Carbon Sequestration on Surface Mine Lands

Quarterly Report

Reporting Period Start Date: 01/01/05
Reporting period End Date: 03/31/05

Principal Authors: Donald H. Graves
Christopher Barton
Richard Sweigard
Richard Warner

Date Report Issued: June 22, 2005
DOE Award Number: DE-FC26-02NT41624

Name and Address of Submitting Organization

University of Kentucky
Department of Forestry
Lexington, Kentucky 40546-0073

DISCLAIMER

"This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents, that its use would not infringe on any privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

ABSTRACT

An area planted in 2004 on Bent Mountain in Pike County was shifted to the Department of Energy project to centralize an area to become a demonstration site. An additional 98.3 acres were planted on Peabody lands in western Kentucky and Bent Mountain to bring the total area under study by this project to 556.5 acres as indicated in Table 2. Major efforts this quarter include the implementation of new plots that will examine the influence of differing geologic material on tree growth and survival, water quality and quantity and carbon sequestration. Normal monitoring and maintenance was conducted and additional instrumentation was installed to monitor the new areas planted.

TABLE OF CONTENTS

LIST OF GRAPHICAL MATERIAL

INTRODUCTION

EXECUTIVE SUMMARY

During the three years of this project 383,000 trees have been established on over 556 acres in three different physiographic areas of Kentucky. A monitoring program continues to measure treatment effects on above and below ground C and nitrogen (N) pools and fluxes. Sampling continues that will provide statistical comparisons of various species within the various planting conditions and sites. Major efforts this quarter include the implementation of a new study site to examine the influence of differing geologic material on tree growth and survival, water quality and quantity and carbon sequestration. Below is an overview of this project.

EXPERIMENTAL

GEO-HYDROLOGY STUDY

Excessive compaction of spoil material is the biggest impediment to the establishment of productive forests on surface mines in the eastern United States. Reforestation researchers recommend that topsoil, weathered sandstone and/or the best available material be placed on the surface and loosely graded to create a non-compacted growth medium that is no less than 1.2 meters deep. Reclamation practitioners have expressed confusion as to what actually constitutes the best available material other than topsoil. Researchers have reported on the attributes of loose-graded brown weathered sandstone spoil separately from loose-graded gray un-weathered sandstone spoil on different mine sites. However, no side-by-side comparisons of these two spoil types have been made on the same mine site. Six research plots have been established on a surface mine for the purpose of evaluating the influence of three different loose-graded spoil types on tree performance and carbon sequestration. The three spoil types are: (1) predominately brown weathered sandstone; (2) predominately gray un-weathered sandstone; and (3) equally mixed brown weathered and gray un-weathered sandstones. Four species of tree seedlings were planted into the loosely graded spoil and tree height, tree diameter, and above and below ground biomass will be measured in June of 2005, 2006 and 2007. The null hypothesis of this research is that all spoil types generate the same tree performance. The research hypothesis is that trees respond differently to different spoil types. This research has the potential of testing the validity of controversial and costly regulations imposed upon the mining industry concerning the redistribution of specific spoil types.

Seedling heights and diameters continue to be measured for initial status and re-measured on an annual basis to quantify growth. Leaves are being harvested to determine leaf area and are dried and weighed to determine C and N content. Whole trees are being extracted to determine biomass levels above and below ground and to evaluate the C and N levels in all components of the trees. Clip plots continue to be gathered to determine herbaceous production and litter is collected on a monthly basis in baskets to quantify the C & N levels.

Soil samples of all new areas were collected to determine the chemical and mineralogical characterization of each area. All areas are being monitored to determine the bulk density of the soils both when initially planted and over time to more fully understand the total physical attributes of surface mine soil development.

Hydrology and water quality measurement is being conducted on all areas. Weather data is continually recorded and measures precipitation values, temperature, relative humidity, wind speed, and direction, and solar radiation.

Additional studies have been added to address specific questions pertaining to carbon flux, previously installed studies continue to be monitored and measured.

OBJECTIVES

1. To evaluate tree performance in three types of loose-graded spoil.
2. To determine which spoil type is best for tree performance and sequestration of carbon.
3. To evaluate water movement in the three types of loose-graded spoil.
4. To provide information pertaining to water utilization and evapotranspiration by the growing trees.

JUSTIFICATION

Since the implementation of the federal Surface Mining Control and Reclamation Act of 1977 (SMCRA) in May of 1978, many opportunities have been lost for the reforestation of surface mines in the eastern United States. Soil scientists and foresters have claimed that excessive compaction of spoil material in the backfilling and grading process is the biggest impediment to the establishment of productive forests as a post-mining land use (Ashby et al., 1984, Burger et al., 1997, Graves et al., 2000).

In the 1950's and 1960's, a regulatory requirement of surface mining performed in the gently rolling terrain of the Midwestern states was referred to as "strike-off" reclamation. This requirement consisted of making one or two bulldozer passes down the length of each parallel ridge of soil, pushing it into the parallel valleys on both sides. If viewed from the air, the result of "strike-off" reclamation would look like the rough surface of a giant washboard. Trees were then planted at the rate of 1500 to 2000 per hectare into this loosely graded spoil bank. The growth of those trees in this non-compacted spoil over the past 40 to 50 years has been remarkable (Ashby et al., 1978).

Stability of mine sites was a prominent concern among regulators and mine operators in the years immediately following the implementation of SMCRA. These concerns resulted in the highly compacted, flatly graded, and consequently unproductive spoils of the early post-SMCRA era. However, there is nothing in the regulations that requires mine sites to be overly compacted as long as stability is achieved. It has been cultural barriers and not regulatory barriers that have contributed to the failure of reforestation efforts under the federal law over the past 27 years. Efforts are being taken to change the perception that the federal law and regulations impede effective reforestation techniques and interfere with bond release.

Drawing on the recommendations generated by surface mine reclamation research over the past 40 years, the United States Department of Interior's Office of Surface Mining Reclamation and Enforcement and the seven state regulatory authorities in the Appalachian Region advocate the following forestry reclamation techniques: (1) Create a suitable rooting medium for good tree growth that is no less than 1.2 meters deep and comprised of topsoil, weathered sandstone and/or the best available material; (2) Loosely grade the topsoil or topsoil substitutes placed on the surface to create a non-compacted growth medium; (3) Use native and non-competitive ground covers that are compatible with growing trees; (4) Plant two types of trees – early succession species for wildlife and soil stability, and commercially valuable crop trees; and, (5) Use proper tree planting techniques (Office of Surface Mining, 2005).

Although the second recommendation dealing with compaction is generally considered the most important, it is the first recommendation involving the selection of a suitable spoil type as the rooting medium that has generated the most controversy and confusion. Researchers have reported on the attributes of loose-graded brown weathered sandstone spoil (Burger and Torbert, 1992). Other researchers have identified loose-graded mixed un-weathered sandstone and shale (mine run) spoil as being highly productive (Conrad et al., 2002). Although these studies do not conflict in regards to their findings, the economic considerations implied by each are significant. Furthermore, several gaps currently exist in the scientific literature concerning the selection of a suitable spoil type as the rooting medium. Most of the studies concerning this subject lack statistical validity and provide, at best, only pseudo replication of treatments. Because of cost and space limitations the studies involving the selection of a suitable spoil type are more demonstration projects than research projects. Also, no side-by-side comparisons of brown weathered sandstone spoil, gray un-weathered sandstone spoil and mixed sandstones/shale from the same overburden have been made to date. This study is designed to make those comparisons.

METHODS

Research plots were established in March 2005 on an active mountaintop removal operation for the purpose of evaluating tree performance, conducting water characterization studies and determining the mineralogical, chemical and physical characteristics of three different types of loose-graded spoils (see Figure A – Aerial photograph of research plots). The mine site is located on Bent Mountain on Brushy Fork near the community of Meta in Pike County Kentucky (latitude N 37° 35′ 50″, longitude W 82° 23′ 38″). Three spoil types are involved: (1) predominately brown weathered sandstone; (2) predominately gray un-weathered sandstone; and (3) equally mixed brown weathered and gray un-weathered sandstones. The three spoil types are the three treatments in this experiment and they are applied as a one-way treatment structure in a completely randomized design structure. Each of the three treatments was installed in a square plot that measures 63.7 meters on each side. The total area of each plot is 4050 square meters. The three treatments were replicated once, creating a total of six plots or experimental units (see Figures 1 and 2). The three treatments were randomly assigned to the six plots. Each of the six plots was physically separated and isolated from each other by a 2.5-meter buffer zone where no loose spoil was dumped. The buffer zones will also serve as an access to drain pipes and instrumentation installed in the six plots.

A rectangular foundation for the six plots was prepared with spoil material from the mountaintop removal operation. The foundation, which is about 3.5 hectares in size, was orientated along the long axis in a northwest-southeast direction on a 2% slope with the highest elevation occurring on the southeast edge. The foundation was then divided in half along the short axis and graded on a 2% slope so that the center line of each plot is at a lower elevation than the northeast and southwest edges (forming a "bathtub" configuration to facilitate the flow of water to the center and then to the exit point of each plot). The spoil in the foundation was then highly compacted by repeated passes of both rubber tired and tracked heavy equipment so that it is impervious to water.

At the exit point of each plot and in the area of the buffer zones, a pit was dug into the compacted foundation that measured 2 meters by 2 meters and 1 meter deep. The floor of the pit slopes to a 20-centimeter diameter hole drilled through about 5 meters of the compacted foundation and about 12 meters of rock overburden to an abandoned underground mine in the Peach Orchard coal seam below the plots. The underground mine is an abandoned conventional room and pillar operation on 6 meter by 18 meter centers. The drainage system to the underground mine below the plots was installed to completely isolate each plot so that no drainage from one plot can mix with drainage from any other plot.

Prior to the placement of the three spoil types on the six plots, a system of drainage pipes and lysimeters were installed on top of the compacted foundation. Each of the six plots is drained by a perforated 10.2 cm PVC pipe (see Figures 3). The PVC pipes span the entire length of each plot down the center of the "bathtub" to the exit point and into the pit where drainage enters into the underground mine below. Three pan lysimeters were also installed on top of the compacted foundation of each of the six plots (see Figures 3). The lysimeters are 4.6 meters square and are drained to the exit points by PVC pipes that are 2.5 centimeters in diameter. The lysimeters and the PVC pipes were then carefully covered with approximately 1 meter of the spoil type specific to each plot to protect them from the impact of the spoil and rocks that would be dumped on them.

Once the lysimeters and PVC drainage pipes were installed, spoil was dumped out of the end of large dump trucks onto the compacted foundation into tightly placed piles that are about 3.7 meters deep. The spoil piles were placed in parallel rows in such a way that they closely abut one another across each of the six plots. The spoil piles were then "struck-off" with one pass of a small bulldozer (D-5) down the length of each parallel ridge of spoil, pushing it into the parallel valleys on both sides. The spoil was dumped in the six plots and struck off as specified in Reclamation Advisory Memorandum Number 124 issued by the Kentucky Department of Natural Resources. Soil samples were collected from the sites and are currently being analyzed.

Four species of tree seedlings of 2:1 nursery stock were planted into the loosely graded spoil of the six plots on April 2, 2005. The four species were white oak *(Quercus alba)*, red oak *(Quercus rubra)*, yellow-poplar *(Liriodendron tulipifera)*, and green ash *(Fraxinus pennsylvanica)*. The tree seedlings will be the sampling units. The response variables will be tree height, tree diameter, and above and below ground biomass. These measurements will be taken during June of 2005, 2006 and 2007.

In collaboration with the American Chestnut Foundation, sub-plots were established on each of the six plots to determine the survivability of American chestnuts (*Castanea dentata)* planted in the different spoil types. The purpose of this research is to investigate some specific aspects of Phytophthora root rot on American chestnut restoration and some of the implications of that disease regarding the suitability of American chestnut reforestation for mined land reclamation. However, rodent herbivory caused extremely high mortality of the hand planted nuts in the spring of 2005. Planting of tree seedlings instead of nuts will be attempted in the next tree-planting season (spring 2006).

The instruments installed include modified rain gauges at the ends of each of the six drains located in the pits (see Figures 2 and 3), 36 sensors for time domain reflectometers (6 per plot) located at three different depths in the spoil, and a complete weather station.
In addition to the six end-dumped research plots, approximately 7.3 hectares of triple and single shank ripping was preformed with a D-11 bulldozer. Also, a new

treatment for previously compacted spoil called "push-up" was installed with a D-11 bulldozer. This innovative treatment consisted of pushing compacted spoil up into long parallel rows that were 2.5 – 3 meters high on which no strike-off grading was preformed. In a similar fashion, end-dumped spoil was also pushed up into long parallel rows. Both types of pushed-up spoil (previously compacted and end-dumped) covered an area of about 0.8 hectares. Trees were planted in both the ripped areas and the area where spoil was pushed up. In the push-up area, trees were planted in both the ridges of the rows and in the valleys of the rows to determine which location was best for survival and growth.

The operator of the mountaintop removal operation, Appalachian Fuels, contributed to this project by installing the foundation and the six plots at a total cost of $199,462.56.

RESULTS AND DISSCUSSION

As a preliminary to the above research established in 2005, 15 research plots were established on this mining operation in late 2003 and early 2004 for five different spoil treatments: end-dumped spoil, triple shank ripped spoil, single shank ripped spoil (with a modified ripping blade), excavated spoil, and compacted spoil. Each of the five spoil treatments was established in three plots that measured 50 meters by 50 meters. The end-dumped spoil material consisted of mixed sandstones/shale (mine-run) spoil, which was graded with one pass of a D-11 bulldozer. The passes with the bulldozer were spaced 7.5 to 9.0 meters apart. The single shank ripping was performed on previously compacted slopes and penetrated 2.0 to 2.5 meters deep. The triple shank was used on compacted spoil that was level. The excavated spoil was prepared with an excavator that dug 0.9 to 1.0 meter deep into previously compacted spoil. Each bucket of spoil was dug and then dumped in place. The following is a list of the ten tree species and the approximate numbers planted on the 15 plots and adjacent areas on a spacing of 2.4 meters by 2.4 meters in mid-February 2004:

Green Ash	13,000
White Oak	12,000
Northern Red Oak	17,250
Sugar maple	4,500
White Pine	3,000
Black Locust	6,500
Redbud	2,250
Yellow Poplar	6,500
Dogwood	2,000
Sycamore	6,000
Total Trees Planted	73,000

During the spring of 2004, all of the trees in the 15 research plots were tagged and measured. Tree number, species and height to the nearest centimeter were recorded. Also recorded was vigor class (0 = dead, 1 = nearly dead, 2 = Intermediate/stressed, 3 = vigorous/some stress, 4 = vigorous/no stress) and distinguishing features (B = browsed, D = dieback, S = sprout after dieback). Second year measurements of each tree in the research plots established in 2004 are currently ongoing. First year measurements of each tree in the research plots established in 2005 will commence later in the spring.

OTHER ACTIVITIES

Conducted a tour of the surface mine test areas for:

- Kentucky Secretary Environment and Public Protection Cabinet: LaJuana Welcher
- US Army Corp of Engineers Commander: Colonel Robert Rowlette
- US Environmental Protection Agency, Region 4 Administrator: Jim Pulmer

All monitoring equipment was inventoried, tested and received necessary maintenance. All sites were inspected and adjusted as necessary. New monitoring devices were installed as necessary for new installation data analysis were continued or initiated on all research areas.

The United States Department of Interior, Office of Surface Mining (OSM) and the seven states in the Eastern coalfields are showing considerable interest in this research complex. On June 16, 2005, staff members from OSM's London Area Office, Lexington Field Office, and Pittsburgh Regional Office will visit this research complex. The site visit will include OSM's Appalachian Regional Director and OSM's Field Office Director for Kentucky. The Commissioner and Director of Field Services for the Kentucky Department of Natural Resources will join them. On August 3, 2005, approximately 50 members of the Appalachian Regional Reforestation Initiative will conduct a field tour of the research at this location for the purpose of learning the techniques of the loose-grade forestry reclamation approach and applying them in the other coal states. Included in this group will be reclamation and reforestation research scientists from eight different Universities and regulators from seven different coal states and OSM. Other field trips are being planned for this site. This high level of interest can be attributed to the growing controversy involving the use of brown sandstone versus gray sandstone.

CONCLUSIONS

No conclusions are determined as an additional year of data is scheduled to be gathered and analyzed. There are some very enlightening trends beginning to emerge. However, it seems that three years may not be long enough to determine the full impact of this research since trees are a long term commodity that requires years of growth to fully evaluate them for a total impact, and it takes at least three years to find any discernable differences.

REFERENCES

Ashby, W.C., C.A. Kolar, M.L. Guerke, C.F. Persell and J. Ashby. 1978. Our reclamation future with trees, coal extraction, and utilization. Research Center, Southern Illinois University at Carbondale. 101 pp.

Ashby, W.C., W.G. Vogel, C.A. Kolar and G.R. Philo. 1984. Productivity of stony soils on strip mines. Erosion and productivity of soils containing rock fragments. p 31. Soil Science of America, Madison, WI.

Burger, J.A. and J.L. Torbert. 1992. Restoring forests on surface-mined lands. Virginia Polytechnic Institute and State University Publication 460-123, Blacksburg, VA.

Burger, J.A. and J.L. Torbert. 1997. Restoring forests on surface-mined land. Virginia Cooperative Extension. http://www.ext.vt.edu/pubs/mines/460-123/460-123.html.

Cochran, W.G., and G. M. Cox. 1957. Experimental Designs. Second Edition. John Wiley and Sons. New York. http://duke.usask.ca/~rbaker/NumReps.html.

Conrad, P.W., R.J. Sweigard, D.H. Graves, J.M. Ringe and M.H. Pelkki. 2002. Impacts of spoil conditions on reforestation of surface mined land. Mining Eng. 54:10.

Graves, D.H., J.M. Ringe, M.H. Pelkki, R.J. Sweigard and R. Warner. High value tree reclamation research. In: Singhal and Mehrotra (Ed.) Environmental Issues and Management in Energy and Mineral Production. p 413. Balkema, Rotterdam, The Netherlands.

Office of Surface Mining Reclamation and Enforcement. 2005. Office of Surface Mining and Reclamation Enforcement, U.S.D.I. – Appalachian Regional Reforestation Initiative. Web site: http://arri.osmre.gov/

Table 1. Tree Species Planted in Eastern Kentucky and Western Kentucky by percent each species

Tree Species Planted in Eastern Kentucky and Western Kentucky (percent each species)

Eastern Kentucky		Western Kentucky	
Green Ash	14.9	Green Ash	14.7
Sycamore	3.6	N Red Oak	13.5
White Oak	17.4	Shumard Oak	8.3
Chestnut Oak	7.2	White Oak	14.1
N Red Oak	24.6	Bur Oak	12.8
Sugar Maple	3.3	Yellow Poplar	14.1
Yellow Poplar	9.1	Bald Cypress	1.9
Black Locust	8.7	Black Locust	8.3
White Pine	4.7	Pitch/Lob Pine	5.8
Red Bud	3.3	Silky Dogwood	3.8
Dogwood	3.2	Redbud	2.7
	100.00		100.00

Table 2. Trees planted by year and location for Department of Energy grant number DE-FC26-02NT41624

LOCATION	NUMBER OF TREES	ACRES
17 West (Martin County)	72760	107
Peabody Coal (Western KY)	38760	57
2003 Total	**111520**	**164**
Peabody Coal (Western KY)	38760	57
(Study Area)	5000	5
Pittston (Breathitt County)	81600	120
(Study Area)	5000	5
Bent Mountain (Pike County)	73661	107.2
2004 Total	**204021**	**294.2**
Peabody (Western KY)	47600	70
Bent Mountain (Pike County)	19860	28.32
2005 Total	**67460**	**98.32**
Total of All Years	**383001**	**556.5**

Figure 1. Bent Mountain Research Area Layout

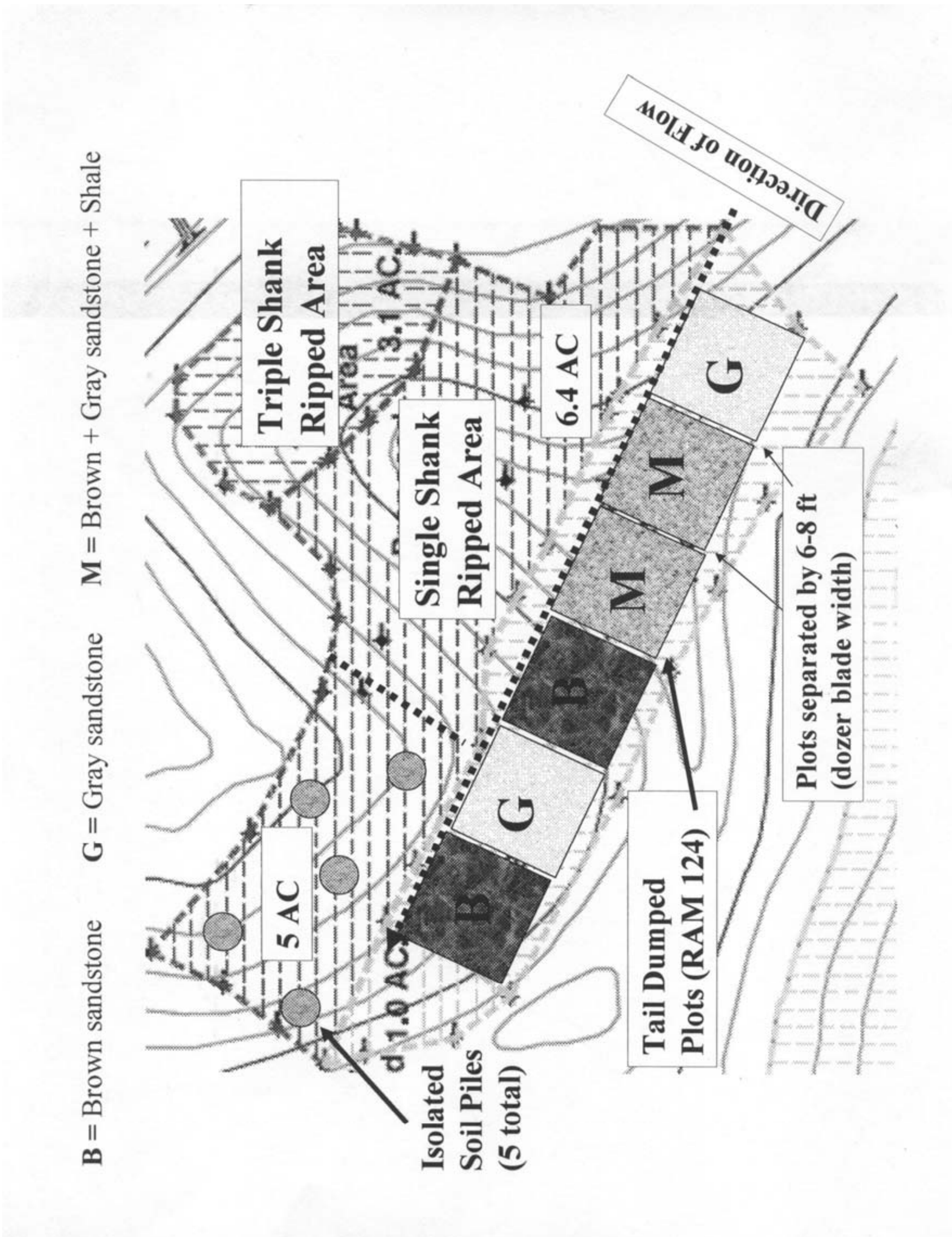

Figure 2. End View of Bent Mountain Tail Dump Plots

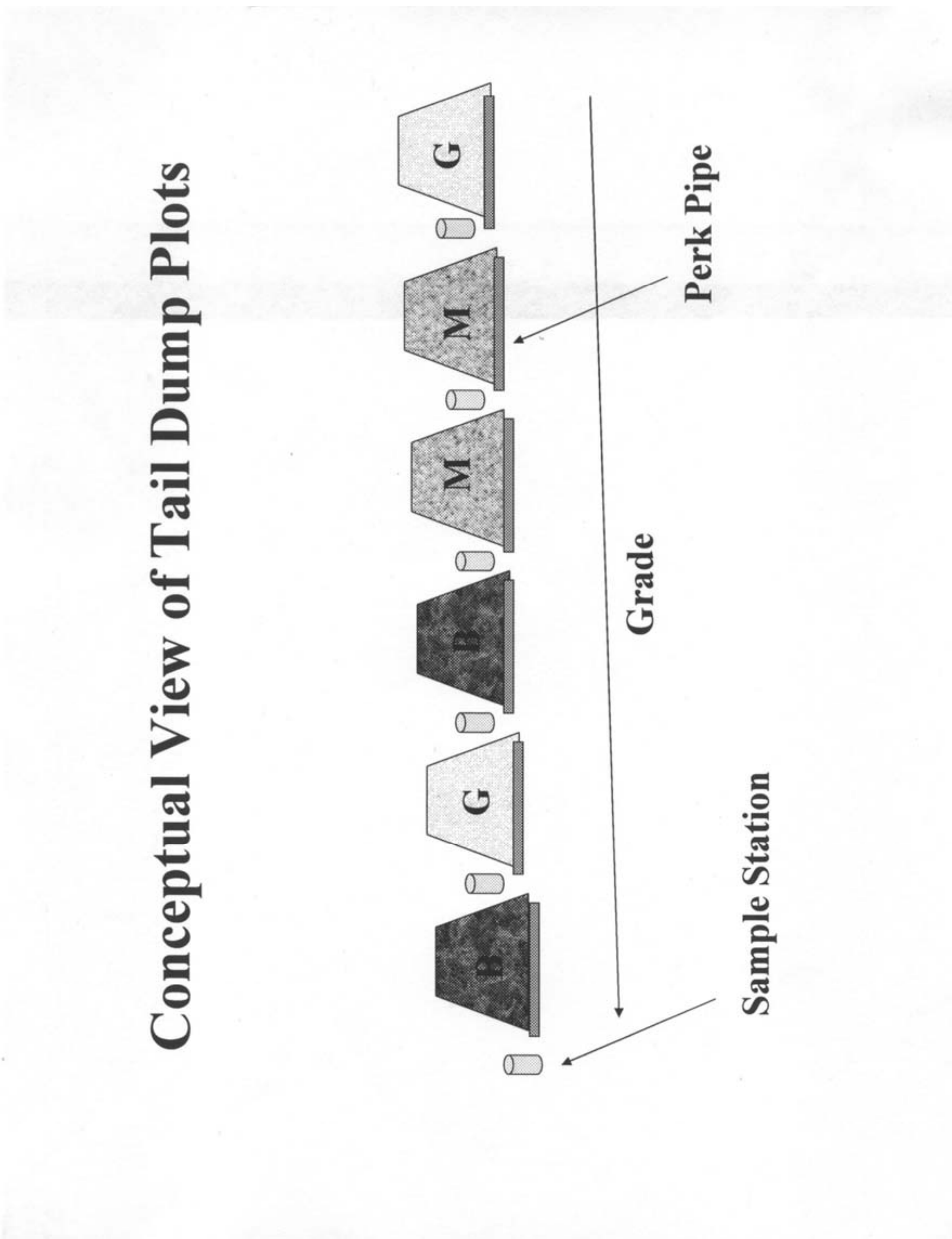

Figure 3. Internal View of Bent Mountain and Dump Plots

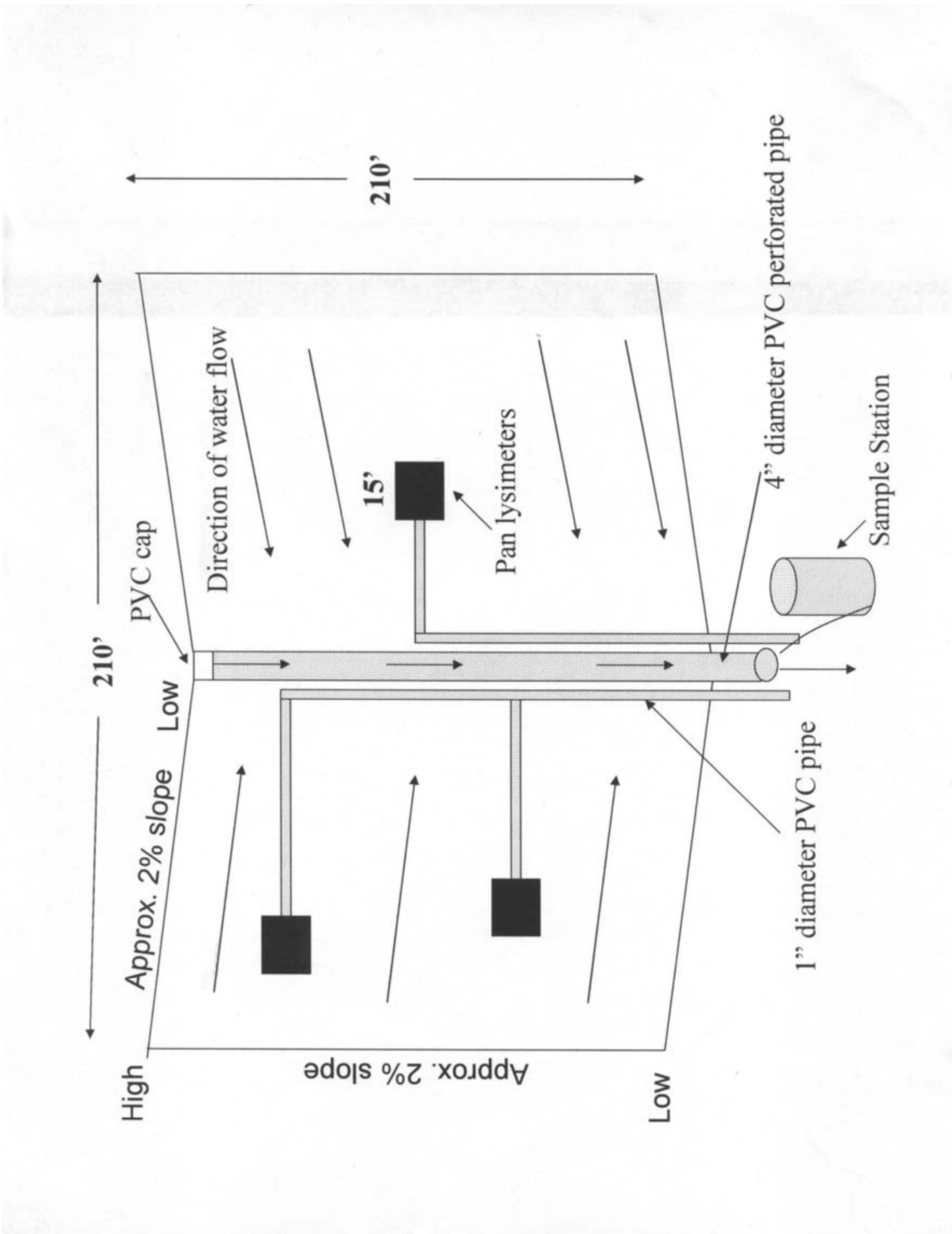

Photo 1. Bent Mountain Loose Dump Spoil Test Plots