Performance Testing of Coagulants to Reduce Stormwater Runoff Turbidity

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Preparing for EPA Effluent Limitation Guidelines

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Schedule of Research Activities

Task 1: Literature Review and Current DOT Practices

Task 2: Controlled Testing of Coagulants

Task 3: Construction Site Field Monitoring

~~Task 4: Development of Monitoring/Sampling Protocols~~

~~Task 5: Statewide Field Testing to determine Effectiveness of Recommended Practices and Sampling Protocols~~

~~Task 6: Revision and Submittal of Monitoring/Sampling Protocol~~

Task 7a: Provide Material for Revision of TxDOT *Stormwater Managements Guidelines for Construction Activities*

~~Task 7b: Develop and Conduct Training Workshop~~

Task 8: Preparation of Reports

Numeric Effluent Limit Timeline

- 2009 - The EPA issued a numeric effluent limit (NEL) for construction site stormwater runoff
- 2011 – Several organizations filed petitions to stop the NELs from going into effect
- 2013 – EPA entered into a settlement to put the NELs' "on-hold pending further review"
- 2014 – EPA published final rule that removes the NEL yet reserves this section for future action

Literature Review

- Current DOT Practices
- Background on Construction Numeric Limits and ELG Development
- Numeric Limits By Other States
- Typical Runoff From Construction Sites
- Existing Construction Site Sampling Programs

Coagulants/Flocculants

- **Coagulation** – a process that causes colloids to ***attract/adhere*** to each other to form larger particles or flocs
- **Flocculation** – a process where ***bridges are formed*** between colloids to form larger particles or flocs
- Examples of coagulants/flocculants
  - PAMS – Polyacrylamides
  - Chitosan

Controlled Testing of Coagulants

- Multiple soil samples were collected from highway construction sites across the state (Lubbock, Austin, College Station)
- Properties analysis of samples determined by Midwest Laboratories, Inc (Omaha, NE)
- A modified synthetic stormwater runoff was created using the soil analysis.

Controlled Testing at Center for Transportation Research (CTR)

Sample	pH	Ca (mg/ kg)	Mg (mg / kg)	CEC[a] (meq / 100g)	Organic Matter (%)	Sand (%)	Silt (%)	Clay (%)
183ANBC	8.2	4618	149	24.9	1.1	28	36	36
College Station	9.28	3956	231	22.2	1.6	38	40	22
W Loop	8.3	3222	434	20.7	0.7	52	28	20
127 Lub	7.8	2066	509	16.6	0.7	58	22	20
Hearne I	4.8	1195	371	17.8	1.5	18	30	52
Hearne II	7.8	569	64	3.5	0.2	86	6	8
E Texas	5.0	621	134	7.4	0.5	60	12	28

[a] **Cation exchange capacity**

Controlled Testing at Center for Transportation Research (CTR)

PAM Type	Molecular Weight (mg/mol)	Charge Density (%)
SF N300	15	Neutral
LMW SF N300	6	Neutral
A 110	10-12	16
A 130	10-12	33
A 150	10-12	50
A 110 HMW	10-14	16
Cyanamer P-21	0.2	10
Chitosan	NA	Positive
APS #705	NA	NA

Controlled Testing at Center for Transportation Research (CTR)

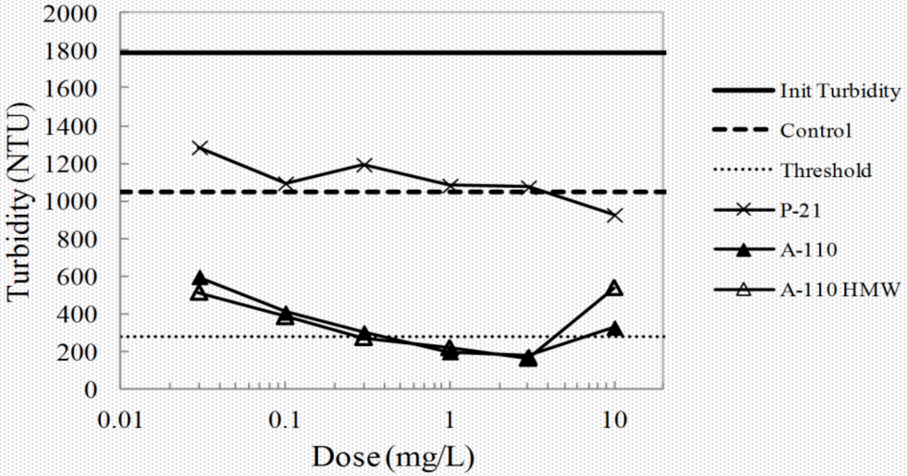
- Nine flocculants were evaluated using Decanter to remove large particles from soil suspension
- Turbidity was measured to determine flocculant effectiveness

Controlled Testing at Center for Transportation Research (CTR)

- Flocculation tests were performed to understand the soil characteristics, polymer characteristics, and doses that promote flocculation.
- Researchers generated turbidity curves as a function of polymer dose added for each modified synthetic stormwater runoff.
- Comparison of these curves and the soil characteristics gives insight about the interactions between the PAM and the particles in the modified synthetic stormwater runoff.

Controlled Testing at Center for Transportation Research (CTR)

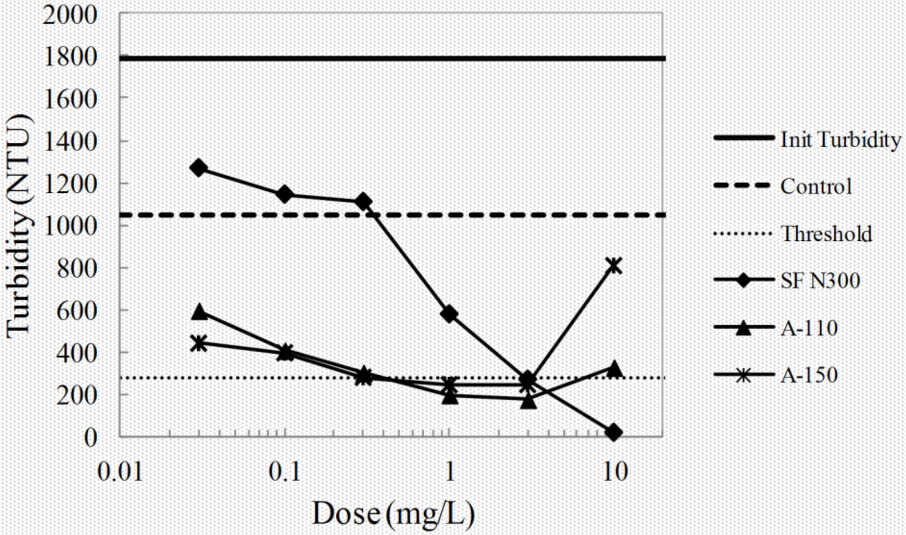
- The higher the molecular weight of the polymer, the longer it's grappling distance.
- Therefore, flocculants with higher molecular weights are expected to be more effective at promoting flocculation due to their improved ability to bridge particles.



Impact of Molecular Weight on Turbidity Reduction for Modified Synthetic Stormwater Runoff for WLoop Soil

Controlled Testing at Center for Transportation Research (CTR)

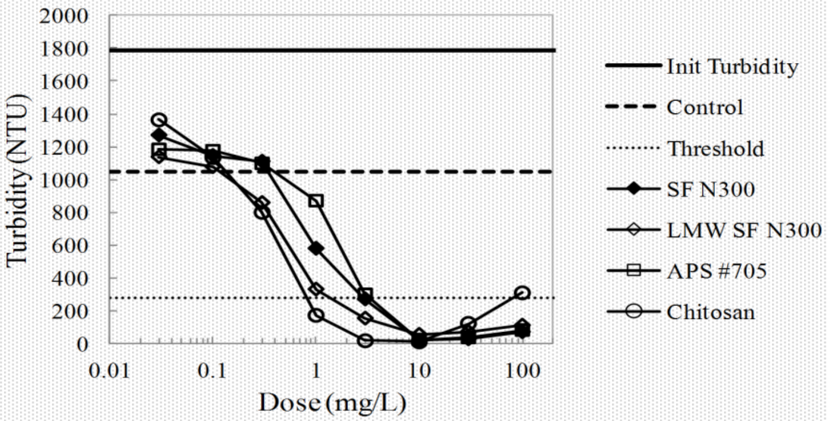
- The non-ionic PAM, SF N300, is the most effective polymer.
- A-110 (16% charge density) is less effective than non-ionic PAM, but more effective than A-150 (highest charge density of 50%).
- The turbidity curves clearly indicate that as charge density increased, the effectiveness of PAM decreased.
- Occurred in all synthetic runoff samples tested.



Effect of Charge Density on Flocculation for Modified Synthetic Stormwater Runoff Using Wloop Soil

Controlled Testing at Center for Transportation Research (CTR)

- The optimal dose for SF N300 was 10 mg/L compared to the optimal dose for the anionic PAMs of 3 mg/L.
- The optimal dose for the anionic PAMs and the non-ionic PAMs varied between 1-3 mg/L and 10 mg/L, respectively, for all the synthetic runoff tested.
- The optimal dose for anionic PAMs was lower than those of non-ionic PAMs for kaolinite suspensions.



Most Effective Flocculants for Modified Synthetic Stormwater Runoff Wloop

Controlled Testing at TTI SEC Lab

- Four different PAM/blanket combinations were evaluated under artificial rainfall simulators
- Total Sediment Loss and Turbidity were determined to evaluate effectiveness

Controlled Testing at TTI SEC Lab

Surface Condition	No PAM Treated	PAM Treated	Difference
Bare soil	52,857 NTU	51,987 NTU	-870
Jute ECB	over 4,040* NTU	over 4,040* NTU	NA
Excelsior ECB	3,603 NTU	3,450 NTU	-153
Straw ECB	4,180 NTU	9,037 NTU	+4,857

Controlled Testing at TTI SEC Lab

Surface Condition	No PAM Treated	PAM Treated	Difference
Bare soil	175.50 lb	163.10 lb	-12.40
Jute ECB	17.25 lb	19.05 lb	+1.80
Excelsior ECB	6.97 lb	5.43 lb	-1.54
Straw ECB	0.40 lb	10.17 lb	+9.77

Controlled Testing at TTI SEC Lab

- Sediment retention device testing flume was used to determine effectiveness of SRD with PAM
- Influent & effluent turbidity and flow rate were measured to determine sediment retention effectiveness

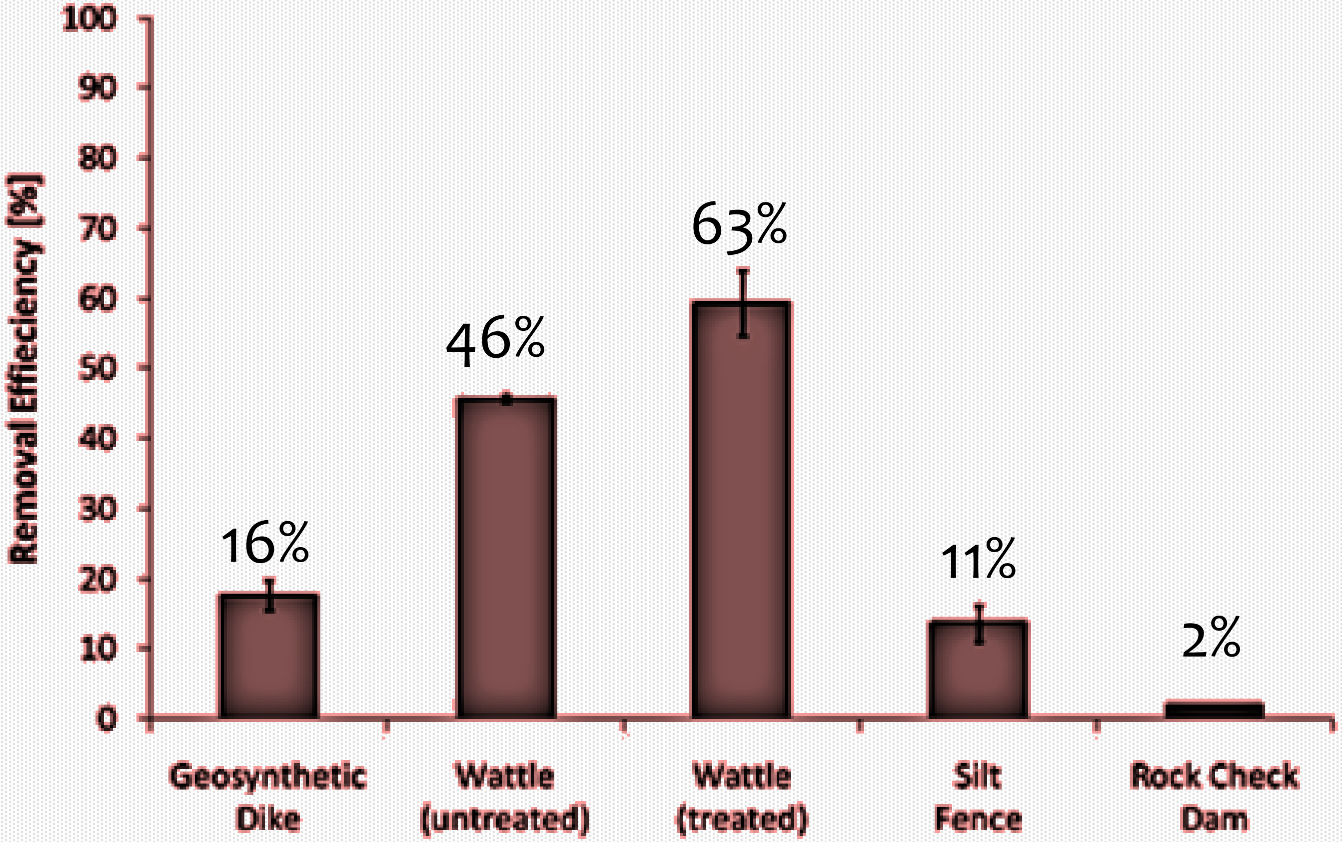
Controlled Testing at TTI SEC Lab

- Flow-through rate (cfs)
- Maximum flow rate (gpm)
- Ponding volume (gal)
- Turbidity at inlet and outlet (NTU)
- Suspended Sediment Concentration (SSC) (mg/L) at inlet and outlet
- Mass loading (lb)
- Removal efficiency (%)

Controlled Testing at TTI SEC Lab

- 12.5 lb of SIL-CO-SIL®49 and 12.5 lb of ball clay was placed in 1500 gal of water to create sediment-laden water having a SSC of 2000 mg/L.
- The sediment laden water continually stirred in the mixing tank throughout the test.
- The entire 1500 gal of sediment-laden water was emptied into the flume.
- The test monitoring continued until there was no water retained behind the SRD.
- Three repetitions of this test were conducted on SRD before removing it from the installation zone.

Sediment Removal Efficiency



*Average of 3 test runs under controlled conditions

Construction Site Field Monitoring

To determine ‘typical turbidity’ of TxDOT construction sites stormwater runoff was collected and analyzed from active sites in Bryan, Lubbock, & Austin TxDOT Districts

Typical Monitoring Sites

Typical Monitoring Sites

Watershed 3 Example – Bryan District

- Comprised of two drainage areas and a vegetated swale with five silt fences installed.
- Swale connects to a creek through a vegetated channel.
- Two drainage areas are relatively flat and well tilled.
- Made areas act like detention basin that can hold a large amount of rainfall runoff.
- Drainage areas released turbid water once the rainfall volume exceeds the capacity due to the bare soil.

Sampling Methods

Manual Sampling

- Collected downstream of discharge location using a clean collection bottle with the opening facing in the direction of the flow.
- Care was taken to ensure the bottle did not overflow and the sampling site was not disturbed by agitating particles upstream.
- For low flows, a scoop was used to capture a sample so that the bottom settlements were not disturbed, and for hard to reach locations, a pole was attached to a bottle to retrieve a sample.
- A single grab sample from each sampling location was considered sufficient.

Sampling Methods

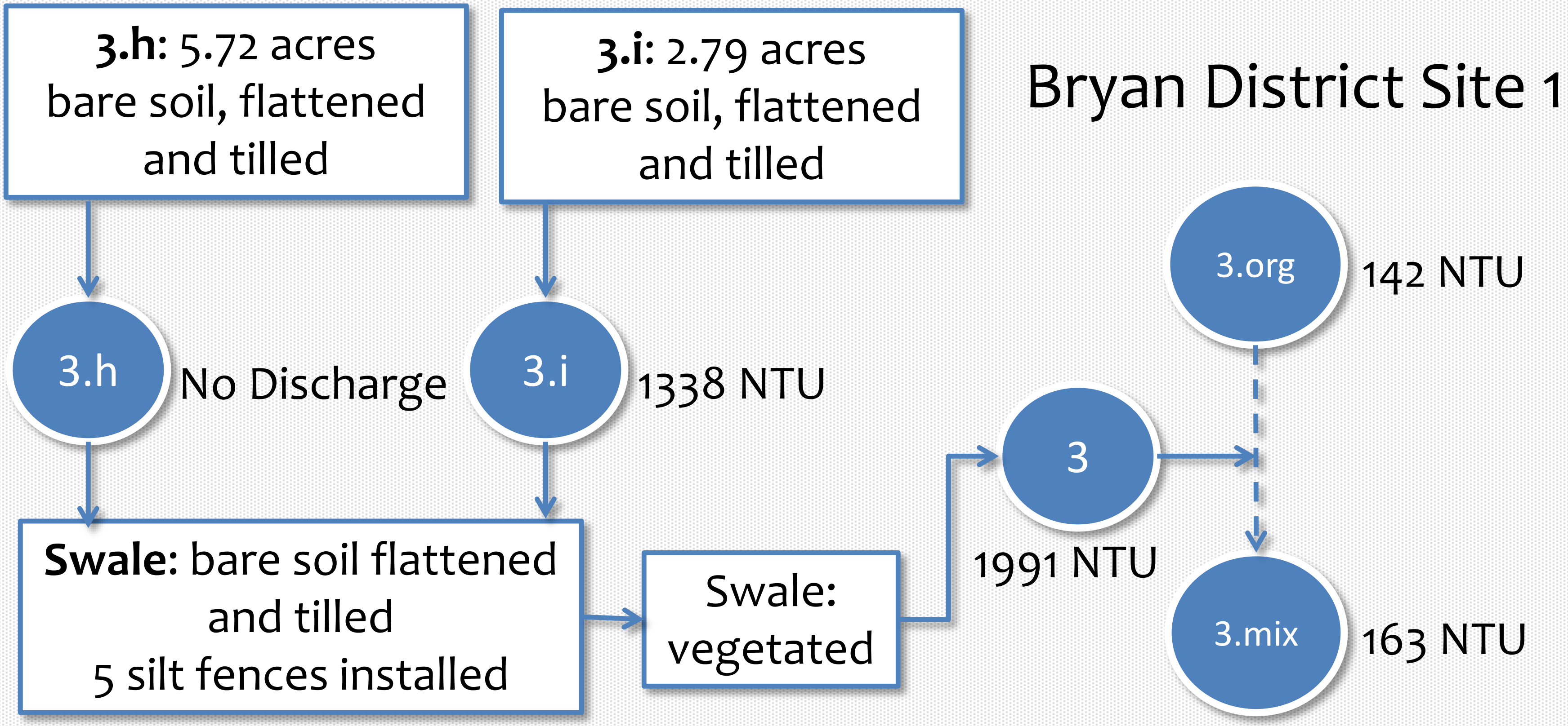
Automatic Sampling

- Bryan District used an ISCO 6712 sampler
- Samples were collected once every hour after activated at a certain level of runoff flow.
- An ISCO 730 bubbler flow module was attached to the sampler and read flow depths once every five minutes for selected rain events.
- Turbidity readings were conducted within 48 hours using the Hach 2100N turbidimeter used for the grab samples.

Turbidity Measurements

- Runoff sample analysis followed EPA method 180.1 with two modifications.
- Modification 1 – used Hach 2100N turbidimeter, which has a range of 0 to 4,000 NTU.
- Modification 2 - The samples were immediately transported to the lab, where they were analyzed for turbidity or stored in the 4°C cold room to be analyzed within 7 days.
- Typically, samples were analyzed within 48 hours, but for some sampling events, analysis was performed after 48 hours.
- Samples were gently shook and the bubbles allowed to dissipate prior to performing the turbidity measurements.

Discharge Monitoring Example



Bryan District Site 1

3.h: 5.72 acres
bare soil, flattened
and tilled

3.i: 2.79 acres
bare soil, flattened
and tilled

3.h No Discharge

3.i 1338 NTU

Swale: bare soil flattened
and tilled
5 silt fences installed

Swale:
vegetated

3 1991 NTU

3.org 142 NTU

3.mix 163 NTU

3 – Final Site Discharge Location

☐ Area

● Sampling Location

Watershed 3 Vegetated Channel and Discharge to Creek

Watershed 3 Relatively Flat Drainage Area with Bare Soil

Watershed 3 Swale with Silt Fence on Bare Soil

Watershed 3 Sample Turbidity Results

Date	Rain (inches)	Sampling Time	Turbidity (NTU)					Surface Condition
			3.h	3.i	3	3.mix	3.org	
12/24/2010	0.66	raining	1334					Tilled bare soil
1/9/2011	1.69	1-hr later	1863	1338	1991	163	142	
1/16/2011	0.7	raining	197	182	358	75	67	
2/3/2012	4.11	6-hr later	4	7	19	32	30	Mulched but no vegetation
2/4/2012	2.15	1-hr later	19.3	11	7	37	38	
2/10/2012	0.20	1-hr later	6	8	N/F	-	-	
2/13/2012	0.54	1-hr later	11	18	19	47	11	
2/15/2012	0.45	1-hr later	44	25	73	80	30	
2/18/2012	1.16	1-hr later	22	12	12	-	-	
3/10/2012	2.62	3-hr later	15	3	40	-	-	
3/20/2012	2.38	raining	37	20	11	-	-	
3/29/2012	2.27	2-hr later	15	7	5	104	36	

Watershed 3

- Runoff samples from the drainage area ‘i’ show a large disparity in turbidity between two different rain events even though the surface conditions were almost consistent during that period.
  - e.g., 1338 NTU in the first event and 182 NTU in the second at the sample point ‘3.i’
- This is probably due to the difference in precipitation volume, 1.69 inches for the first event and 0.7 inches for the second.

Watershed 3

- The swale installed with five silt fences on bare soil surface did not help reduce turbidity.
- The turbidity at the final outlet ‘3’ in both rain events is greater than the turbidity of discharge from the drainage area ‘3.h’ and ‘3.i’.
- This indicates that the series of swales is an additional source of sediments at first glance.
- However, the turbidity of the accepting creek was not changed much by the construction site discharge
  - e.g., 21 NTU from 142 to 163 NTU in the first rain event

Watershed 3

- Silt fences in the swale held a large volume of water and discharged at the significantly lower flow rate, thus the absolute amount of sediments per time may be lower at the end.
- However, this type of detention is not efficient or effective during rain events beyond the silt fence’s capacity.
- This method will not be able to reduce the flow rate in but, rather has the risk of discharging higher rate of turbid flow when the silt fences fail.

Results/Conclusions

- The PAM application used for **erosion control** was not effective in significantly reducing turbidity or soil loss on clay soils with 1:3 slopes.
- Maximum turbidities of all tested ECB treatments were very high, ranging from 3,450 to 9,037 NTU.
- The turbidity of the effluent from the bare soil plot reached 52,857 NTU.
- Average dry soil losses overall agreed with turbidity results.

Results/Conclusions

- Due to the high range of turbidity the efficiency of PAM could not be determined.
- Although PAM showed a lower turbidity and average dry soil loss on bare soil and excelsior ECB than untreated counterparts, the differences were negligible.
- Furthermore, when applied with jute and straw erosion control blankets the reduction in turbidity decreased.
- This result was unexpected because straw ECBs are typically considered excellent performers in a 1:3 clay soil application.

Results/Conclusions

- Test results demonstrated that PAM treated sediment control devices were significantly more successful at reducing turbidity than untreated ones
- Removal efficiencies of treated devices ranged from 8% to 18% improvement

Results/Conclusions

- The flocculants tested all performed well at reducing turbidity
- Dosing rates affect the performance

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