# SEDIMENT WATTLE CONFIGURATION AND OPTIMIZATION OF PASSIVE POLYMER APPLICATION FOR TURBIDITY REDUCTION IN CHANNELIZED RUNOFF

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**ABSTRACT**

Effects of accelerated erosion resulting from such anthropogenic land disturbing activities as agriculture, timber, harvesting and construction are numerous and well-documented. In addition, elevated turbidity from eroded soil has gained recognition as an indicator of sediment associated impairment to water quality. Previous research has shown that passive polyacrylamide (PAM) can be effective in reducing soil erosion when applied to irrigation water in agricultural settings. Water soluble anionic PAM was identified as highly effective at preventing erosion and increasing infiltration when used with furrow irrigation. The focus of this research was to maximize turbidity reduction within channelized flow using passive polyacrylamide (PAM) applications in association with excelsior fiber sediment wattle installation. Four treatments were applied to assess various PAM application methods including; (i) a control with no PAM; (ii) granular PAM applied in 100-g doses directly on each of five sediment wattles before five simulated runoff events; (iii) granular PAM applied in 100-g doses directly on each of five sediment wattles only once before five simulated runoff events; (iv) granular PAM held in a permeable bag applied with 500-g doses. Results provide evidence that PAM application can be an effective practice for turbidity reduction within channels. Sediment wattles without PAM application provided no reduction in turbidity (F-stat = 0.0588, p = 0.9975, n = 60). Passively applied PAM was greatly more effective in reducing turbidity than the evaluated permeable PAM bag. Mean turbidity, over five simulated runoff events, was 202 NTU using three sediment wattles when PAM was applied. This research provides considerable evidence that highly turbid, sediment-laden channelized site runoff can be remediated using passive granular PAM application and sediment wattle installation.

**Keywords:** erosion, polyacrylamide, PAM, simulated runoff, best management practices, wattles

## 1. INTRODUCTION

Because sediment pollution can result in significant environmental impacts, federal and state agencies actively regulate total suspended solid (TSS) in construction site discharge. TSS is comprised of inorganic solids, sand, silt, clay sediment particles, and organic solids, algae and detritus. As a surrogate parameter, turbidity is gaining recognition as a regulated indicator of pollution associated with sediment-laden discharge from construction activities. Turbidity is a measure of optical properties associated with water clarity. Turbidity measurements are easily obtained and can provide an accurate estimation of fine sized soil particles transported by runoff.

Research shows that common structural best management practices (BMP) such as sediment basins, can meet design specifications but still cause elevated turbidity levels (Line and White, 2001; Wu et al., 1996). Traditional sediment basins often provide inadequate settling times for clay-sized particles. Such smaller particles can be resuspended during rain events and ultimately discharged off site. Temporary erosion control devices such as rolled erosion control products (RECPs) and polyacrylamide (PAM) dosing have demonstrated effectiveness in reducing suspended sediment and turbidity (McLaughlin and McCaleb, 2010).

This research evaluated sediment wattle configuration with passive PAM application for optimized turbidity reduction. Specific objectives included examining sediment wattle configuration, PAM application and polymer desiccation between runoff events.

## 2. Methodology

A 56.4 m triangular channel, 3.66 m wide with an average depth of 0.50 m, at a 7% slope was constructed and lined with 50-mil high-density polyethylene HDPE. The channel was lined to prevent scouring and erosion, which might affect turbidity during experimentation and potentially compromise results. Ditch checks were deployed with 508 mm diameter American Excelsior Curlex® sediment wattles (AEC, 2012). Sediment wattles were installed within the channel at 7.62 m intervals following South Carolina Department of Transportation (SCDOT) specifications (SCDOT, 2011). Based on channel length, five sediment wattles were used in series.

To determine an experimental flow rate, 1-yr, 24-hr rainfall events were averaged for Greenville, Richland, and Charleston counties in South Carolina, USA. The peak flow from the average 1-yr, 24-hr rainfall depth (86.6 mm) over a newly graded 0.404 ha site at a 2% slope is 0.07 $m^3 \cdot sec^{-1}$. An 18.2 $m^3$ collapsible tank was selected to simulate runoff and produced a peak discharge rate of 0.05 $m^3 \cdot sec^{-1}$ with an average flow rate of 0.02 $m^3 \cdot sec^{-1}$.

A sediment-laden solution was needed to simulate runoff from a construction site. A naturally occurring kaolinite clay was selected to represent the silt/clay fraction found in a regional Piedmont soil. An 8200 watt pump with a flow rate of 20 l $sec^{-1}$ was used to recirculate the tank solution. Initial turbidity in the tank ranged from 1,600 to 2,000 nephelometric turbidity units (NTU) and was measured by an Analite NEP160 display with NEP260 probe handheld turbidity meter (McVan, 2012).

Six automated ISCO 3700 units were deployed for sample collection. Liquid detectors activated the sampler routine comprised of 4-minute intervals and continued until channel flow ceased. Intake strainers were placed directly at the tank outlet and on the downstream side of each wattle. Samples were analyzed using a Hach 2100AN turbidimeter following Standard Method 2130 B (APHA, 2005).

Three polymer application treatments were evaluated using the experimental methods described below:

- Treatment 1. 100-g of polymer sprinkled directly on each of the five sediment wattles and reapplied each time prior to five simulated runoff events.
- Treatment 2. 100-g of polymer sprinkled directly on each of the five sediment wattles applied only once before five simulated runoff events.
- Treatment 3. 500-g of polymer in a 15.24 cm x 61 cm smooth weave 400 micron permeable bag placed on the tank outlet and the downstream stream side of each sediment wattle.

Each run simulated a single runoff event and consisted of draining one full tank as described above. Each treatment consisted of five separate runs completed within a 24-hour period. All procedures were duplicated for statistical accuracy. Following each treatment, wattles were discarded, channel cleaned, and excess sediment accumulation within the tank was removed.

Statistical methods to quantify results include regression analysis, analysis of variance, and t-tests. An alpha value of 0.05 is used and all statistical calculations were performed with SAS JMP software.

## 3. RESULTS AND DISCUSSION

3.1 Analysis of Application Techniques - A JMP model using analysis of variance (ANOVA) and paired t-testing was developed to assess response of mean turbidity across runs and sample locations. Simple means testing within each treatment quantified the degree to which a change in turbidity resulted from each PAM application technique. The sample location for tank outlet, sediment wattle 1, sediment wattle 2, sediment wattle 3, sediment wattle 4, and sediment wattle 5 will be referred to as L0, L1, L2, L3, L4, and L5, respectively (Figure 1).


**Figure 1. Channel layout schematic**

3.1.1 Control - Control results where no polymer was applied suggest a significant difference in mean turbidity between runs. ANOVA results show an increase in mean turbidity over 5 runs (F-stat = 10.4867, p< 0.0001, n = 60). Such an increase in turbidity across runs may be attributed to accumulation and resuspension of settled clay particles within the tank. To assess whether reductions occurred across sample locations, mean turbidity values were then used for all runs. Mean turbidity discharged at L0, L1, L2, L3, L4 and L5 was 3276, 3098, 3162, 3126, 3213, and 3105 NTU respectively. F –test results revealed mean turbidity across sample locations (F-stat = 0.0588, p = 0.9975, n = 60) was not significantly different (Figure 2). Simple means testing further indicated there were no statistical differences in turbidity values across sample locations. Had sediment wattles created any measurable reduction, turbidity values would have been statistically different across sample locations. The lack of turbidity reduction in the control experiments suggest that sediment wattles alone are ineffective at reducing turbidity. While cumulative turbidity percent reduction values may visually appear to suggest a slight reduction, results show no statistical difference (p = 0.9817).

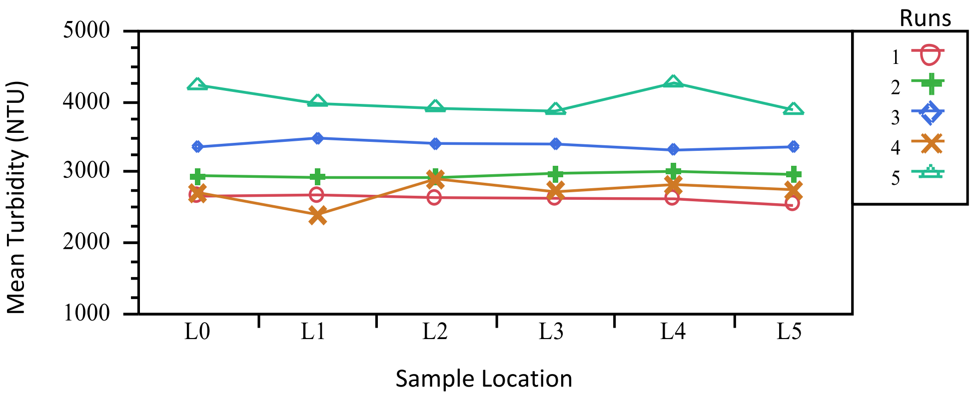


**Figure 2. Mean turbidity by run across sample locations for control experiment.**

3.1.2 Treatment 1: Repeated PAM Application - To test various PAM application methods, Treatment 1 applied 100-g granular APS #705 PAM to each of five sediment wattles before each run. ANOVA results failed to show a difference in mean turbidity over all 5 runs (F-stat = 0.3720, p= 0.8266, n = 60). Across sample locations, results further revealed that mean turbidity (F-stat =246.95, p = <.0001, n = 60) was significantly different. Additionally, t-test results show a significant difference in mean turbidity across locations L0, L1, and L2 but failed to find a significant difference between locations L3, L4, and L5. These results suggest a statistically significant decrease in mean turbidity is achieved with only three sediment wattles in series as shown in Figure 3.

Utilizing five sediment wattles, a mean cumulative reduction of 96% turbidity is  was achieved. T-test results indicate a significant difference in mean turbidity percent reduction across locations L1, L2, L3, and L5. These results can subsequently be used to determine the number of sediment wattles needed in a treatment series for optimized turbidity reduction.

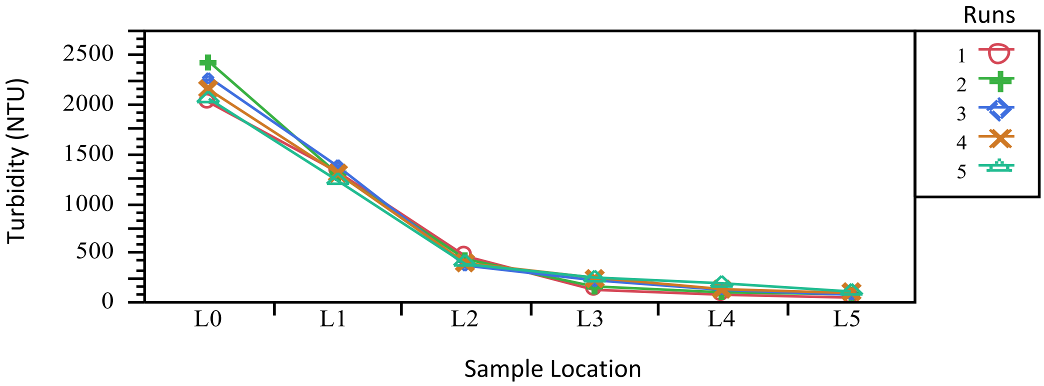


**Figure 3. Turbidity across sample locations for each run within Treatment 2.**

3.1.3 Treatment 2: Single PAM Sprinkle - To evaluate the potential effectiveness of a single PAM dose, 100-g granular APS #705 PAM was sprinkled on each of five sediment wattles before an initial run and not applied again prior to subsequent runs. ANOVA results show a difference in mean turbidity across runs (F-stat = 5.0713, p = 0.0044, n = 54) with follow-up t-tests suggesting run 4 was higher than runs 1-3. The increase in turbidity associated with run 4 may be attributed to a buildup of settled clays within the mixing tank during the course of experimentation. Analysis of variance revealed that mean turbidity across sampled locations was significantly different (F-stat = 114.60, p <.0001, n = 54). T-test comparisons show a statistical difference between sample locations L0, L1, L2, and L3 (p<0.0001). Results therefore suggest if only a single dose of PAM is applied, then a minimum of four sediment wattles is necessary to achieve maximum reduction (Figure 4).

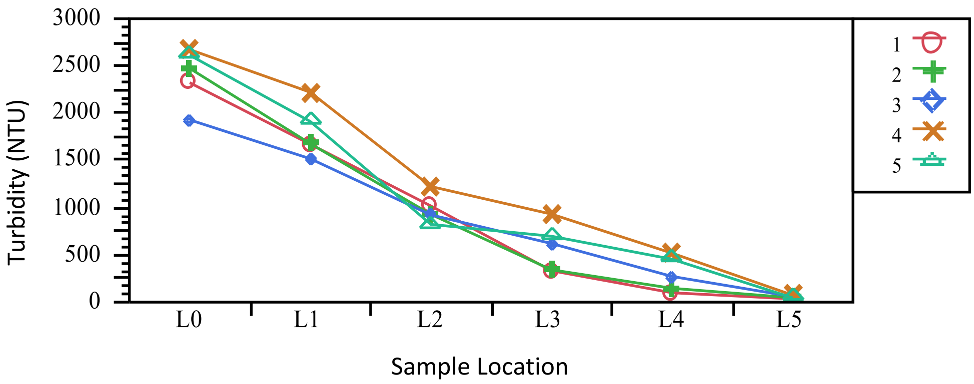


**Figure 4. Turbidity across sample locations for each run within Treatment 2.**

Mean turbidity reduction at location L5 is 97%. Based on t-test results, observations at all locations were significantly different (p<0.0001), indicating turbidity reductions were occurring at each sediment wattle.

Results from Treatment 2 further support the effectiveness of PAM application for turbidity reduction in sediment-laden runoff. Single dose PAM application runs had an average turbidity of 61 NTU and mean reduction was 97%.

3.1.4 Treatment 3: PAM Bag - ANOVA results show a significant difference in mean turbidity across runs (F-stat = 8.5054, p = 0.0001, n = 58), which suggests a decrease in effectiveness of the PAM bag application over time (Figure 5). F–test results revealed that mean turbidity across locations (F-stat = 48.4705, p<0.0001, n = 58) is significantly different. T-test comparisons show no statistical difference for sample locations L1 and L2 and between L3, L4 and L5. Mean turbidity discharged from sediment wattle 5 was 915 NTU. Cumulative turbidity percent reduction achieved for Treatment 3 was 71%.

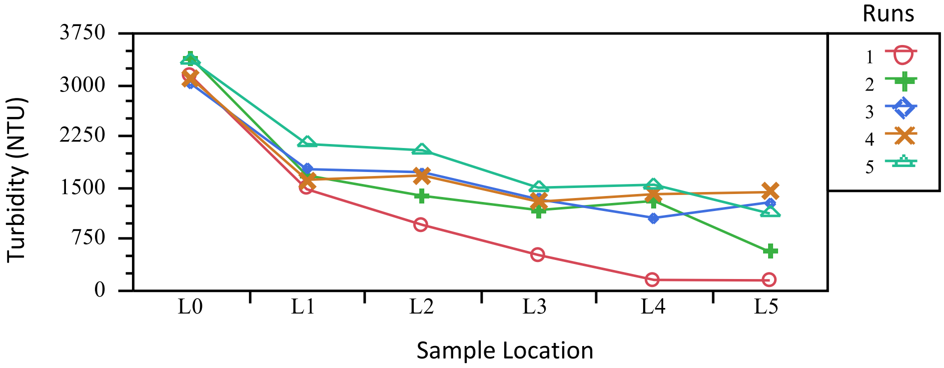


**Figure 5. Turbidity across sample locations for each run in Treatment 3.**

Figure 5 suggests the PAM bag losses efficacy after only a single run. Turbidity measured at the terminal point of Run 1, at L5 was 152 NTU. After Run 1 it was observed that the granular PAM had swelled and became a cohesive gelatinous mass. By Run 5, discharged turbidity at the same location had increased to 1127 NTU. While clearly effective for a single run, such an increase in turbidity across multiple runs suggests the use of such a PAM bag in channelized flow would be ineffective over time.

3.2 Comparison of Treatments - ANOVA and t-tests were conducted to determine whether turbidity values from each treatment were different. Figure 6 shows mean turbidity for all treatments across sampled locations. ANOVA results show a difference in mean turbidity across sample positions within treatments (F-stat = 37.7199, p<0.0001, n=232). Results did indicate a significant difference (p <.0001) in mean turbidity at location L5 between the Control (3104 NTU) and Treatment 3 (915 NTU). Additionally, mean turbidities for Treatments 1 & 2 were statistically lower (p = 0.0002) than those for Treatment 3. T-test results failed to show a difference (p = 0.9253) between mean turbidity values at location L5 for Treatment 1 (82 NTU), and Treatment 2 (61 NTU), suggesting little resulting difference between these two PAM application techniques.

T-test results comparing percent reduction found no significant difference (p = 0.8156) between Treatment 1 and Treatment 2 at location L5. Results did show a significant difference (p<.0001) in percent reduction across locations L2 and L3 for Treatment 1 compared to Treatment 2. These results suggest Treatment 1 creates a more rapid reduction in turbidity than the other test treatments, thus requiring fewer wattles and lower BMP costs.

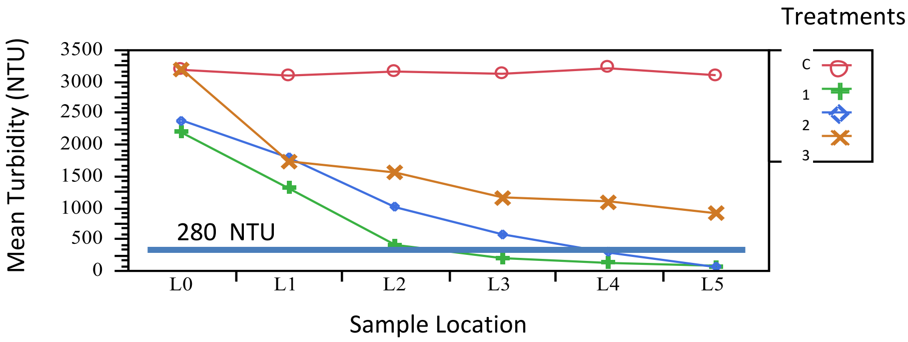


**Figure 6. Comparing mean turbidity across sampled locations for each treatment.**

## 4. Conclusions

The objective of this research was to reduce turbidity using passive PAM application techniques by optimizing wattle configuration in simulated construction site runoff. The following conclusions can be summarized from the results.

1. Under simulated conditions, sediment wattles alone provided no reduction in turbidity.
2. PAM applied before each run (Treatment 1) decreased turbidity to target levels using fewer wattles than PAM applied only once (Treatment 2) before all runs.
3. Turbidity levels meeting the proposed EPA 280 NTU effluent limit were achieved after 3 sediment wattles when PAM was applied before each run.
4. While PAM applied once did ultimately achieve target turbidity levels, this application technique required five sediment wattles.
5. PAM bag deployment technique did not result in target turbidity levels beyond the initial run.

This research suggests passive polymer treatment may be necessary to meet nationally promulgated turbidity standards for construction site discharge. Of those techniques assessed, granular PAM applied directly to excelsior wattles resulted in the highest turbidity reductions by providing a large surface area for interactions with small clay particles. Even using polymer application techniques described here, fine clays and flocs that temporarily settle behind wattles are resuspended and mobilized with each simulated runoff event, suggesting that regular maintenance of wattles may be required to consistently achieve target turbidity levels in site discharge.

## References

American Excelsior Company. 2012. Curlex® Sediment Logs®. Retrieved from website: http://www.americanexcelsior.com/erosioncontrol/products/sedimentlogs.php

Line, D.E., and N.M. White. 2001. Efficiencies of Temporary Sediment Traps on Two North Carolina Construction Sites. Transactions of American Society of Agricultural Engineers 44(5):1207-1215.

McLaughlin, R.A. and McCaleb, M.M. (2010) Passive Treatment to Meet the EPA Turbidity Limit. American Society of Agricultural and Biological Engineering Presentation Paper Number: 711P0710cd, St. Joseph, MI.

McVan Instruments. 2012. Analite NEP160 Turbidity Meter for Field and Laboratory Applications. Retrieved from website: http://www.mcvan.com/images/stories/acrobat/nep160.pdf.

South Carolina Department of Transportation (SCDOT). 2011. Supplemental Technical Specification for Rolled Erosion Control Products (RECP). Retrieved from website: http://www.scdot.org/doing/technicalPDFs/supTechSpecs/SC-M-815-9.pdf.

Wu, J.S., R.E. Holman, and J.R. Dorney. 1996. Systematic Evaluation of Pollutant Removal by Urban Detention Ponds. Journal of Environmental Engineering 122(1):983-988.