Carbon Sequestration on Surface Mine Lands

Annual Report

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ABSTRACT

The 2002-2003 Department of Energy plantings amounted to 164 acres containing 111,520 tree seedlings in eastern and western Kentucky. Data gathered on these trees included an inventory to determine survival of all planted species. A sub-sample of seedlings was selected to assess the height and diameter of individual species of seedlings established. Additional efforts involved collection of soil sample and litter samples, analysis of herbaceous ground cover from vegetation clip plots and leaf area on each tree species, and development of tissue collections. All areas were sampled for penetration resistance, penetration depth (or depth to refusal), and bulk density at various depths. Rain fall events and flow rates were recorded. The water quality of runoff samples involved the determination of total and settleable solids and particle size distribution. A study was initiated that will focus on the colonization of small mammals from forest edges to various areas located on reclaimed surface mines. This effort will provide a better understanding of the role small mammals and birds have in the establishment of plant communities on mine lands that will be useful in developing and improving reclamation techniques.

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INTRODUCTION

EXECUTIVE SUMMARY

When the University of Kentucky was advised that the United States Department of Energy had approved the proposal for a research project entitled "Carbon Sequestration on Surface Mine Lands," the planning stage began. Efforts were initiated to notify cooperating land owners to expect to initiate the project on their properties. The securing of tree seedlings and tree planters was also initiated.

The procurement of project staffing is a continuous process as activities change, as is the identification of land for the project, potential property owners, partners and cooperators. However, there seems to be a number of willing individuals for the objectives. Site plans were developed for each area planted and base line data was collected pre-planting and shall be conducted on a continuous basis thereafter.

There are some activities being conducted to modify standard reclamation procedures by requesting "experimental practices" variations on certain mine sites. Site preparation was conducted on areas, where required by the land holders/owners.

Over 160 acres (64.8 ha) of trees were planted in eastern and western Kentucky that depicted a mixed stand similar to the natural vegetation of the area. It was decided that the initial plantings would be area plantings of mixtures that emulate climax forests in the regions as near as possible given the species constraints available from the nurseries. The species numbers planted on the eastern Kentucky site at 17 West is shown in table 1 and similar data for western Kentucky at Peabody Coal is shown in table 2.

Maps of all the areas planted have been developed and furnished to the Department of Energy Project Director. These maps will be amended on a continuous basis as additional plantings are completed. At the completion of the 2003 tree planting operations, the sites were evaluated and potential locations were selected for installation of monitoring equipment. An assessment of down gradient sediment controls was conducted to ensure protection of the environment.

A standardized protocol for training personnel in field data acquisition was developed as well as one for the inspection and monitoring field data acquisition equipment Protocols were developed for sediment analysis. Field personnel have constructed six critical flow trapezoidal flumes and six stilling wells. They have also prepared ISCO samplers and calibrated pressure transducers for field deployment. Automated weather stations are ready to assemble in eastern and western Kentucky. Recording rain gauges have been installed.

Sample plots were established in the mixed species planting areas at both western and eastern Kentucky reforestation sites. Plots were designed in a manner to both adequately sample each species planted and to account for differences with respect to site

preparation activities and micro-topographic variability amongst planting units. These plots will also be utilized for measuring carbon pools within the sites.

Detailed studies to address specific questions pertaining to carbon flux have been initiated with additional manipulative plots to examine the influence on spoil depth, mycorrhizea, chemical and mineralogical properties and use of amendments on forest establishment. Seedlings used for the study are being grown at the Kentucky Division of Forestry Nursery. Seedlings were monitored throughout the summer and an inoculation index will be performed in the fall months.

All planting areas in eastern and western Kentucky have been sampled with the recording cone penetrometer to determine the relative level of compaction or depth of refusal. All areas are also sampled with a nuclear density gauge as another measure of soil density. The project milestones are depicted for the three year period in table 3.

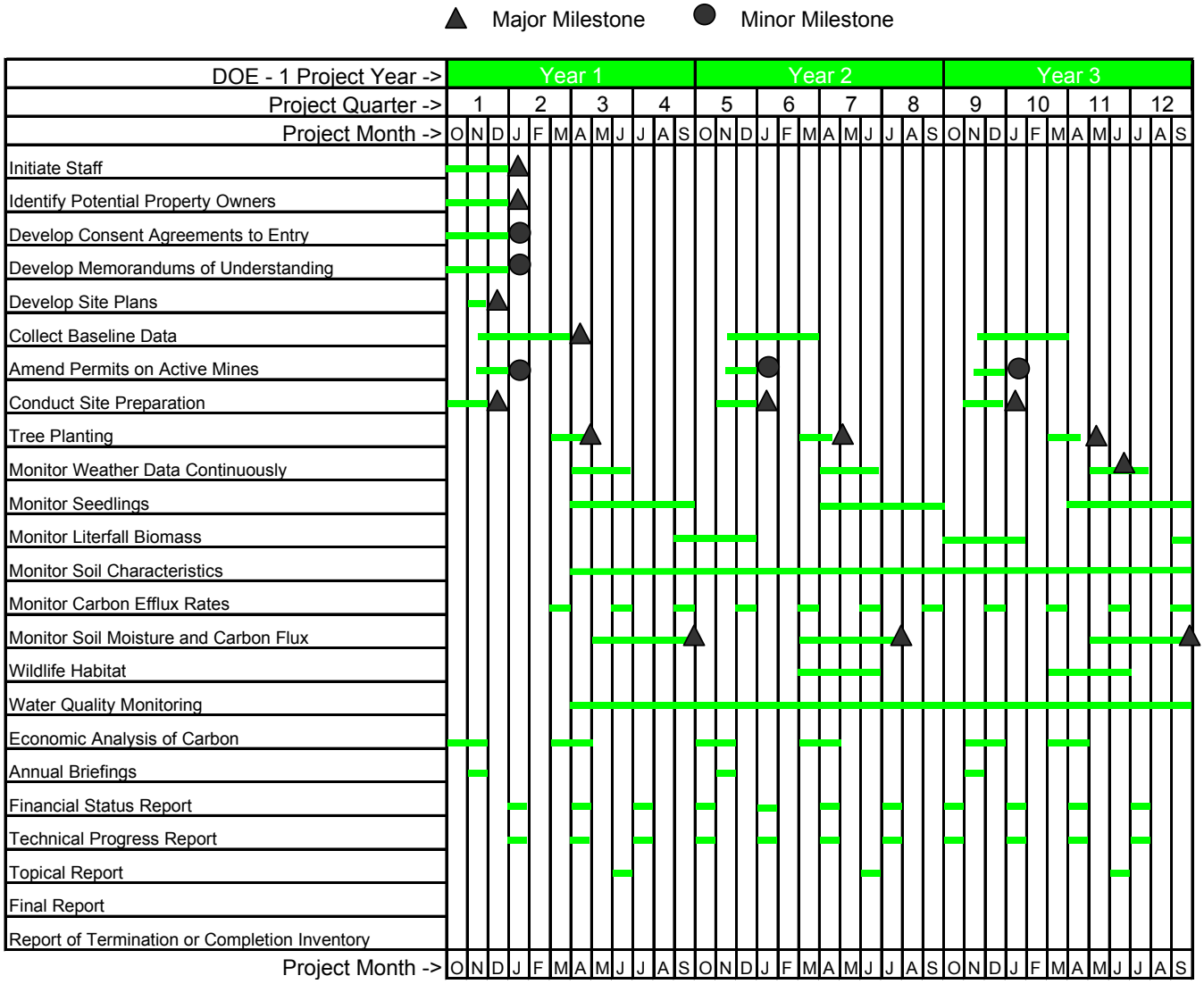
Table 1.
17 West DOE Plantings – Year 2003
Eastern Kentucky
72,760 seedlings
107 acres (43.3 ha.)

Species	Total	Per Acre
White Oak	14,959	139.8
Northern Red Oak	14,959	139.8
White Ash	14,959	139.8
Yellow Poplar	9,248	86.4
Sugar Maple	3,158	29.5
Black Locust	7,422	69.4
White Pine	4,133	38.6
Gray Dogwood	1,950	18.2
Redbud	1,950	18.2

Table 2.
Peabody DOE Plantings – Year 2003
Western Kentucky
38,760 seedlings
57 acres (21.5 ha.)

Species	Total	Per Acre
Cypress	3,341	58.6
Loblolly Pine	1670	29.2
Persimmon	1,000	17.5
Grey Dogwood	1,000	17.5
Cherry Bark Oak	5012	87.9
Shumard Oak	3,341	58.6
Southern Red Oak	3,341	58.6
White Oak	5,012	87.9
Northern Red Oak	5,012	87.9
Green Ash	5,012	87.9
White Ash	4,050	71.1
Black Locust	1,000	17.5

Table 3. Milestones



EXPERIMENTAL

The study is taking place in three distinct mining regions in Kentucky's eastern and western coalfields regions. Specific mining sites are located in southeastern Kentucky near the West Virginia border, in southeastern Kentucky near Hazard and in western Kentucky near Central City.

Tree species selections are intended to provide a gradient of tree growth and litter quality. Tree species included white ash, yellow poplar, white pine and other available species (Tables 1 and 2). Seedlings of each species were planted randomly in mixed species plots on compacted (control), dozer ripped and leveled loose-dumped spoil at two of the three mining locations.

A monitoring program was implemented to measure treatment effects on aboveground and belowground C and nitrogen (N) pools and fluxes for the planting areas. Sample plots were established in the mixed species planting areas at the two reforestation sites. Plots were designed in a manner to both adequately sample each species planted and to account for differences with respect to site preparation activities and micro-topographic variability amongst planting units. As such, multiple 50 x 50 meter plots (8) were set within planting units that exceeded 8 hectares in area. This scenario was replicated within each reforestation site and for the differing reclamation practices employed (ripped vs. uncompacted vs. compacted). In addition, complete seedling inventories were analyzed in several smaller plots (1-2 ha.) that presented unique features in both reforestation areas. The sampling strategy will provide for a minimum of 100 seedlings per species per planting unit, which will allow for statistical comparison of the differing species within the differing planting conditions and sites. These plots will also be utilized for measuring carbon pools within the sites

Seedling height and diameter were measured within the monitoring plots and will be remeasured annually. Notes were taken on seedling health, vigor, growth form and level of herbivory. Leaf area measurements were performed on a subset of trees from each plot (3 per species per plot). Once measured, individual leaves were collected, dried, weighed and analyzed for C and N. Aboveground seedling biomass production shall be estimated with allometric equations developed from the above information for the individual species. Plots were planted with enough seedlings so that select trees can be later sacrificed to determine whole tree biomass, and evaluate C and N levels in stems, branches and roots. Root biomass will be measured using sequential soil coring over an annual cycle, and through whole tree harvesting. Clip plots were used to measure herbaceous production on the mine soil. Litter was collected from the plots using 0.5 m^2 plastic litter baskets. The baskets are emptied each month and the litter is dried, weighed and analyzed for C and N.

Soil samples were collected from each plot at 0-5, 5-10, 10-20 and 20-40 cm increments for chemical and mineralogical characterization. Physical attributes of soils on the sites were determined using a recording cone penetrometer and a nuclear density

gauge. Both instruments provide information on the relative level of compaction or depth of resistance.

Hydrology and water quality monitoring equipment was installed at the eastern and western Kentucky reforestation sites. Flumes and stilling wells were placed adjacent to the planting areas to measure runoff from rain events. ISCO automatic water samplers were installed to evaluate export of solids and C from the planting areas. Solar panels and liquid level actuators were connected to the ISCO samplers to: 1) provide a constant power source and 2) to initiate sampling only when runoff was detected. Pressure transducers and mini-dataloggers were installed to provide continuous (10 minute interval) stage data for determination of flow rates. Water samples were collected from the ISCOs after each event that produced sample; then, transferred to the University of Kentucky in coolers at 4^0C where they were analyzed for total and suspended solids, total dissolved solids, particle size analysis, and total organic carbon. A weather station consisting of a tipping bucket style rain gauge was installed to monitor rainfall events at each flume location. Data is recorded at five-minute intervals using HOBO event datalogger. Additional weather stations will be installed at each of the major reforestation sites to measure precipitation volume, temperature, relative humidity, wind speed and direction and solar radiation. The weather stations will be centrally located among plots within each site.

Detailed studies to address specific questions pertaining to carbon flux are being initiated with the development of additional manipulative plots to examine the influence of spoil depth, mycorrhizae, chemical and mineralogical properties, and use of amendments on forest establishment. Based upon earlier studies by UK and the USDA Forest Service, mycorrhizal fungi have been shown to play a major role in the survival, nutrient uptake and biomass development (above and below ground) of seedlings planted on mined sites and abandoned industrial areas. Given that the current reforestation study intends to examine the potential for enhanced carbon sequestration on mined sites via C accumulation in soil and forest biomass, then efforts to maximize seedling survival and growth should be further examined. As such, a factorial experiment using inoculated vs. non-inoculated species in non-fertilized, fertilized only, amended (organic mulch) only, and fertilized + amended plots will be examined. Seedlings used for the study are being grown at the Kentucky Division of Forestry Nursery. Currently, the Nursery does not inoculate their beds with mycorrhizae, so the mycorrhizal trees used for the study will be initially inoculated in the beds and later treated with root dip applied at the time of transplanting. As such, preparation of seedling beds was performed this year at the Morgan Co. Nursery for the experimental study. Beds were prepared using a tractor drawn-inoculator that places a vegetative inoculum of *Pisolithus tinctorius* (Pt) and *Scleroderma cepa* (Sc) at a depth of approximately 10 cm between the seedling rows. Seedlings were monitored in the beds throughout the summer and an inoculation index was performed in the Fall.

RESULTS AND DISCUSSION

The analyses of the first year data is currently in process. This information should be completed and included in the next annual report. At that time we should have information on survival percent by species, average seedling height and diameter, spoil density, hydrology characteristics, soil characteristics, plant biomass, tissue analysis and litter content and a general assessment of initial carbon pools.

CONCLUSIONS

There are no conclusions at this time. The project is scheduled to continue for two more years.