Management, Indiana Division of Reclamation, Sugar Ridge Fish and Wildlife Area, IN Division of Water, and the Patoka South Fork Steering Committee. Meetings were held, methods of analysis were discussed, data gathering and interpretation were embarked upon.

Efforts to neutralize acidity in the lake, as well as acid seeps entering the lake, began in the summer of 1999 with the dumping of approximately 100 tanker loads of calcium hydroxide directly into Augusta Lake. In addition several alkaline recharge trenches were constructed within the basin.

These trenches were excavated and filled with calcium hydroxide, a waste product from the production of acetylene gas, donated by Airgas, Inc. These trenches were dug to intercept groundwater flow so that alkaline material in the trench would intercept and neutralize the subsurface flow of acid water, which enters the lake.

**Acid Neutralization within the Augusta Lake Drainage Basin**

The approach to neutralizing AMD in the Augusta Lake watershed was formulated early in the project, with the approach being to neutralize acid surface and groundwater flowing into the lake. The goal, after all, was simply to make a good (recreation) lake for public use. In order to accomplish this goal, alkaline chemicals were added to numerous locations within the drainage basin as shown on Figure 2. The year of each location is the date each treatment was created.

**Acetylene Waste – Calcium Hydroxide (Liquids)**

Haul Road 1999 – this all weather road was constructed in the beginning of the project as an easy access point for Airgas, a local acetylene producer in Evansville Indiana to haul acetylene waste. A total of 234 tanker loads of calcium hydroxide acetylene waste, commonly referred to as "liquids", were dropped directly into the lake. The alkaline value of each tanker load (typically 5,000 gallons, with some 4,000 gallon loads in 2001), was a pH of 12.3, with alkalinity being 3,500 ppm, and there was no less than 500 pounds of calcium hydroxide (solids), a sludge from the acetylene process, included with each full tanker load.

East High Wall Lake 2001 – 19 tanker loads were dropped into this end-cut lake. It measures approximately four acres (including a small body of water immediately south). The pH was 5.4, 100 ppm acidity in March 2001, and had risen to pH 7.57, 46 ppm alkalinity by October 2001. Note: groundwater flow moves to the east and any groundwater improvement would be noticed at lake sample point #11.

Surface Treatment 2001 – 40 tanker loads of liquids were added at this point, approximately 1 mile from the lake. This was a surface flow application and helped to neutralize acidic seeps.

Surface Treatment 2000 – Six tanker loads of liquids added; drainage moves toward sample point #5.

South East GW Holes 1999 – Seven tanker loads of liquids added; drainage also moves toward sample point #5. These small ponds were used for surface and groundwater neutralization.

South East Branch Treatment Pool 1999 – Seven tanker loads of liquids added; drainage moves toward lake sample point #9. This small pond was used for surface and groundwater neutralization.

ART 2001 – 11 tanker loads of liquids added to this alkaline recharge trench; drainage moves toward sample point #5.

North ART 1999 – Four tanker loads of liquids added to this alkaline recharge trench. This trench does not intercept overland flow. It is a groundwater point of neutralization.

As of the end of calendar year 2001, 328 tanker loads of acetylene waste liquids were added to the Augusta Lake watershed (approximately 1,640,000 gallons of a pH 12.3). Since a quarter of a ton of calcium hydroxide solids was delivered with each tanker load, that corresponds to 82 tons of calcium hydroxide.

**Acetylene Waste - Calcium Hydroxide (Solids)**

In 1999 and 2000, Airgas dredged out two settling basins at their plant. The corresponding 247.88 and 600.6 tons, respectively, of calcium hydroxide was used at nine locations within the watershed for groundwater neutralization as follows:

North East CARPS 1999 – 87.88 tons added to three small concentrated alkaline recharge trenches.

North ART 1999 – 160 tons added to one large alkaline recharge trench, in direct contact with acid groundwater.

East Spoil Pool 2001 – 50 tons of solids added, plus approximately 20 tons of turkey manure (wetland enhancement). Overland flow moves toward sample point #3.

North East Art 2001 – 200 total tons of solids added to two alkaline recharge trenches, in direct contact with acid groundwater.

F&WS ART 2000 – 30 tons of solids added as a surface dressing to a long (300+ foot) alkaline recharge trench, in direct contact with acid groundwater.

Speed Bump Trench 2001 – 50 tons of solids added to a trench, in direct contact with acid groundwater. Surface flow was redirected to enter the trench.

Rock Check Dams 1999 – 40 tons of solids added behind two of three check dams; neutralization of overland flow.

South East Branch Treatment Pool 1999 – 40.6 tons of solids added to this alkaline recharge trench, with surface flow going towards lake sample point #9 (the east lobe of the lake).

South East Valley Trenches 1999 – 190 tons of solids, and approximately 20 tons of turkey manure was added to three rock check dams that were modified to be trenches, in direct contact with acid groundwater. Surface flow moves toward sample point #5.

**Other Alkaline Chemicals**

Three other types of alkalinity were used within the drainage basin: Code H, Soda Ash Briquettes, and 50 percent Caustic Soda, at the following four locations:

F&WS ART 2000 – a trench of over 300+ feet was created for groundwater neutralization using 27 tons of Code H, a commercially produced, fine powder calcium carbonate material by the US Fish and Wildlife Service. Also, 110 gallons of 50 percent Caustic Soda, donated by a local coal mine were poured directly into the trench.

ART 2001 – another groundwater trench created by the Fish and Wildlife Service where 27 tons of Code H was used.

West Scout Wetlands 1999 – one sand bag dike wetlands created by a Boy Scout Troop where five tons of soda ash briquettes were added.

East Scout Wetlands 1999 – two sand bag dike wetlands created by two Boy Scout Troops, a Girl Scout Troop and a Youth-at-Risk Group where five tons of soda ash briquettes were added.

In an attempt to improve the fishery habitat of the watershed, small trees were sunk into the southwest end-cut lake. This typical end-cut lake is approximately 700 feet long, 100 feet wide and has an average depth of nearly 12 feet. It lacked the subsurface structure to support a viable sports fishery and the trees were the first attempt to create this structure.

## Results

Table 2 shows the post-treatment water quality for samples taken at various sample stations throughout Augusta Lake. Acid concentrations leaving the lake have dropped 94% since 1997. This has reduced the acid load to Mill Creek by over 166 tons of acid of acid per year. The result has been a significant improvement in the water quality of the lake and of its receiving stream, Mill Creek. In 2001, the US Fish and Wildlife Service conducted a biological survey of Mill Creek. Table 3 contains the results of this study. This is significant because prior biological

**Table 2: Post-treatment water quality of samples taken within Augusta Lake**. *Refer to Figure 1 for locations of numbered sample stations.*

| August 30, 2000 | | | | September 28,2000 | | | | November 1,2000 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Station | pH | Alk ppm | Acid ppm | Sample Station | pH | Alk ppm | Acid ppm | Sample Station | pH | Alk ppm | Acid ppm |
| 1 | 4.81 | | 50 | 1 | 4.23 | | 20 | 1 | 4.22 | | 22 |
| 2 | 4.82 | | <10 | 2 | 4.4 | <10 | 14 | 2 | 4.35 | | 13 |
| 3 | 3.41 | | 52 | 3 | 3.5 | | 120 | 3 | 3.26 | | 210 |
| 3 stp | 10.21 | 170 | | 3 stp | 9.49 | 120 | | 3 stp | 10.26 | 640 | |
| 4 | 6.7 | 84 | <10 | 4 | 6.42 | 40 | <10 | 4 | 5.75 | 52 | <10 |
| 5 | 3.97 | | 52 | 5 | 3.67 | | 54 | 5 | 3.28 | | 100 |
| 6 | 7.15 | 140 | | 6 | 7.5 | 250 | | 6 | 7.3 | 330 | |
| 7 | 4.21 | | 19 | 7 | 4.28 | | 16 | 7 | 4.4 | | 24 |
| 8 | 4.44 | | 17 | 8 | 4.2 | | 16 | 8 | 4.18 | | 16 |
| 9 | 4.45 | | 24 | 9 | 4.21 | | 16 | 9 | 4.21 | | 20 |
| 10 | 4.15 | | 15 | 10 | 4.25 | | 14 | 10 | 4.22 | | 16 |
| 11 | 2.95 | | 420 | 11 | xxx | | xxx | 11 | 3.03 | | 210 |
| 12 | 3 | | 210 | 12 | xxx | | xxx | 12 | 3.05 | | 530 |

| August 14, 2001 | | | | September 13,2001 | | | | October 11,2001 | | | | December 11,2001 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Station | pH | Alk ppm | Acid ppm | Sample Station | pH | Alk ppm | Acid ppm | Sample Station | pH | Alk ppm | Acid ppm | Sample Station | pH | Alk ppm | Acid ppm |
| 1 | 4.06 | | 26 | 1 | 3.96 | | 61 | 1 | 4.13 | | 34 | 1 | 5.5 | <10 | 14 |
| 2 | 3.92 | | 24 | 2 | 4.03 | | 32 | 2 | 4.04 | | 26 | 2 | 5.15 | | 14 |
| 3 | 2.93 | | 310 | 3 | 3.25 | | 200 | 3 | 3.48 | | 130 | 3 | 3.93 | | 150 |
| 3 stp | 5.78 | 48 | <10 | 3 stp | 3.84 | | 120 | 3 stp | | | | 3 stp | | | |
| 4 | 6 | 48 | <10 | 4 | 6.48 | 54 | | 4 | 6.21 | 22 | 18 | 4 | 5.64 | 60 | <10 |
| 5 | 3.28 | | 120 | 5 | 5.81 | <10 | 58 | 5 | 6.26 | 22 | 18 | 5 | 5.8 | <10 | 98 |
| 6 | NF | | | 6 | 7.66 | 240 | | 6 | 7.71 | 300 | | 6 | 6.36 | 140 | |
| 7 | 3.88 | | 34 | 7 | 3.88 | | 38 | 7 | 4.12 | | 24 | 7 | 5.04 | | 16 |
| 8 | 3.87 | | 28 | 8 | 3.89 | | 38 | 8 | 3.98 | | 36 | 8 | 5.34 | | 24 |
| 9 | 3.89 | | 28 | 9 | 3.88 | | 42 | 9 | 3.97 | | 32 | 9 | 5.35 | | 16 |
| 10 | 3.9 | | 24 | 10 | 3.93 | | 32 | 10 | 4 | | 34 | 10 | 5.47 | | 34 |
| 11 | NF | | | 11 | NF | | | 11 | 3.1 | | 170 | 11 | 3.7 | | 200 |
| 12 | NF | | | 12 | NF | | | 12 | 3.09 | | 340 | 12 | 3.44 | | 580 |

surveys did not find any “critters”. Also, fishing at the confluence of Mill Creek and the Patoka River, two miles distant from Augusta Lake, began in earnest in 2001, something that has not occurred here for nearly 40 years.

As for the lake itself, no biological survey has been done, yet casual observations in 2000 and 2001, indicate the presence of minnows, water snakes, frogs, numerous algae, and increasing amounts of waterfowl.

## Discussion

Table 4 shows the cost efficiency evaluations completed on the Augusta Lake project. Section A is the WV model for passive treatment system evaluation. This evaluation depends upon the estimated treatment cost for this passive treatment system divided by the acid load removed and the expectant service life of the system. This method using standard material costs and does not include the cost of building infastructure, such as haul roads or site preparation.

**Table 3: Results of a 2001 biological stream survey conducted by the US Fish and Wildlife Service on Mill Creek, the receiving stream of Augusta Lake.** *Tolerance refers to the species ability to tolerate habitat and water quality degradation.*

**Location:** Pike Co, IN, Mill Creek, SR 364 Bridge

| Species Found | Taxa | Tolerance |
|---|---|---|
| Creek chub | Fish | tolerant |
| Green sunfish | Fish | tolerant |
| Blackside darters | Fish | intolerant |
| Mud darter | Fish | moderate |
| *Fallicambarus fodiens* | Crayfish | moderate |
| *Cambarus* new species | Crayfish | moderate |
| *Orconected immunis* | Crayfish | intolerant |
| Central newt | Amphibian | intolerant |

**Location:** Pike Co, IN, Mill Creek, u/s CR 450E

| Species Found | Taxa | Tolerance |
|---|---|---|
| Green sunfish | Fish | tolerant |
| *Cambarus* new species | Crayfish | moderate |

Based on these calculations, the neutralization efforts at Augusta Lake are treating 166.6 tons of acid per year at a cost of $103,996. The estimated service life of this system was calculated to be 10 yrs. Therefore, if the system continues to treat an average of 166.6 tpy of acid it will cost $62 to treat one ton of acid per year for 10 years.

Section B shows the efficiency of the system based on Clean Stream dollars spent. What this method shows is the real Clean Stream dollars spent to treat acid with all other values donated by various organizations. During this project, 31 ACSP dollars were used in the neutralization of one ton of acid at Augusta Lake.

Section C shows the efficiency of the treatment system based on "real dollars" spent with all other values being donated. This value includes infrastructure cost and is calculated to be $89,754. So, due to the actions of several generous benefactors the reclamation activities at Augusta Lake have only cost $59 real dollars per ton of acid per year.

**Table 4. Cost Efficiency Evaluation of the Augusta Lake AMD Neutralization Project. Acid loads shown are for pre-treatment versus post treatment acid loads at the discharge of Augusta Lake, ie sample point #1.** *The treatment technology line shows the costs of the neutralizing system, such as the alkaline materials and the excavation of the alkaline recharge trenches. The remaining two cost analysis shows the efficiency of the system based on ACSP money spent and on the real dollars spent, discounting the cost of donated materials and labor.*

| Sampling Station # | acd load tpy | acd load removed tpy | Treatment | Ca(OH)2 tons | Code H tons | Soda ash briquettes tons | Caustic tons | Excavation cost | Ca(OH)2 cost @ $70 per ton | Code H cost @ $50 per ton | Soda ash cost @ $260 per ton | Caustic cost @ $243 per ton | total exc/mat Cost | efficiency $/ton acid load removed | efficiency over 10 yrs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment Technology** | | | | | | | | | | | | | | | |
| pre-treat | 199.0 | | Alkaline | | | | | | | | | | | | |
| post-treat | 32.4 | 166.6 | addition | 930.48 | 54 | 10 | 0.239 | $33,504 | $65,134 | $2,700 | $2,600 | $58 | $103,996 | $624 | $62 |
| **ACSP Funds Spent** | | | | | | | | | | | | | | | |
| pre-treat | 199.0 | | Alkaline | | | | | | | | | | | | |
| post-treat | 32.4 | 166.6 | addition | | | | | | | | | | $47,453 | $285 | $31 |
| **All Real Dollars Spent** | | | | | | | | | | | | | | | |
| pre-treat | 199.0 | | Alkaline | | | | | | | | | | | | |
| post-treat | 32.4 | 166.6 | addition | | | | | | | | | | $89,754 | $539 | $59 |

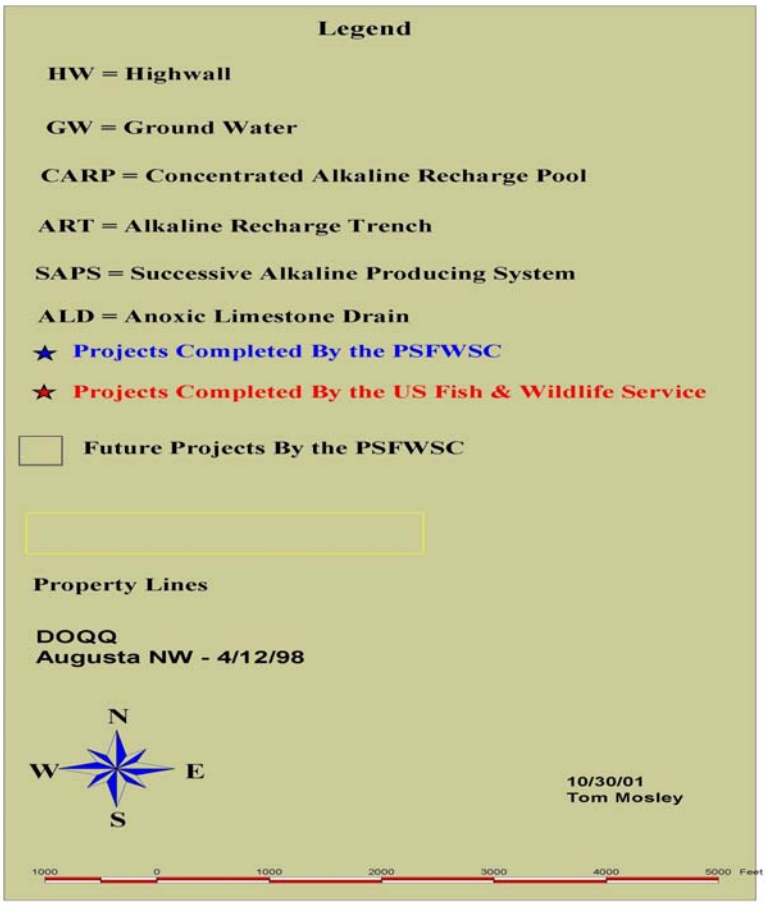
Neutralization efforts at Augusta Lake have been supported by funding through the US Office of Surface Mining (Clean Stream Program) and the US Fish and Wildlife Service. In addition, Airgas, Kindill Coal Company, Indiana Department of Natural Resources, US Geological Survey, University of Southern Illinois and several youth organizations have made valuable contributions to the project in the donation of materials and labor.

Future activities needed to complete the AMD project, and the estimated costs, are as follows:

- North Central GW Alkaline Recharge Spoil Basin - five alkaline recharge trenches will be excavated and approximately 1,200 tons of alkaline material added.
- North East GW Alkaline Recharge Spoil Basin - one long alkaline recharge trench will be excavated and 800 tons of alkaline material added.
- South East (W-3) Seasonal GW Pool - two trenches will be excavated and approximately 1,500 tons of alkaline material added.
- Additions of donated acetylene waste (liquids) will continue at key points within the watershed basin.
- The state of Indiana has plans to rework the dam and the two spillways of Augusta Lake in 2003. If all the trenches in the Northcentral Alkaline Recharge Spoil Basin are in place, approximately 104 acre-feet of lake water (2 ft) will be pumped into the trenches, which will provide the following benefits:
    - No cost of treating and flushing water down Mill Creek and
    - Flushing 104 acre-feet of water (hydraulic head) through designed alkaline recharge trenches.

The estimated cost for all trench excavations and alkaline purchases is $350,000, and could be completed by the autumn of 2003. If water quality rises and stays above a pH 6.4, fish stocking could begin in earnest.

For more information on the Augusta Lake Acid Neutralization Project, please visit http://www.mcrcc.osmre.gov/Indianapolis/Projects.htm.



# Augusta Lake Remediation Projects Done In Conjunction With Patoka South Fork Watershed Steering Committee Funds