2008 Powell River Project Funding Proposal

Long-Term Mine Soil Weathering and Treatment Effects

Or

Do Topsoil Substitutes Really Mimic Natural Soils?

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Summary

Funding is requested for continuing (second-year) funding for new study initiated in 2007 to determine the long-term (20+ years) effects of overburden rock type and surface treatments on important mine soil morphological, physical, chemical and microbiological properties. We are also measuring the net TDS elution potential of a range of fresh, partially weathered and well-weathered topsoil substitute materials. Finally, we will combine our findings to predict the ability of selected overburden materials to weather and transform into mine soils suitable for the support of native hardwoods and hayland/pasture vegetation, and to estimate their rate of transformation. This project combines sampling soils and associated fresh mine spoils from existing long-term mine soil studies like the Controlled Overburden Placement experiment along with other collaborative research locations in the region where baseline samples and data sets exist. Our data sets and results will provide important information for the mining industry, reclamation planners, regulators, and citizen groups regarding essential inter-relationships between topsoil substitute type and the long-term ability of resultant mine soils to support appropriate post-mining land uses, particularly native forest vegetation and managed hayland/pasture. The project will also generate essential basic information on the relative contribution of various spoil types to TDS loads in seepage and base-flow discharge emanating from mining sites, along with predictions of how TDS loadings will change with time. Finally, this research program will allow us to inter-relate important findings from numerous long-term mine soil studies funded by the Powell River Project and tie them into a number of current issues of regional concern.

Funding Requested: $34,370

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Introduction and Background

The Surface Mine Control and Reclamation Act (SMCRA) of 1977 contained a number of contentious provisions including return to original contour (AOC), long-term liability bonding periods, and return to "equal or better" post-mining land use conditions. However, one of the more stealthy provisions was SMCRA's allowance for use of pre-selected overburden materials as topsoil substitutes when (A) the native A+E horizon materials are less than 6 inches thick, and (B) the physical and chemical properties of the proposed substitute spoil materials are deemed suitable for such use. Since native topsoil layers throughout the Appalachian coalfields are usually less than six inches thick, and removing them from steep slopes is difficult and expensive, the vast majority of coal mined lands in the region have employed topsoil substitutes.

In 1982, the USDI Office of Surface Mining and the Powell River Project co-funded the installation of the Controlled Overburden Placement (COP) experiment to objectively assess the viability of the topsoil substitute concept and to determine whether or not organic amendments would be beneficial. In one component of the COP experiment we are directly comparing five mixes of sandstone:siltstone (SS:SiS) overburden while in a separate experiment we are following the effects of topsoil return, sawdust addition and four incremental loading rates of biosolids. All treatments are replicated four times and the plots are split between herbaceous (dominantly tall fescue) and forest (red oak following pine) vegetation. We intensively monitored those two side-by-side experiments through the late 1980's, and our results can be reviewed at the PRP web site and at http://www.cses.vt.edu/revegetation/minereclam.html. In summary, we found that (A) properly selected and placed spoil materials provided an outstanding soil medium for tall fescue production and allowed vigorous invasion of native herbaceous species; (B) higher pH spoils such as the siltstone strata employed were deleterious to pine tree growth; and (C) higher rates of biosolids amendments drove high fescue production while suppressing the pines. The COP experiment remains the longest intact and continuously monitored study of mine soil genesis in the World. Follow-up studies by our group at other sites in the 1990's and early 2000's also characterized the wider effects of biosolids applications and the nature of inherent variability in mine soil properties in the Research & Education Center. However, very little detailed soil analyses have ever been performed on the native pre-mining soils in the Research & Education Center area for direct comparison.

Over the past decade, the concept of topsoil substitution has been directly and indirectly criticized from a number of perspectives. First of all, advocates of the return of Appalachian mined lands to native forest covers have pointed to the lack of topsoil salvage and the inclusion of higher pH unweathered spoils as directly inhibiting effective reforestation. These objections have been raised by citizens and certain well-trained scientists alike. Secondly, the fact that relatively unweathered spoils (such as those employed in the COP study) release significant total dissolved solids (TDS) loads to drainage waters over time has been implicated as a component of mining related surface water degradation under both low and moderate pH conditions. Finally, the ability of these mine soils to accumulate organic matter, maintain a stable and viable microbial biomass and available nutrient pools, and overall productivity potentials beyond the requisite five-year performance liability period is also questioned by many citizens' groups.

In 2008-2009, we propose to continue our newly established study of mine soil X mine spoil X leaching interactions along with comparative native soil sampling and analysis. This program utilizes long-established baseline experiments at the Research and Education Center, and at other locations where long-term baseline data sets are available, that allow us to study changes in mine soil properties and productivity relationships over prolonged periods of time. Furthermore, we will directly compare mine soil properties for a range of important parameters (e.g. pH, organic matter content, P-forms, microbial biomass) with a suite of unmined native soils forming out of the same rocks. Thus, by a combination of direct and differential analysis, we propose to meet the following objectives:

Research Objectives

1. To determine the long-term (20+ years) effects of overburden rock type and surface treatments on important mine soil morphological, physical, chemical and microbiological properties.

2. To directly compare the properties of weathering mine soils of varying age with unmined native soils formed from the same strata.

3. To measure the net TDS elution potential of a range of fresh, partially weathered and well-weathered topsoil substitute materials.

4. To predict the ability of selected overburden materials to weather and transform into mine soils suitable for the support of native hardwoods and hayland/pasture vegetation, and to estimate the rate of transformation.

Methods and Procedures

Overall Approach

We are fortunate to have an array of well-characterized, documented and "preserved" research sites throughout the Powell River Project Research & Education Center area and the surrounding region. These include the COP experiment, areas to the north of Powell River that have been minimally disturbed since 1990, and certain limited locations south of Powell River that have not been re-mined since 1990. While much of the 1990 aged mine soil surface received a uniform treatment of biosolids+compost, there are significant areas of that surface that did not. By differentially sampling across these contrasting treatment areas, we will be able to directly determine the net effect of organic matter additions on long term soil development process and important mine soil productivity parameters.

Furthermore, the recent re-mining activity to the south of Powell River will allow us to sample and "pair up" mine soil pedons that are very young (1 to 10 years) with much older mine soils (25+ years) to the north that formed out of identical parent materials. Finally, we also have access to a range of relatively intact native forest soils in the overall Powell River area that occur between mining disturbances. Through our long term cooperative relationship with our coal

industry partners, we also have access to a wide range of mine spoil materials that will allow us to directly measure short-term weathering and TDS release from varying spoil types.

In 2007, we proposed a three-year study to meet all objectives as stated above. In year one (2007/2008), we are focusing field work on sampling mine spoils and mine soil pedons within the immediate vicinity of the Research & Education Center as described above. In year two (2008/2009), we will work with Jim Burger, Jon Rockett and other collaborators to locate pedons south of Powell River and across the region where we can be assured of good "control" of spoil age and type and treatments, and where we have access to archived original spoil samples (where possible) or original data sets to determine rates of change of various mine soil properties. In the final year (2009-2010), we will complete all laboratory work, sample or re-sample additional pedons to fill out the data set, and construct a qualitative model of how basic mine soil morphological, chemical, physical and microbiological properties respond to (A) initial spoil type and (B) initial surface treatments over extended periods of time.

Overall Research Plan and Approach

In addition to sampling existing mine soils and native soils as described below, we have sampled a wide range of mine spoil materials (16) from the Powell River Project Research & Education Center area and the surrounding region to develop a set of mine spoils for detailed leaching and TDS release studies. We intentionally sampled both fresh and partially weathered mine spoils from the same lithologies wherever possible. These fresh mine spoils have been crushed to pass a 2.5 cm screen and packed into leaching columns similar to those employed in our coal combustion product leaching research program in past years. The spoils will then be leached with simulated rainfall (5 cm per week) over a one year period and bulk leachate solutions collected weekly. These leachates will be analyzed for TDS, pH, and all major cation (e.g. Ca and K) and anion (e.g. Cl and SO_4) constituents.

Mine soil sampling in year one (summer of 2008) will be focused on the COP experiment and areas north of Powell River that were differentially treated with/without biosolids in 1990. We will also locate at least five pedons in typical native soils in hardwood forest cover over the same strata. From soil pits, we will sample three pedons each from the pure SS, 1:1 SS:SiS, and pure SiS treatments in the rock mix experiment; and three pedons each from the control (2:1 SS:SiS), topsoil, sawdust, 25 T/Ac, and 50 T/Ac biosolids plots. With Jim Burger's concurrence, we will also sample small "mini-pits" in the forest side of the COP plots from the same eight treatments, at two sample depths (0 to 5 cm and 20 to 25 cm of mineral soil) that corresponds to the exact depths we sampled in the 1980's.

Furthermore, at least three pedons each will be sampled from the 1990 reclaimed Taggart Bench area to the north from previously mapped and sampled areas that were reclaimed with/without biosolids. It is important to note that we have archived original untreated spoil samples (May 1982) from every plot in the COP experiment and a range of samples from deep pits in the Taggart bench area from 1990 and 1991. Thus, we anticipate sampling approximately 35 pedons in the first project year.

At each location (mine soils and native soils) we will carefully describe mine soil morphology, rooting features, and spoil packing/settling patterns. We will also take digital photographs with a superimposed grid to allow later quantification of rock amount/size, coarse rooting and other important features. We will then incrementally sample the mine soils with depth by both morphological horizon (e.g. A-Bw-C) and by depth 15 cm increment to allow quantification of changes in physical and chemical properties with depth. Utilizing a backhoe, we will extract samples from as deep as is possible (2 to 3 m+?) at each location to provide what will presumably be the least weathered/leached materials. Sub-samples will be chilled/preserved appropriately for microbial and organic matter forms analyses.

Each morphological horizon sample and selected depth increment samples will be analyzed for the following parameters:

pH and total titratable acidity
Saturated paste electrical conductance and solid salts species (cations + anions)
Total organic carbon and Walkley-Black organic matter
Organic matter fractions
Microbial biomass
Bulk microbial activity (incubation/CO_2 evolution)
Total-P and fractions (e.g. OM-P, Ca-P, Fe-P)
Total-N
Exchangeable cations
Dilute acid extractable nutrients and metals
Extractable Fe and Mn oxides
Total-S and S-forms if $S \geq 0.2\%$
Calcium carbonate equivalence
% Rock fragments
Particle size analysis
Aggregate stability
Moisture desorption/water holding capacity on < 2mm fractions

In addition, the incremental depth samples will all be subjected to the soluble salt and dilute acid extractable nutrients+metals analyses described above. This suite of extracts will also be run on the 1982 and 1990 archived samples for each matching pedon. This will allow us to determine both the mass leaching that has occurred over time within pedons and the net amount lost over 15 to 25 years.

Once we have completed the Powell River Education Center mine soil sampling as described above, we will expand sampling to areas near the Research & Education center that lie to the south of Powell River and to other more distant locations where we can develop adequate data base control on original spoil conditions, site/weathering age, and treatments applied. For example, we still have existing pine stands and small islands of undisturbed 1970's era mined lands in isolated pockets long the Taggart bench and certain higher levels. At several of these locations, our program described and sampled soil pits in 1980, and Dr. Burger's program has continuously monitored pine stand plantings. Directly adjacent to almost all these locations we can sample relatively young mine soils and/or raw spoils.

Progress to Date

Upon receipt of our initial funding for this project in August of 2007, word was relayed to us by Carl Zipper that the Powell River Project Proposal Review Committee was particularly interested in the estimated TDS leaching component of this work as being important to the industry in the near term. This was also emphasized by various media reports and conversations with the regulatory community. Therefore, we focused on implementing this aspect of our work plan over the late fall and winter of 2007/2008. We are currently (April 2008) completing total elemental and sequential extraction analysis on these samples (16) and we are setting up the laboratory leaching columns. We intend to initiate leaching by late May.

In the fall and winter of 2007/2008, we sampled three complete native soil profiles (5 to 6 horizons each) along with the over 15 different mine spoil materials discussed above from the Education Center area and the surrounding region. We also conducted preliminary mapping and confirmation on the Controlled Overburden Placement (COP) Experiment to relocate old soil pits and decide upon new sampling locations. We intend to complete sampling of the COP experiment pedons and Education Center mine soils over the summer of 2008 and complete basic lab analyses on these pedons by the late fall of 2008.

Data Analysis and Synthesis

At the end of year one (Fall 2008), essential baseline data on TDS release and constituents from fresh vs. weathered mine spoils will be available. By the winter of 2008-2009, we will be able to directly determine and report on the relative effect of rock type and surface treatments in the COP experiment on 25 years of mixed herbaceous vegetation and tree growth. We will also be able to contrast the differential effects of the two different vegetative cover conditions on surface soil properties. Similarly, by comparing the properties of the biosolids treated/untreated 15 year-old Taggart mine soils, we will be able to confirm overall rates of important mine soil transformation such as pH reduction and organic matter accumulation in an initially high pH sandstone system. By the comparing the bulk salt and acid extractable nutrient+metal data for each pedon with depth, we will be able to calculate the mass "TDS leaching potential" of each mine spoil material and assess how much of the TDS load appears to have leached over 15 and 25 year time spans and from what depth. Finally, we will directly compare and contrast all mine soil pedons with nearby natural soils over the same strata. Similar, but more far-reaching comparisons will be made at the end of project year 3 (2009-2010).

At the completion of the study, we will integrate all data sets from all components of the study to specifically address and meet our first three objectives. The latter part of the final project year will be focused upon constructing a qualitative (but well quantified!) model of how SW Virginia mine soil properties change with time, and the relative effects of original spoil type and surface treatments on those processes.

Project Benefits for Southwestern Virginia

This project will provide important information for the mining industry, reclamation planners, regulators, and citizen groups regarding essential inter-relationships between topsoil substitute type and the long-term ability of resultant mine soils to support appropriate post-mining land uses, particularly native forest vegetation and managed hayland/pasture. The project will also provide important basic information on the relative contribution of various spoil types to TDS loads in seepage and base-flow discharge emanating from mining sites, along with a prediction of how TDS loadings will change with time after spoil placement. Finally, this research program will allow us to inter-relate important findings from numerous long-term studies funded by the Powell River Project and tie them into a number of current issues of regional concern.

Schedule and Deliverables

The proposed schedule to complete this project (should continuing funding be made available) is provided in the detailed methods section above. Deliverables will include the annual report prepared in mid-summer of each project year. A final comprehensive Cooperative Extension Bulletin will be prepared for the Powell River Project Reclamation Guidelines series after the project is completed. We also anticipate that a number of symposia proceedings (e.g. ASMR) and refereed journal articles will result from this project.

Proposed Budget for 2007-2008

Graduate Research Assistant (9 mos. + tuition)	$22,000
Res. Assoc. – Lab Supervisor (part time; 2 mos.)	4,500
Fringe Benefits	
GRA @ 7% on stipend portion ($12,888)	902
Res Assoc. @ 21.5%	968
Travel	3,000
Materials and Supplies	1,000
Contractual Lab Work (VT soil test lab)	2,000
Total Direct Cost:	**$34,370**