

Sediment Based Turbidity Analyses for Representative South Carolina Soils

K.E. Resler¹, C.B. Sawyer², C.V. Privette, III³, J.C. Hayes⁴

AUTHORS: ¹Staff Professional, AMEC Environment & Infrastructure, Inc., Columbia, SC 29210, USA, ²Assistant Professor, Clemson University, Clemson, SC 29634, USA, ³Associate Professor, Clemson University, Clemson, SC 29634, USA, ⁴Professor Emeritus, Clemson University, Clemson, SC 29634, USA

EXTENDED ABSTRACT: 2012 South Carolina Water Resources Conference, held October 10-11, 2012 at the Columbia Metropolitan Convention Center

ABSTRACT. Construction activities have been recognized to have significant impacts on the environment. Excess sediment from construction sites is frequently deposited into nearby surface waters, negatively altering the chemical, physical and biological properties of the water body (Bilotta and Brazier, 2008). This environmental concern has led to strict laws concerning erosion and sediment control, such as imposing permit conditions that limit the concentration of suspended solids that can be present in effluent water from construction sites. However, sediment concentration measurements are not routinely used to detect and correct short-term problems because laboratory analysis of sediment concentrations is time-consuming and costly (Thackston and Palermo, 2000). Nevertheless, timely accurate field estimation of sediment loading could be facilitated through the development of empirical relationships between suspended solids and turbidity.

Turbidity is an expression of the optical properties of a liquid that causes light rays to be scattered and absorbed rather than transmitted in straight lines through a water sample (Anderson, 2005). Though constituents such as organic matter can impact water clarity, typically the inorganic fraction derived from particulate matter such as sediment dominates turbidity level in surface waters (Davies-Colley and Smith, 2001). Cloudiness of water results from intense scattering of light by fine particles typically with diameters smaller than 0.050 mm (Davies-Colley and Smith, 2001). Hence, waters with high concentrations of fine suspended sediment are frequently described as turbid. Turbidity is a vivid visual indicator of pollution associated with sediment-laden runoff.

Previous research indicates that turbidity measurements may be a more practical method of estimating sediment loads by indirectly relating sediment concentration to turbidity. In addition, recognition as an indicator of pollution in surface runoff from disturbed areas has resulted in efforts by the U.S. Environmental Protection Agency (EPA) to implement turbidity effluent limitation guidelines to control the discharge of

pollutants from construction sites. For example, in December 2009, EPA issued a numeric limit of 280 NTU for turbidity in the final effluent guideline rule for the Construction and Development Point Source Category (EPA, 2009). Numeric turbidity limits for construction site discharge are expected to be required in the near future.

Turbidity is not an inherent property of water, such as temperature or pH. However, the recognition of turbidity as an indicator of the environmental health of water bodies has increased, resulting in a growing demand for high-quality objective turbidity measurements (Anderson, 2005). Therefore, given the importance of a proposed turbidity limit, focus of this research is to determine relationships between representative soils and corresponding turbidity as a function of suspended sediment concentration and sediment settling. Turbidity is not only a function of suspended sediment concentration, but also of particle size, shape, and composition (Foster et al., 1992; Hayes et al., 2001); so this research was needed to analyze turbidity responses based on sediment characteristics of representative South Carolina soils.

METHODS. The most predominant twenty five soils were found using U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) soils data for each county in South Carolina. Soil area by county was aggregated and ranked based on percent coverage for the entire state. For each soil, their topsoil and subsoil was analyzed for this project.

In order to classify a soil for analysis purposes, the distribution of particle sizes in a given soil mass was needed. Therefore, first, a wet sieve and pipette analysis were conducted in order to obtain an aggregate size distribution (ASD) for each topsoil and subsoil. This was not a primary particle size distribution because the procedures did not use sodium hexametaphosphate to disperse aggregates formed. For this research, ASD analysis was conducted to use representative soils in their

undisturbed condition, as they would be found on sites across South Carolina. The scope of this project is on behavior of particles smaller than 0.063 mm (silt and clays) because larger particles settle from surface water flow relatively quickly, whereas small particles remain in suspension longer, thus contributing as sources of turbidity. Therefore, the remaining soil-water mixture from the ASD analysis was saved to determine relationships between the representative soils and corresponding turbidity as a function of suspended sediment concentration and settling time.

To derive empirical relationships between turbidity and settling time of the selected South Carolina soils, the Hach 2100Q was chosen to obtain turbidity readings based upon determining the meter's reliable accuracies and precisions (Resler, 2011). It was also chosen because its secondary calibration standard of a stable formazin was found to be better suited to mimic sediment found in surface water samples (Resler, 2011). First, the remaining soil-water mixture in a 1L graduated cylinder was inverted until the solution was completely mixed. Fifteen milliliters of the soil-water mixture was drawn at specified times from two inches below the surface of the sample. Specified times spanned two weeks and included readings taken at 0 min, 5 min, 30 min, 1 hour, 2 hour, 4 hour, 24 hours, 48 hours, 4 days, 7 days and 14 days. Five turbidity readings were recorded for each sample and averaged. For each soil's top soil and subsoil, results were plotted on a graph displaying turbidity versus time. Each sample was saved for utilization for the total suspended solids (TSS) analysis.

To develop unique relationships for concentration of South Carolina suspended sediments versus turbidity, analysis was conducted in sequence with the turbidity versus settling time procedure. After the five readings were recorded, 10 ml of each sample was placed in a pre-weighed dish and dried in the oven at 105 degrees Celsius for a minimum of 24 hours (Bolton, 1979). Once samples were dried, they were weighed on a balance to the nearest 0.0001 gram to obtain concentrations in mg/L. Resulting concentrations were plotted on a graph versus its corresponding turbidity from the above procedure.

RESULTS. First, to analyze relationships between turbidity with respect to total suspended solids concentration, measured turbidity averages and calculated sediment concentrations were plotted for the soil's top soil and subsoil. Plotted results were used in a regression analysis to model turbidity as a function of sediment concentration. Trends were arbitrarily chosen

based on similar turbidity responses to suspended sediment concentration. However, trends could not be explained because there were no common denominators to classify the soils' relationship of turbidity with suspended solids concentration. As a result, top soils and subsoils were examined depending on South Carolina regions (Piedmont, Central, and Coastal). Once soils were divided by SC regions, top soil and subsoils were sorted based on 1) measured clay content, 2) measured fine content, and 3) the ratio of measured clay to fines to establish any trends from each scenario. Measured values were derived from ASD. Each scenario was evaluated and it was found that for each region, trends were best formulated from soils' measured clay content compared to the other two scenarios.

Based up correlation coefficients of the predicted equations, derived trends for suspended sediment concentration to turbidity correlated well with either a linear or log relationship (R^2 values ranging from 0.7945 to 0.9846), as opposed to previous research utilizing a power function or the assumption of a one-to-one relationship.

To determine if an empirically derived relationship between settling time and turbidity existed for the selected soils, results were divided by South Carolina regions and the top soils and subsoils were sorted based on the same measured clay content ranges formulated previously to remain consistent with classifying the soil. For the correlation of turbidity and sediment settling time, trends were correlated with a power function based upon the correlation coefficients of the predicted equations (R^2 values ranging from 0.7674 to 0.9347). It was also found that majority of the soils were not below a value of 280 NTU until 24 hours, or later, of settling.

After the fulfillment of analyzing turbidity with respect to concentration and settling time, a potential predictive model of turbidity's response to particle size was evaluated to possibly support the previous findings. Prediction models, such as SEDIMOT II, utilize particle diameters from an eroded particle size distribution to estimate effluent sediment loads from best management practices. Therefore, it would be beneficial if a correlation existed between particle diameter and turbidity for use in prediction models. To be able to compare all selected soils, the ratio of turbidity to concentration was plotted versus particle diameter. First top soils and subsoils were evaluated collectively, but no correlations were determined. As a result, soils were once again analyzed depending on SC regions, and the top soil and subsoils were sorted based on the same measured clay content ranges formulated previously. Unlike trends

found in the above analyses, correlation coefficients of the predicted equations did not correlate as well with a classification based on measured clay content. For the most part, the figures seem to follow an increasing trend from larger particles to smaller particles. As particle sizes decrease, the ratio of turbidity to concentration increases. However, due to potential procedural errors, correlations were inconclusive and future analysis is encouraged to refine this relationship of turbidity/concentration to particle size.

CONCLUSIONS. The overall goal of this research was to determine if relationships could be established to relate sediment concentration and sediment settling time to turbidity based on sediment characteristics of representative South Carolina soils. The following conclusions were established:

- 1) It was found that the relationship of turbidity versus sediment concentration of selected SC soils were well correlated when top soil and subsoils were classified by South Carolina physiographic region (Piedmont, Central, and Coastal) and measured clay content. Such results are supported by previous research that relationships must be derived from site specific characteristics. As a result, for each region, research suggests that as concentration of fines increase, turbidity increases; and soils with higher clay content produce higher turbidity values compared to soils with less clay.
- 2) Empirically derived measured clay content best modeled the behavior of soils' turbidity with respect to concentration as opposed to measured fines content (silts and clay). This was because fines content could not rationalize the behavior of soils that aggregated and quickly settled from suspension.
- 3) Based on correlation coefficients of the predicted equations, trends for suspended sediment concentration to turbidity correlated well with either a linear or a log relationship (R^2 values ranging from 0.7945 to 0.9846) as opposed to previous research utilizing a power function or the assumption of a one-to-one relationship.
- 4) For correlations of turbidity and sediment settling time, trends also correlated well when top soil and subsoils were classified based on their predominant SC physiographic region and measure clay content. From the correlation coefficients of the predicted equations (R^2

values ranging from 0.7674 to 0.9347), all trends correlated well with a power function. This suggests that the relationship was governed by Stoke's Law; where smaller particles remain in suspension longer. As a result, the smaller particles contributed more to turbidity compared to soils with less clay content.

- 5) Majority of the soils were not below a value of 280 NTU until 24 hours, or later, of settling. In other words, it would take longer than a day for soils to be below EPA's proposed effluent limitation guideline of 280 NTU.
- 6) The empirical relationships found for turbidity versus suspended sediment concentration and turbidity to sediment settling time are expected to work well for predicting behavior of all SC soils. Correlations can be utilized if soil's measured clay content is determined from an aggregate size distribution (ASD). Also, if soil's measured clay content does not fall within the empirical ranges, to account for gaps in clay content ranges, interpolation between trendlines can be conducted to predict soil's behavior with respect to turbidity, concentration and sediment settling time.
- 7) Lastly, the relationship of turbidity to particle size was evaluated to potentially support finding of turbidity to sediment concentration and settling time. Soils did not correlate well when soils were examined based on SC region and measured clay content (R^2 values ranging from 0.0028 to 0.8634 from power functions), resulting in inconclusive relationships. Due to potential procedural errors, it is encouraged to refine this relationship of turbidity/concentration to particle size in order for it to be used in future prediction models. Better separation of particle sizes, as opposed to conducting a subtraction method, should yield in better results for determine particle size's effect on turbidity.

Altogether, results of this research will provide a step in determining 1) potential site-specific equations relating sediment concentration to turbidity and sediment settling time to turbidity, 2) aid in the design of future best management practices on construction sites, and 3) provide information for potential regulatory compliance.

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