Use of Reclaimed Mined Land for Woody Biomass Production: Installation and Year One Results

Daniel M. Evans, Carl E. Zipper, James A. Burger, and Chris Fields-Johnson

Introduction

The extensive hardwood forests of the Appalachian Mountains could help meet the current and future demand for biomass materials for energy production. However, the long-term outlook for this commodity market is uncertain. If demand for energy increases or future government policies limit carbon emissions from energy production, demand for carbon-neutral fuels such as biomass products may increase. Additionally, the construction of "hybrid" power plants in the Appalachian region that are contracted to burn a percentage of non-coal materials will increase demand for biomass products. For example, Dominion Resources' Virginia City Hybrid Energy Center, currently under construction in Wise County, will use coal and up to 20 percent biomass for its fuel (Dominion Resources 2009).

Under-utilized mined lands in the coalfields of Virginia and surrounding coal-producing states could provide biomass fuels in addition to those that can be harvested sustainably from non-mined native forest land to fuel power plants and to provide woody biomass for emerging technologies such as cellulosic biofuels. There are many advantages and benefits of using mined lands to produce biomass materials. If mined land can provide increased biomass production, it will reduce the impact on native forests, which can be used for traditional forest products and ecosystem services. Local economies also benefit through the production of a renewable forest product on lands deemed unproductive by past generations.

Research has demonstrated that properly reclaimed mined lands can be highly productive (Burger and Fannon 2009, Burger 2004). Fast-growing tree crops, such as hybrid poplar or black locust, are most productive when they are able to extend their root systems to exploit large soil volumes. Mine soils offer soil-like materials comprised of freshly fractured rocks at thicknesses far deeper than many of the region's natural soils. These freshly-fractured geologic materials often have chemical characteristics, including pH levels and nutrient cation availabilities, that are favorable to plant growth (Burger et al. 2007).

More than 100,000 acres in the southwestern Virginia coalfields and about 1.5 million acres throughout Appalachia have been mined for coal and reclaimed under the Surface Mining Control and Reclamation Act of 1977, and many of these areas remain accessible because mining access roads were left in place. Research on unmined lands suggests that productivity (tons of biomass produced per acre per year) of fast-growing woody crops growing on favorable sites can be on the order of 3 to 5 times that of long-rotation natural forests on mountainous sites (Amichev 2007). For example, in an analysis of data collected from eight unmined native hardwood forest areas adjacent to coal mining areas, Amichev (2007) found that total tree carbon accumulation averaged 0.85 Mg C ac^{-1} yr^{-1} (2.1 Mg C ha^{-1} yr^{-1}) over 60-year rotations. In contrast, he estimated that hybrid poplar growing on favorable sites with short rotations in a similar climate have the potential to accumulate total tree C at a rate of 4.44 Mg C ac^{-1} yr^{-1} (11 Mg C ha^{-1} yr^{-1}).

Past mining practices have left many sites with highly degraded site productivity due to soil compaction and lack of tree-compatible vegetation. We hypothesize that mined sites with favorable soil chemical characteristics can be managed for intensive tree biomass production regardless of past soil and vegetation management. This study is designed to test the capability of previously mined lands to be used for tree biomass production. It tests biomass production for differing tree species and planting densities. This report summarizes our methods and initial tree survival one year after planting. This study is part of a greater research effort that is intended to achieve four goals:

1. Measure and compare biomass production of woody and herbaceous biofuel crops on mined lands.
2. Measure and compare optimum harvest cycles of woody crops on mined land.
3. Determine the potential of herbaceous and woody biofuel/bioenergy crops growing under optimal soil conditions to sequester atmospheric carbon in above-ground and below-ground forms.
4. Develop and describe a method for preparing mined sites that have been reclaimed in previous years and are currently unused for biofuels production.

Methods and Future Management Plan

Three sites in Wise County, Virginia, were included as replicate blocks in this study (Fig. 1). Each site provided at least 5 ac (2 ha) of relatively flat ground (<15% slope) that could be reached by heavy equipment for site preparation and harvesting. In December 2007, each site was disked and ripped to till under existing vegetation and to alleviate possible compaction, leaving loose soil for tree planting and root growth (Photo 1). This was accomplished with a heavy forestland disc harrow used to break up the soil, followed by a second pass to deep-till and mound the tree planting row. The tillage tool had a 3-ft center shank that ripped a deep trench through the compacted mine soil, while large disks around the shank produced a mound of loose soil over the rip where the trees are planted. Smaller shanks to the right and left of the center shank broke up the surface to 1 ft on either side of the planting location.

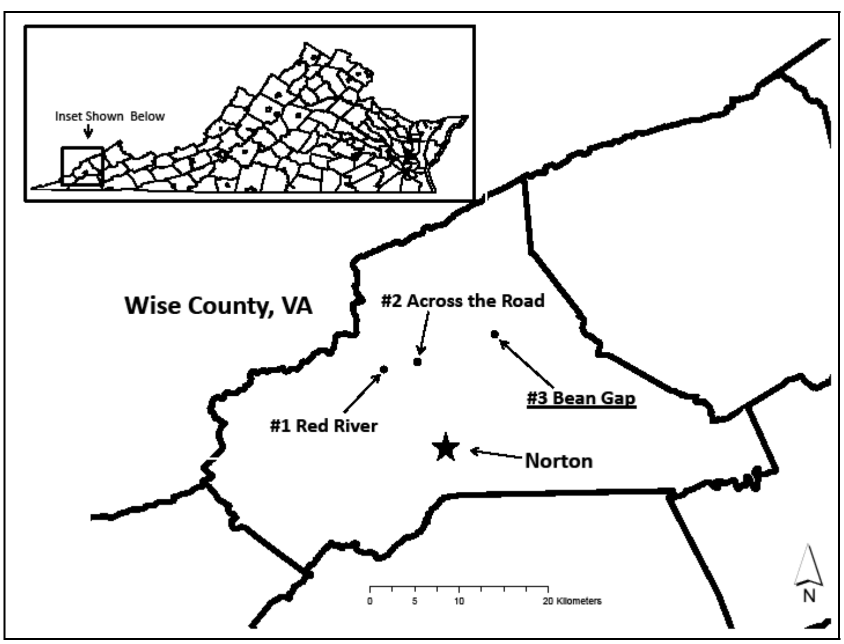

Figure 1. Biomass block locations in Wise County, Virginia.

Photo 1. An advanced ripping tool used to prepare the biomass research sites by Union Concrete Products of Maxwelton, West Virginia, under the direction of J. K. Rose.

Each of the three sites was broken down into four treatment areas of approximately 0.5 acres (Figs. 2-4). Trees were planted by Williams Forestry and Associates in January 2008. In the early winter of 2008, each treatment plot received hybrid poplar (*Populus sp.* x *Populus sp*.), sycamore (*Platanus occidentalis*), and black locust (*Robinia pseudoacacia*), planted at two densities. The low-density treatment was planted along the 11-ft furrows with an intended target of 11 x 11 ft spacing or 450 trees ac^{-1} (1100 trees ha^{-1}). The high-density treatment was planted at half the distance between trees, both on the furrows and in between the furrows, with an intended target of 5.5 x 5.5 ft spacing or 1400 trees ac^{-1} (3400 trees ha^{-1}).

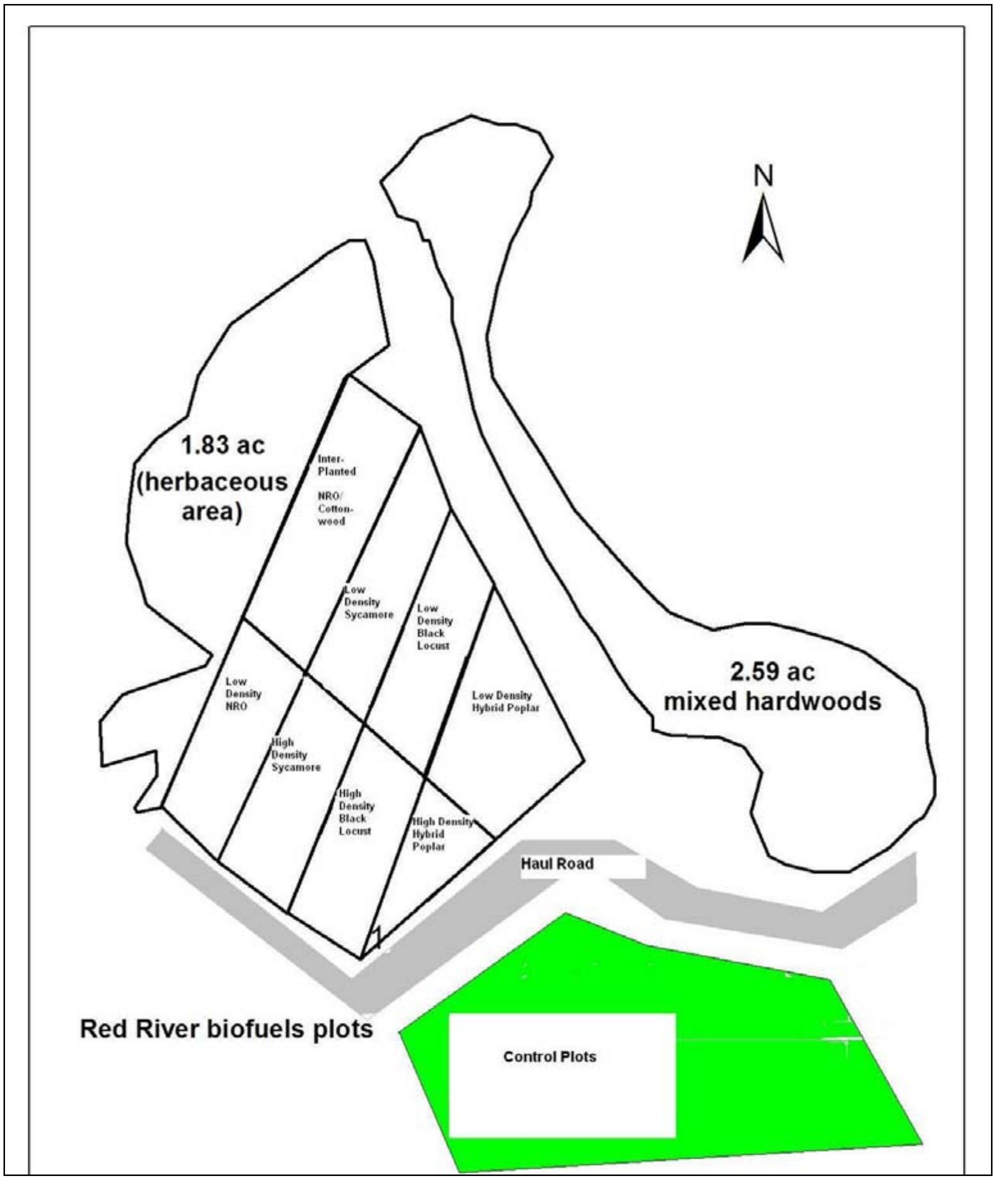

Figure 2 . Treatment plot layout at Block 1 (Red River). The "herbaceous areas" were established with the intention of establishing fast-growing herbaceous crops, such as switchgrass, to enable direct comparison of biomass production rates with the woody crops, but available funding did not enable herbaceous crop establishment.

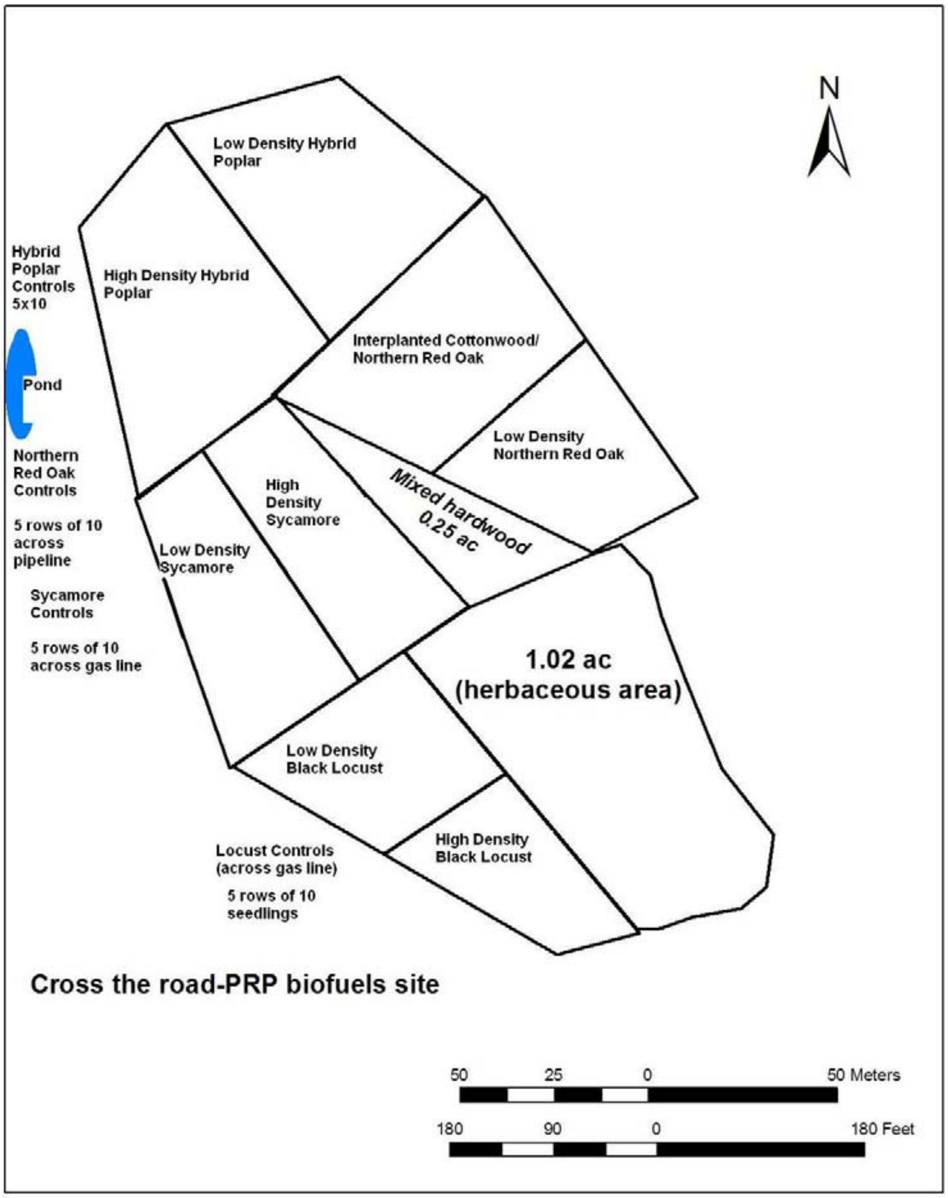

Figure 3. Treatment plot layout at Block 2 (Across the Road).

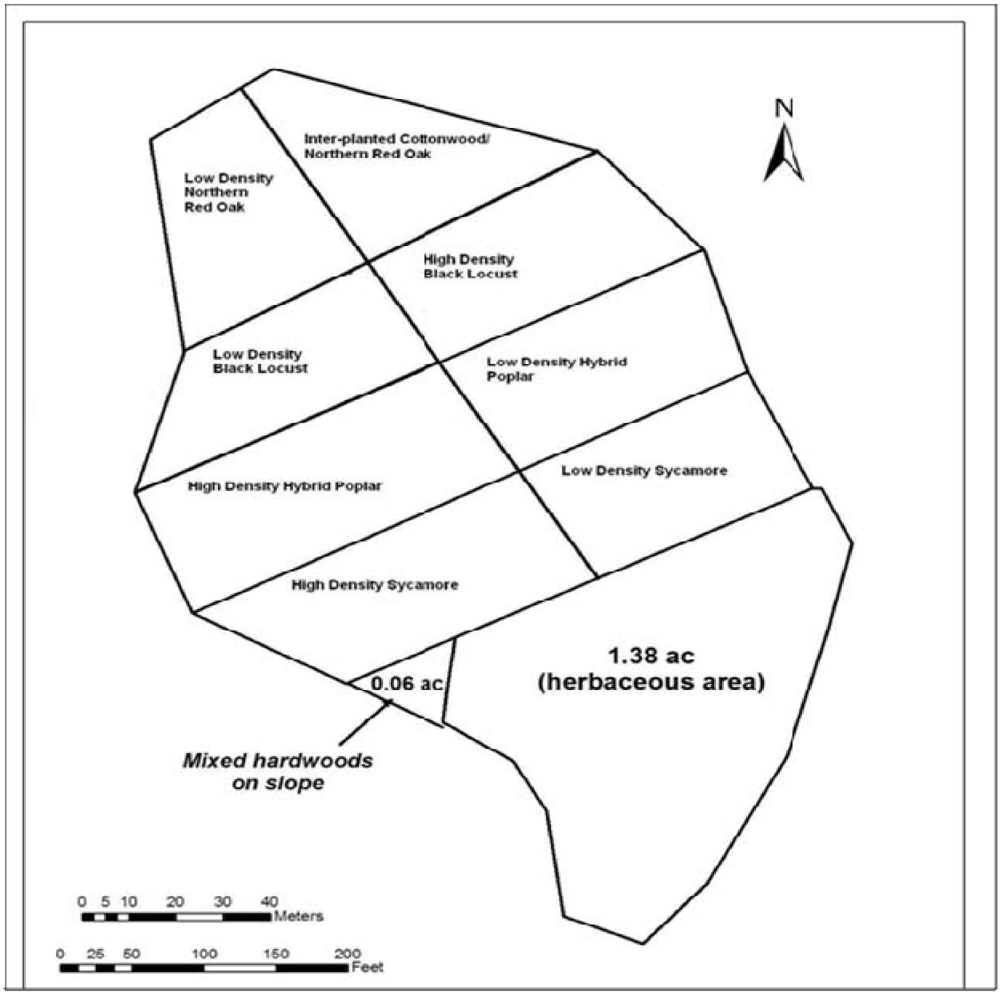

Figure 4. Treatment layout at Block 3 (Bean Gap).

Harvesting methods drove the rationale for these planting densities. The high-density planting is suitable for harvesting at a very young age (5-10 years) using a "mowing and chipping" type of harvesting equipment with an operating mechanism that resembles agricultural harvest equipment. The low-density planting would be suitable for harvesting with traditional whole-tree forestry equipment after a longer rotation. Within each treatment area and planting density, we installed permanent measurement plots of 7500 ft^2 (700 m^2). A few treatment areas were in non-homogeneous areas of the unit, so we reduced the size of these measurement areas to ensure relatively homogeneous ground in each treatment (Table 1).

Table 1. Biomass Year 1 stocking (measured March 2009).

	N	Mean Ht. (in)	Mean GLD (in)	Area (ft^2)	Trees ac^{-1}
Block 1 (Red River)					
High-density black locust	210	35.6	0.5	7500	1220
Low-density black locust	69	41.5	0.6	7500	401
High-density hybrid poplar	184	23.8	0.3	7500	1069
Low-density hybrid poplar	83	29.2	0.4	7500	482
Red oak	102	19.3	0.2	7500	592
Red oak/cottonwood	91/77	17.9/16.0	0.2/0.2	7500	976
High-density sycamore	154	18.5	0.3	7500	894
Low-density sycamore	40	17.9	0.4	7500	232
Mixed hardwood	46	20.0	0.3	7500	267
Block 2 (Across the Road)					
High-density black locust	164	31.7	0.5	6000	1191
Low-density black locust	55	30.5	0.5	5000	479
High-density hybrid poplar	130	21.8	0.4	7500	755
Low-density hybrid poplar	47	20.1	0.4	7500	273
Red oak	87	14.3	0.2	6000	632
Red oak/cottonwood	107/120	16.6/15.6	0.2/0.2	7500	1318
High-density sycamore	244	17.1	0.3	7500	1417
Low-density sycamore	62	15.4	0.3	7500	360
Mixed hardwood	20	11.5	0.2	2812	310
Block 3 (Bean Gap)					
High-density black locust	209	30.7	0.4	7500	1214
Low-density black locust	84	43.6	0.6	7500	488
High-density hybrid poplar	216	19.7	0.2	7500	1255
Low-density hybrid poplar	87	16.2	0.2	7500	505
Red oak	101	17.5	0.2	5000	880
Red oak/cottonwood	115/110	18.0/16.0	0.2/0.2	7500	1307
High-density sycamore	136	19.2	0.3	6250	948
Low-density sycamore	80	18.9	0.3	7500	465
Mixed hardwood	29	26.1	0.3	1250	1011

A fourth treatment included an additional high-density treatment of northern red oak (*Quercus rubra*) (11 x 11 ft) interplanted with rows of eastern cottonwood (*Populus deltoides*) (5.5 ft within row). This treatment was included to test the use of the fast-growing eastern cottonwood's ability to train the slower-growing but higher-value red oak. Red oak is a high-value sawtimber species that is native to Appalachian forests. The value of red oak as sawtimber can be increased by training its stem form at an early age by interplanting with eastern cottonwood, which can be harvested for biomass products at a relatively short rotation age. A low-density red oak treatment (11 x 11 ft) without cottonwood was included to compare against the interplanted red oaks. A final treatment of mixed hardwoods was included where space allowed, comparing biomass production of the more common planting of mixed hardwoods at low planting density (8 x 8 ft or 680 trees ac^{-1}).

In the late spring of both 2008 and 2009, a release spray of 2% glyphosate was used to reduce competition from weeds in a 3-ft (1-m) diameter circle around each of the trees in the treatment area. This spray was hand-applied using backpack sprayers. Because of a droughty summer in 2008 and low viability of seedling stock, red oak and eastern cottonwood survival was poor. Therefore, we replanted the red oaks and eastern cottonwoods in the late winter of 2008 to bring the density back to desired levels. In March of 2009 we measured each of the treatment areas for survival, height and groundline diameter (GLD).

Estimated rotation ages are 12 years for the hybrid poplar, black locust, and sycamore biomass crop, with a 60-year rotation for the red oak sawlog crop. The hybrid poplar and black locust will be grown strictly for biomass products. Although it is among the fastest-growing native Appalachian hardwood species when planted on suitable soils, the growth rate of sycamore is not as fast as those of black locust and hybrid poplar. However, its value at rotation age will be much higher if its butt log is used for sawtimber while the rest of the tree is chipped for biomass products. At age 12, the interplanted eastern cottonwood will be row-thinned and the red oaks will be left free to grow for a sawtimber rotation. The interplanted treatment will evaluate the silvicultural response of the oaks (i.e., determine whether or not the faster-growing poplars "train" the oaks to achieve a straight and tall stem form which is highly valued in timber markets) to the interplanted eastern cottonwoods, as well as total biomass production. This treatment will also help determine the effect of early revenue from biomass on a sawtimber forest enterprise.

Initial Results

Our initial measurement of survival indicates that the planting was successful (Table 1). Stocking levels are close to our projected levels. However, there is a range of stocking levels at each site and for each treatment. High-density first-year stocking ranged from 755 to 1317 trees ac^{-1}, while low-density stocking ranged from 232 to 505 trees ac^{-1}. Due to this range of stocking levels, future biomass production estimates will be conducted on a per-tree and per-acre basis to allow land managers to estimate probable operational biomass production.

Black locust had the highest mean height and groundline diameter at all three sites. Hybrid poplar generally had the next highest mean height and groundline diameter, with sycamore being slightly smaller at Year 1. The red oak and eastern cottonwood have the smallest mean heights and groundline diameters at Year 1. We did not calculate biomass or carbon production using these Year 1 measurements. Measurements at Year 3 or Year 5 will be used for an initial estimate of comparative species performance.

Future Analysis

We plan to track growth over the rotation ages for each treatment with a focus on aboveground biomass production, above- and belowground carbon sequestration, and sawtimber production. Analysis will be conducted addressing optimum harvest scheduling timing, as well as per-acre expenditures and possible revenue streams for all of the management scenarios that this study represents.

Acknowledgments

The authors extend thanks to Alpha Natural Resources and the Powell River Project for funding this research. Thanks also to Forestland Group, Penn Virginia Resource Partners, and Red River Coal for their assistance, including granting access to the experimental sites. Thanks to Amy Villamagna for field assistance.

Literature Cited

Amichev, B. 2007. Biogeochemistry of carbon on disturbed forest landscapes. Ph.D. Dissertation. Department of Forestry, Virginia Tech, Blacksburg. VA.

Burger, J. A., and A. G. Fannon 2009. Capability of reclaimed mined land for supporting reforestation with seven Appalachian hardwood species. pp. 176-191. In: R. A. Barnhisel (ed.). Proc., 26th Natl. Mtg., Amer. Soc. for Mining and Reclamation, Billings, MT. ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

Burger, J. A. 2004. Restoring forests on mined land in the Appalachians: Results and outcomes of a 20-year research program. In: R. I. Barnhisel (ed.). Proc., 21st Natl. Mtg., Amer. Soc. for Mining and Reclamation, and 25th West Virginia Surface Mine Drainage Task Force Symp.

Dominion Resources. 2009. Virginia City Hybrid Energy Center. http://www.dom.com/about/stations/fossil/virginia-city-hybrid-energy-center.jsp Verified 23 July 2009.