ESTABLISHING THE RELATIONSHIP BETWEEN TURBIDITY AND TOTAL SUSPENDED SEDIMENT CONCENTRATION

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Abstract. This laboratory work examines the relationship between turbidity (NTU) and total suspended sediment concentration (TSS, mg/L) for a Cecil A_p soil, a common Southeastern Piedmont soil type. We show a 1:1 correlation between NTU and TSS for the silt and clay fractions, but a smaller ratio for clay and bulk-soil samples. These results suggest that NTU measurements can be used to estimate sediment concentrations for fine soil fractions, but underestimates the total sediment concentration when sand-size fractions are present.

INTRODUCTION

Landscapes are dramatically altered as the population increases, due to the need for new roadways, housing, businesses, and internal infrastructure to support the needs of growing communities. This new development, and associated land disturbing activities, has proven to have adverse impacts on navigable waters and upstream tributaries by allowing sediment to enter the natural ecosystem (Paul and Meyer 2001).

Increased turbidity adversely affects aquatic ecosystems by reducing photosynthesis and, therefore, primary productivity at all levels of the food chain (TAG, 2002). Turbidity has also been correlated to indices of biological integrity (IBI) showing that IBI factors are higher with lower NTU values (Walters et al., 2001).

With increasing urbanization and land development, there is no doubt that Georgia streams are at risk to increased sediment loading. Failure of construction sites to correctly apply Best Management Practices and meet sediment total maximum daily loads (TMDLs) will result in stream ecosystem degradation.

The Georgia Erosion and Sedimentation Act (ESCA) of 1975 has been amended several times over the years. One key issue of the ESCA is the assignation of a sediment standard. Further studies conducted by a panel of scientist concluded that an annual mean instream turbidity standard of 25 NTU should be established to identify whether a stream was impaired by sediment (Rasmussen 1995). Rather than use an annual mean, a change in turbidity of) 25 NTU for individual storms was added to the ESCA in 1994.

Furthermore, an effort was made to establish and implement a statewide program to protect waters of the state from excess erosion and sedimentation occurring from land disturbing activities. This resulted in (Georgia R.& Reg. Chapter 391-3-6-16) being amended to the ESCA in 2000 stipulating new regulations for controlling stormwater runoff from construction practices (TAG, 2002).

Along with the ESCA, use of Best Management Practices (BMPs) by agricultural, forest, and urban development have reduced the amount of sediment entering Georgia streams (Rivenbark, 2002). However, land disturbing activities such as road and building construction still cause increases in sediment loading. Increases in sediment from non-point sources in urban areas are causing significant degradation of U.S. rivers and streams (Lettenmaier et al., 1991).

METHODS

The goal of this paper is to establish a unique relationship between turbidity and sediment concentrations using samples of Cecil A_p soil, which is a soil type common in the Southeastern Piedmont region.

Several methods are available for measuring sediment concentrations in water. Typically, sediment concentrations are measured using suspended sediment concentration (SSC), total suspended sediment concentration (TSS) and turbidity (NTU) with the latter now being more common.

Turbidity measurement with nephelometric turbidimeters is considered a good method for estimating sediment concentrations in rivers (Lewis 1996). There are others that question the relationship between suspended sediments and turbidity stating the relationship is not unique because equal concentrations of suspended sediments do not scatter the same amount of light (Pavanelli and Pagliarani 2002).

Although measuring turbidity is easier than measuring suspended solids, more information is needed on their relationship. While a relationship can be established between turbidity and suspended sediments, this relationship can and will change spatially and temporally due to variations in sediment composition and stream energy (Rasmussen 1995).

Whole Soil Slurry Characterization

50 g of oven-dried Cecil A_p soil was placed into a 1-L Nalgene bottle with screw cap. 500 mL of deionized (DI) water was added to the bottle and placed onto an Eberbach shaker and shaken for 24 hr at 300 cycles per minute. Sufficient DI water was added for a total of 1-L. Turbidity values were obtained at concentrations of 5, 50, 500, and 1000 mg/L by taking sub-samples from the original 50 g of soil slurry. Five repetitions were conducted for each concentration using the 2100P Hach Turbidimeter.

Sand Characterization

The whole-soil slurry mixture was sieved through a No. 60 sieve and a No. 270 sieve with a collecting pan underneath. The sieves were rinsed with DI water to wash all of the silts and clays into the collecting pan. The pre-weighed sieves were placed into a drying oven at 120°C for 24 hr to obtain dry weights for sand and fine sand. Turbidity measurements were then recorded for both sand and fine sand using a Hydrolab dataSonde 4a. The turbidity measurements were recorded every 30 s for 24 hr to obtain the settling time.

Silt-Clay Slurry Characterization

The silt-clay slurry from the collecting pan was poured into a 1-L volumetric flask. The collecting pan was rinsed with DI water and poured into the flask. Sufficient DI water was added to obtain 1-L. The slurry was returned to the Nalgene bottle and placed back onto shaker for 10 min. Turbidity measurements were then obtained with 2100P Hach Turbidimeter by taking sub-samples at concentrations of 5, 50, 500, and 1000 mg/L for five repetitions. The sub-sample calculations were done by subtracting total sand dry weight from the original 50 g of whole soil.

Clay Slurry Characterization

A 1-L beaker containing silt-clay slurry was set aside and allowed to rest for 2 hr. Clay was then decanted from the beaker in 10 mL aliquots until separated from the silt layer. The clay and silt were both placed into pre-weighed drying pans and then put into drying oven at 120°C for 24 hr to obtain dry weights. The clay was then hydrated with DI water and placed into a 1-L volumetric flask. Sufficient water was added for a total of 1-L.

The clay slurry was returned to the Nalgene bottle and placed onto shaker for 10 min. Turbidity measurements were then recorded with the 2100P Hach Turbidimeter by taking sub-samples at concentrations of 5, 50, 500, and 1000 mg/L for five repetitions.

Turbidity was also recorded with the Hydrolab every 30 s for 24 hr to analyze the settling times of silt, silt-clay, and clay sized particles. Final concentrations of the Hydrolab data are not known and should not be compared to the Hach turbidity values. Both the Hach and Hydrolab were calibrated using a Hach formazine standard diluted to 40, 100, and 800 NTU.

RESULTS AND DISCUSSION

Results from the Hach Turbidimeter indicate a strong correlation between turbidity (NTU) and the total suspended sediment concentration (TSS, mg/L), as shown in Figure 1. Note that all three soil types follow a power relationship of the form:

$$NTU = a\ TSS^b$$

where a and b are regression-estimated coefficients. Note that **b** is approximately equal to one for all three particle

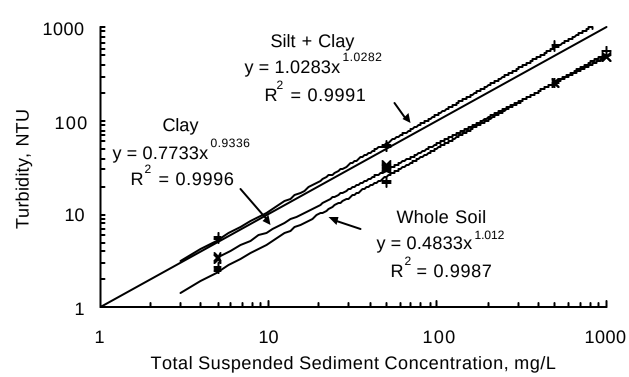

Figure 1. Relationship between observed turbidity and total suspended sediment concentration for three soil slurries.

sizes, while **a** is highest for the silt plus clay fraction, and lower for the clay, and whole soil samples.

The statistical significance (t-stat) of the exponent for the whole soil (b=1.01) and silt plus clay (b=1.03) fractions is too small to say that it is different from unity, so that a linear slope can not be rejected. The slope of the clay fraction line (b=0.93) is significantly different from unity, however, indicating that a linear relationship may not be appropriate.

Preliminary Hydrolab data suggest that sand and fine-sand particles immediately fall from suspension. However, stream energy would be a critical factor when analyzing these particles for turbidity measurements. Turbidity values for silt and silt-clay particles appear to decrease substantially in the first 12 hr. Another experiment needs to be conducted to examine the full effect over a longer duration.

Clay-sized particles maintained a constant NTU over 24 hr suggesting these particles stay in suspension for long periods, as shown in Figure 2. Another experiment should also be conducted over a longer duration to analyze extended settling time.

CONCLUSIONS

Preliminary data suggest a strong positive relationship between turbidity (NTU) and the total suspended sediment concentration (TSS, mg/L) for a Cecil A_p soil, a common soil type in the Southeastern Piedmont. The ratio between NTU and TSS is 1:1 for the silt plus clay fractions, but is lower for the whole soils (NTU is approximately 48% of TSS) and for the clay-only fraction (approximately 77%).

The reason for the underestimation is clear from the Hydrolab data, which shows that the sand-size fraction quickly settles below the zone monitored by the turbidity meter. The reason for the lower measurement for the clay-size fraction is not readily apparent.

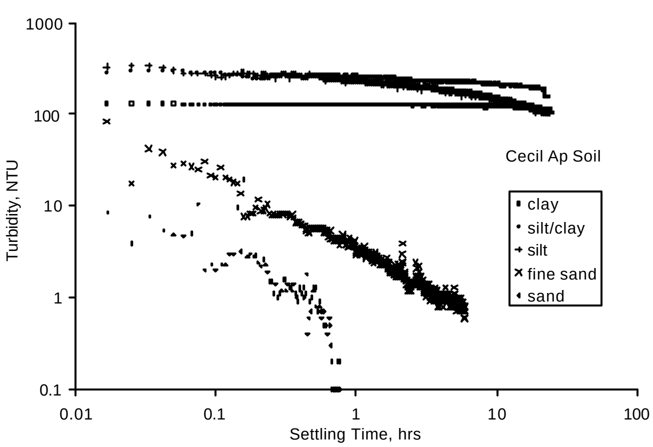

Figure 2. Graph depicting turbidity as a function of settling time for a Southeastern Piedmont soil.

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