Powell River Project Annual Report (2014 – 2015)

Reforestation and Water Quality: Optimizing Plant Systems to Minimize Total Dissolved Solid Delivery to Surface Waters

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Proposal Summary

This proposal requests funds to continue and complete a project that will advance the science and practice of reclamation at the intersection of revegetation and water quality. Recommended reforestation practice, the Forestry Reclamation Approach (FRA), includes guidelines for loose dumping and grading of topsoil substitutes. While highly beneficial to seedling survival and productivity, there are also concerns that such practices will increase infiltration, weathering, and total dissolved solid (TDS) generation from reclaimed mined lands. Much of the focus of Powell River Project and other associated work aimed at mitigating TDS loading to surface waters has been on chemical (e.g., topsoil substitute selection) and physical (e.g., geological confinement) approaches. Less is known about the potential optimization of biological systems to minimize TDS leaching, despite the fact that forest vegetation removes a large proportion of precipitation inputs through evapotranspiration, and a majority of the ions making up typical TDS are nutrients required by plants in relatively large amounts. Thus, this proposed work will test the concept that rapidly aggrading forests can decrease TDS generation through a decrease in the quantity of water leaving the rooting zone (from increased evapotranspiration), and by decreasing the concentration of TDS nutrient ions in percolating waters (from plant demand and uptake). Optimizing biological reclamation strategies to improve water quality would provide reclamation professionals with an economically feasible approach to compliment existing efforts to maintain regional surface water quality.

Scope of Work

Introduction:

Generation of total dissolved solids (TDS) from reclaimed surface mines, and associated impacts on aquatic systems, is a significant challenge facing the Appalachian coal industry. Commonly utilized topsoil substitutes in the reclamation process rapidly weather to generate TDS. In the pH range typical of these spoil materials, the primary components of this TDS are calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), sulfate (SO_4^{-2}) and bicarbonate (HCO_3^-). The most predominant of these ions contributing to TDS (i.e., Ca, Mg, and SO_4^{-2}) are also plant essential macronutrients. While current efforts have focus largely on chemical (e.g., topsoil substitute selection) and physical (e.g., geological confinement) methods to minimize TDS generation from the post-mining landscape, less is known about the potential optimization of biological systems to minimize TDS leaching. This is true despite a long history of revegetation work at the Powell River Project and its significant impact on reclamation practice.

Specifically, reforestation has been one of the great success stories of mineland reclamation in the central Appalachian coalfields. During the first few decades following the implementation of the Surface Mining Control and Reclamation Act (SMCRA) of 1977, reforestation efforts in reclaimed mined lands generally resulted in high seedling mortality and low levels of forest productivity. Decades of work centered at the Powell River Project and led by Dr. Jim Burger have identified a five-step process known as the Forestry Reclamation Approach (FRA) to overcome many of the issues preventing successful seedling establishment, and accelerate the return of a forest community that would otherwise take centuries to achieve through natural successional pathways. The FRA has been identified as a desirable method to support forested land uses on reclaimed mined land by the Appalachian Regional Reforestation Initiative (ARRI), the US Office of Surface Mining and many state mining agencies, including the Virginia Department of Mines, Minerals and Energy. Thus, reforestation is an increasingly feasible and appealing option for reclaiming post-mining landscapes throughout the Appalachian region.

Despite these successes, recent questions have arisen at the intersection of reforestation and water quality. The FRA recommendation of loose grading, meant to promote root development and improve seedling survival and productivity, may also increase rates of infiltration, weathering, and TDS generation. Thus, successful reforestation and the maintenance of high quality surface waters appear to be increasingly at odds. This is new territory for forest land managers, as forests are often viewed as the "gold standard" for the preservation of surface water quality because of their simultaneous influence on hydrologic and nutrient cycles. Namely, forests have a higher water demand than any other ecosystem type (i.e., minimizing runoff), and are often nutrient limited (i.e., minimizing nutrient concentrations in soil solution). Thus, our hypothesis is that rapidly aggrading forests can decrease TDS generation through two primary mechanisms:

1. decrease the quantity of water leaving the rooting zone through increased evapotranspiration, and

2. decrease the concentration of TDS nutrient ions in percolating waters through plant demand and uptake.

Specific to this hypothesis, this proposed work has the following three objectives:

Objectives:

1. Quantify the influence of biology (i.e., transpiration and nutrient uptake in plant systems) on TDS generation from reclaimed mined lands.

2. Evaluate the relative effects of hydrology vs. nutrient cycling on the change in TDS generation from reclaimed mined lands.

3. Determine reclamation strategies that that can optimize biological systems to decrease TDS generation from reclaimed mined lands.

Materials and Methods:

For this study, approximately nine paired plots will be established on sites aged 1-8 years following reclamation/revegetation at the Powell River Project located in southwestern Virginia. Sites that are younger in age are expected to have higher EC values and TDS concentrations compared to older sites since they will be less weathered and have reduced vegetation uptake potential. To further maximize the range of conditions, sites will be selected for varying spoil materials (e.g., sandstone and siltstone), extent of weathering, and vegetation communities (e.g., woody, herbaceous, and mixed).

Vegetated and un-vegetated paired plots will be used to quantify changes in TDS flux attributable to the presence of vegetation. Removing vegetation, manually or with herbicide, will allow for TDS flux in un-vegetated plots to be measured free of vegetation influences, and then compared with values in vegetated plots. Plots that undergo vegetation removal will be treated with herbicide or manual removal at each data collection period if there is significant regrowth. BrushMaster® will be used for broadleaf herbs and Roundup® for grasses. Woody vegetation will be manually removed and placed downslope of plots. Plot size will be variable depending on the dominant vegetation height (Figure 1). This is to ensure that the un-vegetated treatments will be unaffected by adjacent vegetation influencing canopy interception and soil moisture. Three resin lysimeters will be placed approximately two meters apart. The plot perimeter will extend out a minimum of one meter from each sampling point if the dominant vegetation height is less than one meter. Otherwise, the perimeter will extend out the same distance as the height of the dominant vegetation.

Samples will be taken using ion exchange resins placed approximately 30 cm deep to trap inorganic ions present in the soil solution that are responsible for TDS. Ion-exchange resins have previously been used to assess nutrient availability within the soil solution (Lundell, 2001; Brinkley et al., 1986; Tran et al., 1992; Lajtha, 1988). Ion exchange resin will be encapsulated by eight centimeters of ¾ inch screened schedule 20 PVC pipe attached to unscreened PVC pipe with an end cap. Slot width of the screening on the PVC will be 0.01 inches (0.254 mm) spaced at 0.125 inches for an overall screen section of 5.5 inches. A mixed bed resin comprised of Amberlite® IR-120 hydrogen form and Amberlite® IRA-400 chloride form will be used. In order to place and collect the resin with minimal soil disturbance across four sampling periods, PVC screening and pipe will be inserted into the ground at an angle relative to the hillslope so resins sit approximately 30 cm deep. A one inch steel rod and sledge hammer will be used to create a pilot hole for the well screen and PVC pipe. Lysimeters will reside in the ground for two months each sampling period. Samples will be taken seasonally.

Multiple vegetation properties will be characterized at each site in order to assess the effect vegetation has on reducing TDS. In each vegetated plot stem density, basal area for trees with DBH greater than one inch, and ground line diameter for saplings less than breast height will be taken. Cain and Castro (1959) and Oosting (1956) suggest using a plot size of 1 m^2 for sampling herbaceous communities. At each site, outside of plot boundaries, 0.5 m^2 quadrats will be used to randomly harvest herbaceous and small woody vegetation above ground level. Live vegetation and dead or dormant vegetation will be collected and separated to determine the percentage actively transpiring at the sampling period. Vegetation will be bagged, dried, and weighed to determine biomass. Harvesting will occur twice at each site when lysimeters are collected. Leaf area index (LAI) within the vegetated plots will be measured using a plant canopy analyzer (Li-Cor LAI 2200 or SunScan SS1) at each lysimeter collection period. Levy and Jarvis (1999) showed that LAI for continuous and homogenous canopies were accurately estimated using a LAI 2000, the predecessor to the LAI 2200. However, if canopies are discontinuous and clumped, LAI may be underestimated by the LAI 2000 (Chason et al., 1991, Dufrêne and Bréda, 1995). Sone et al. 2009 showed the SunScan SS1 to yield reasonable estimates of LAI for rice crops at various stages of canopy development. Sampling these variables will provide an index for biomass, and with regression analysis correlations can be drawn between the parameters and TDS on site.

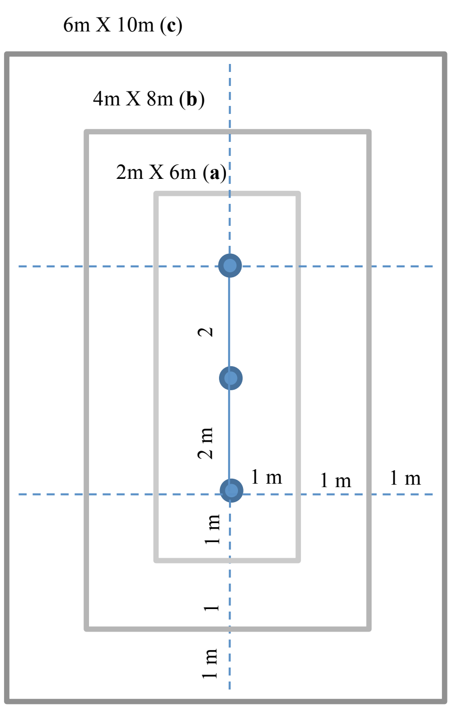

Figure 1
Plot sizes when dominant vegetation is a) 1m b) 2m and c) 3m in height. Subsample locations represented by circles.

Soil properties, such as EC, pH, nutrient content, organic matter, particle size analysis, and hydraulic conductivity, will be assessed on each site. Spoil samples will be taken at each site for a saturated-paste EC analysis (Rhoades et al., 1989) in order to compare TDS generating potentials from the differing spoil types across the various sites. Three soil samples will be taken from each site at 0-10 cm depth and 10-20 cm. Using a 2mm sieve, mineral soil will be separated from course fragments and sent to the Virginia Tech Soil Testing Lab for pH, nutrient (e.g. N, P, K, Ca, Mg), and organic matter. Particle size of the soil will be analyzed using the hydrometer method (Bouyoucos, 1927; Bouyoucos, 1962). An Amoozemeter will be used to determine the hydraulic conductivities among the study sites (Amoozegar, 1989; Amoozegar, 1992). Bore holes will be created using a one inch steel rod, and a ¾ inch diameter well screen will be inserted into the bore hole to keep side walls from collapsing. Six measurements with the Amoozemeter will be taken at each site, three at 5 cm and three at 10 cm depth.

Several statistical analyses will be used to quantify the relative soil and vegetation effects on the change in ion flux. Multiple regression analysis will be used to determine the relationships between soil and vegetation parameters and the dependent variable, the change in ion flux. Graphing the changes in ion flux by season and age will illustrate temporal variations.

Benefits:

The benefits of this study are directly in line with the overall mission of the Powell River Project to enhance the restoration of coal mined lands. The proposed research will support current reclamation/reforestation efforts and address growing social, political, environmental, and regulatory pressures regarding water quality emanating from the post-mining landscape. Specifically, we are prepared to advance the understanding of the intersection between reforestation and water quality. This research would serve two primary purposes:

1. Provide coal operators with economically efficient reclamation practices. Management of topsoil substitutes (e.g., setting aside soils/spoil materials, geoenginering hillslopes) is time consuming and costly. The opportunity to optimize revegetation management to contribute to the same water quality goals may represent a significant savings.

2. Benefit local communities through optimizing biological systems in order to provide valuable ecosystem services such as watershed control and improved water quality.

Schedule:

We have successfully recruited and started a Masters of Science (MS)-level graduate student, Amy Gondran, housed in the Department of Forest Resources and Environmental Conservation at Virginia Tech under the direct supervision of Drs. Brian Strahm and Kevin McGuire. Amy has made exceptional progress, established plots, imposed treatments (vegetation control), made the first quarter of solution monitoring/TDS quantification, and begun general site characterization.

The general timeline of the proposed project remains as follows:

YEAR	2014						2015												2016					
MONTH	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**
MS Student Appointment																								
Plot Identification/Treatment																								
TDS Characterization												Q1			Q2			Q3			Q4			
Plant/Soil Characterization																								
Data Analysis																								
Publication Preparation																								
Conference Presentations												**1**				**2**								**1**

Q1 - Q4 Quarterly analysis of TDS generation using resin lysimeters
1 American Society of Mining and Reclamation Annual Meeting
2 Soil Science Society of America International Annual Meeting

Deliverables:

Deliverables will include the annual report prepared in the summer of each project year. Upon project completion, a comprehensive Virginia Cooperative Extension Bulletin will be prepared for the Powell River Project Reclamation Guidelines series. It is also anticipated that a number of symposia proceedings [e.g. American Society of Mining and Reclamation (ASMR)], conference presentations (Soil Science Society of America), and refereed journal articles will result from this project.