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Concrete Slurry, Wash and Loss Water Mitigation

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Minnesota State University, Mankato

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16. Abstract (Limit: 250 words)

This report presents an evaluation of wastewaters derived from concrete placement and maintenance and the preparation of best management practices (BMPs). Investigation and documentation of existing practices was done to ensure application to real situations and enhancement of constructability for all BMPs. Laboratory analysis of test specimens was done to provide characterization of factors that are likely to positively or negatively influence concrete wastewater composition. Evaluation of sedimentation and filtration through and absorption by sand and geotextile materials provides a simulation of the known control techniques. Development of a constituent occurrence and control model with a strong statistical base achieved through experimental replication supports development of BMPs that are both environmentally protective and constructible.

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Final Report

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EXECUTIVE SUMMARY

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Review of the results presented in this report lead to the following conclusions:

- Concrete sediment characteristics of particle grain size, gradation distribution, material density, pH; and particle reactivity must be defined or conservatively assumed prior to design.

- Control of concrete sediments requires attention to operational factors as well as sediment characteristics when designing the sediment and erosion control plan.

- Removal of sediments by sedimentation process requires hydrometer analysis of the sediments then sizing of the sedimentation basin for the desired removal percentage and the hydraulic flow.

- Filter material may be designed around the principals of maintaining sufficient hydraulic flow and prevention of particle movement through the filter material using the grain size characteristics of the concrete sediment and the filter material.

- Chemical sedimentation or flocculation may be effective in removing suspended concrete sediments, if pH is adjusted to a range of between 6 and 9.

- Treatment of the high pH in concrete sediment contact water requires either recarbonation with carbon dioxide or acid addition. Calculation of acid volume for the measured pH and the normality of the proposed acid is proposed if acid addition is proposed.

Chapter 1 Introduction

This report presents an evaluation of wastewaters derived from concrete placement and maintenance and the preparation of best management practices (BMPs). Investigation and documentation of existing practices was done to ensure application to real situations and enhancement of constructability for all BMPs. Laboratory analysis of test specimens was done to provide characterization of factors that are likely to positively or negatively influence concrete wastewater composition. Evaluation of sedimentation and filtration through and absorption by sand and geotextile materials provides a simulation of the known control techniques. Development of a constituent occurrence and control model with a strong statistical base achieved through experimental replication supports development of BMPs that are both environmentally protective and constructible.

1.1 Background

While there is much anecdotal evidence of concrete wash water containing sediment, there is relatively little reference in the literature to the issue. The Clean Water Act requires control of sediment from construction sites and concrete operation; evidence can be seen in United States Department of Justice (2009) in which a concrete ready mix supplier was fined heavily for infractions related to concrete wash water sediment and caustics, among other infractions. The United States Environmental Protection Agency (2009) provides direction about concrete washout control, describing washout waters as caustic and full of sediment and requiring containment, filtration and neutralization.

The Minnesota Pollution Control Agency (MPCA) has modified regulations affecting the concrete and construction industries (MPCA 2009). On August 1st, 2008, the MPCA approved the reissuance of the General Permit for Authorization to Discharge Stormwater Associated with Construction Activity (Construction Activity Permit). A major change in this permit affecting ready mix concrete deliveries in the state of Minnesota is the section pertaining to concrete wash water. The Construction Activity Permit does not allow any concrete chute rinse water or water used to wash off concrete tools to come into contact with the ground. Excess concrete from forms, pumps, and chutes may come into contact with the ground as long as they are disposed of in accordance with MPCA regulations when in a hardened state. The best management practices (BMPs) suggested are removal of excess water, capture of all sediments and removal or proper beneficial use of hardened solids. MPCA (2009) further states:

> Hardened solids can be removed whole or broken up first depending on the type of equipment available on site. In accordance with Minn. R. 7035.2860, subp. 4, item I; the hardened concrete can be used as a substitute for conventional aggregate. If the material is not utilized in accordance with the standing beneficial use determination referenced above, up to 0.5 cubic yards of concrete washout solids may be managed on-site. If concrete washout solids are buried on site, they should be at least two feet below the surface and must not be buried in the groundwater table. Quantities larger than 0.5 cubic yards of concrete washout solids must either be managed with the rest of the sites solid wastes or obtain an approval from the MPCA's solid waste program for other beneficial use options.

Two states have similarly developed BMPs and requirements for management of concrete waste, particularly WM-8 of California Stormwater Quality Association (2003) and NS-14 of Oregon Department of Environmental Quality (2005). Other states have only requirements in place without developed BMPs (e.g., Louisiana Department of Environmental Quality (2009)). In NS-2 of California Stormwater Quality Association (2003), dewatering operations are discussed that also account for underwater concrete pours such as within cofferdams for bridge pier construction. All BMPs described here suggest capture of sediment by hydraulic detention or filtration, then acid addition for neutralization.

Chini and Mbwambo (1996) evaluated concrete wastewater and found pH values typically ranging between 11 and 12. Suspended solids were measured at 100 ppm after sedimentation, but dissolved concentrations ranged from 500 to 2500 ppm, approximately 5 times the level in drinking water. Concrete wastewaters were shown as containing sulfates and hydroxides from cement, chlorides from calcium chloride, as well as small quantities of both hydrocarbons and admixture compounds including ethanolamine, diethanolamine, formaldehyde, K-napththalene sulfonte and benzene sulfonic acid. Except for the hydrocarbons and admixture compounds, these values are high but representative of groundwater when in contact with limestone or limestone derived soils.

In a study of soil cement mixes, Bhatty and Kozikowski (2004) found that pH varied by cement content, with pH levels of 10.5 to 11 being measured for higher (up to 9%) cement content. pH generally reduced by one half to one unit in three to five days, with pH levels generally below 9 within 180 days. Bhatty and Kozikowski (2004) was the only study found that compared cement treatments across factors of time and cement content for statistical evaluation of runoff composition.

1.2 Summary

Sediments derived from concrete construction have been found to be a potential detriment to surface waters under the Clean Water Act, as enforced by the United States Department of Justice and Environmental Protection Agency, and as regulated in Minnesota by MPCA. Few other states have moved forward with state-specific regulations and guidance, though activity appears to be on-going.

Previous work has shown waters associated with concrete construction have high total suspended solids, total dissolved sediments and pH, with variations caused by cement content and time since hydration.

Chapter 2 Assessment of Current Practices

This assessment is based on the results of field site visit observations and interview/meeting discussions regarding projects done under the control or administration of Minnesota Department of Transportation (MnDOT). The goal of this assessment is to guide laboratory testing and development of best management practices (BMPs), for control of concrete and cement sediments, slurries and contact waters.

2.1 Site Visits, Interviews and Meetings

Site visits, interviews and meetings were conducted during the 2010 and 2011 construction season and reflect current practice and regulation at the time. Persons interviewed during the site visits and meetings variously included: contractor superintendents; resident engineers; storm water control design engineers; environmental inspectors, regulators, plant engineers and construction company or vendor technical representatives. A full description of the site visits and persons interviewed and observations is included as Appendix A.

Questions asked during the site visits and interviews addressed the performance, cost, reliability, and ease of use of sediment control features, as well as the source, quantity and potential mobility of concrete and cement sediments, slurries and contact waters.

Construction site observations for concrete construction and specific sediment controls are listed in Table 1. Observation and discussion result evaluations are summarized in Tables 2 and 3. Table 2 is a presentation of the risk of environmental degradation associated with generalized construction practices. In this situation, risk is defined as a product of the relative quantity of likely byproducts from concrete construction and the potential byproduct mobility. For example, large quantities of highly erodible cement-aggregate fines are associated with high risk, while small pads of concrete spillage from a delivery chute that are likely to harden within a few hours and can be picked up in their entirety with a shovel are associated with low risk.

While subjective, this approach provides a strong indication of where great care will be needed with the design and implementation of BMPs for high-risk situations, and may include design specifically for containment of concrete sediments that are chemically and physically different than most soil particles. Conversely, this approach also indicates where existing soil-oriented BMPs are likely to suffice in low or moderate risk situations, if the BMPs are properly implemented.

Table 3 lists the BMPs generalized for concrete and cement sediment control with the associated design parameters, installation steps and maintenance requirements. The performance of these BMPs are assessed during the capture and containment systems evaluation of Chapter 4, along with treatment systems for caustic components of cement or concrete contact waters.

2.2 Selection of Sediments for Study

Based on these results, the following concrete or cement sediments have been selected for further study during the erosion products quantification study (Chapter 3):

- Concrete bridge deck demolition debris (fine fraction);
- Concrete pavement saw cut slurry sediments;
- Concrete pavement grinding slurry sediments;
- Portland cement (no aggregate) slurry of selected hydration times, to represent precipitation run off from recently poured concrete surfaces, contact waters (e.g., underwater curing) and wash waters;

In the original research proposal, it was suggested that on site testing would be done of water flows emanating from the concrete construction operations. However, this testing proved impractical, as contact water and sediments were generally prevented from release to storm water channels on the sites visited. Practice was thereby shifted to the collection of sediment samples when available, typically consisting of two buckets of five gallon capacity. Contact waters and slurries were reconstructed in the laboratory for evaluation.

2.3 Summary

Construction operations can create concrete sediments, but at different rates and with different characteristics, particularly cementitious activity, grain size, and uniformity. Distance and travel time to surface water, the medium most likely to be impacted, may be the risk factor of most importance when considering the approaches to containment and capture of concrete sediments. Quantity and mobility, assessed qualitatively, are factors that are likely to determine the size and scope of the containment and capture features, as shown by current practice.

Table 1 Concrete Construction and Controls Observed/Discussed		
Site Visit and Contact	**Construction Operations Observed**	**Concrete Sediment and Water Control Methods Observed**
LaSalle Avenue Bridge over Interstate 94 Bridge Deck Reconstruction State Project No. 2781-414, Minneapolis, MN July 10, 2010 • Tom Villar, MnDOT and Justin Gabrielson, Ames Construction	Removal of the bridge deck, in preparation for deck replacement. On-site concrete crushing and reinforcing bar removal prior to load out.	Silt fence, inlet protection, rock bag, inlet filter bag (Dandy bag)
Highway 61 Resurfacing State Project No. 6222-161, Maplewood, MN July 28, 2010 • Eric Rustad, MnDOT	Saw cutting, drilling, excavation of debris, collection of saw cut sediment, placement of rapid set concrete.	Inlet basin protection, sweeping (described, not directly observed).
Interstate 35 Duluth Mega Project, Duluth, MN September 14, 2010 • Dwayne Stenlund, MnDOT	*Pavement Profile Grinding* • Pavement profile grinding, parapet breaking and demolition (activities done prior to date of visit).	Sweeping, catch basin inlet protection.
	Bridge Deck Pour • Concrete delivery, pumping, placement on deck, power screeding.	Inlet protection, silt fence, mulch, pavement sweeping (assumed but not observed).
	Bridge Parapet Pour • Placement of concrete bridge parapet with curing compound application.	None – adjacent controls assumed as perimeter out of sight.
	On Site Wash Out • Ready mix truck wash out.	Sedimentation pond with filter berms.
	High Mast Light Foundation Installation • Foundation construction, including concrete placement and form removal (all activities occurred prior to site observation).	Mulch, inlet protection, silt fence (note: all missing or in significant disrepair).

Table 1 Concrete Construction and Controls Observed/Discussed, cont.		
Site Visit and Contact	**Construction Operations Observed**	**Concrete Sediment and Water Control Methods Observed**
Interstate 35 Duluth Mega Project, Duluth, MN September 14, 2010 Dwayne Stenlund, MnDOT	*Bridge Pier Cap Pour* • Form work and prior placement of concrete for bridge pier, with associated earthwork.	Sedimentation pond with filtration prior to discharge.
	Pavement Grinding Lagoon Disposal • Disposal of concrete pavement grinding sediments.	Sediment pond disposal, cat tracking.
Highway 61 Lester River Bridge, Duluth, MN September 14, 2010 • Dwayne Stenlund, MnDOT	Mortar mixing, material storage piles, joint repointing, block cleaning, and block placement.	Plastic sheeting collection, solid waste disposal.
Miller Trunk Hwy (US Hwy 53/Hwy 194) between Trinity and Haines Roads, Duluth, MN September 14, 2010 • Dwayne Stenlund, MnDOT	Form and place concrete wing walls for existing box culvert.	Temporary stream diversion between lined cofferdam berms.
Central Concrete Ready Mix Plant, Mankato, MN December 7, 2009 • Dennis Jorgenson, Central Concrete	Washout capture and primary treatment.	Grit chamber, sedimentation basin, desander and washout capture.
Reconstruction of Stone Arch Trail Bridge over Round Lake Outlet to Lake Phalen (Bridge No. L8560), St. Paul, MN September 9, 2010 • Mark Daubenberger and Matt Wassman, TKDA	Excavation in preparation for foundation installation.	Cofferdam, dewatering, dewatering fluid filtering, mulch, silt curtain.

Table 1 Concrete Construction and Controls Observed/Discussed, con't.		
Site Visit and/or Contact	**Construction Operations Observed or Evaluated**	**Concrete Sediment and Water Control Methods Observed or Assessed**
TH610 Maple Grove, MN June 16th, 2011 Bob Rabine, Project Supervisor, and Juan Podesta, Field Inspector, MnDOT	*Saw Cutting Green Concrete* • Pavement saw cutting joints approximately 2 inches deep across lanes approximately 8 hours after pour and finish.	Saw cut water flushing sediments from joint, creating slurry. Slurry drainage to aggregate base at shoulder. No sediment observed leaving shoulder that was subject to later treatments.
Lowry Avenue Bridge Minneapolis, MN June 16th, 2011 Paul Backer, Resident Engineer Hennepin County	*Underwater Pour of Concrete by Tremie into Cofferdam or Drilled Shaft Casing* • Form work and placement of concrete for in-river bridge pier, with associated excavation, contained by cofferdam or drilled shaft casing (work partially done prior to visit).	Pump and hose system for transport of excavation support slurry from cofferdam to treatment tank. On shore tank for biodegradation and clarification, followed by sedimentation pond with filtration prior to discharge.
	Bridge Pier Cap, Beams & Deck Pour • Form work and placement of concrete for bridge pier cap, beams and deck, with associated earthwork (work done prior to visit).	Debris capture with barge mounted or pile supported containment system/form work.
Residence Hall Construction, Mankato, MN September 26th, 2011 Perimeter observations only	*Super Sack Mortar Station* • Operation of mortar station using elevated cement storage and metering system. • Operation of metering system created dust cloud which left sediments on nearby surfaces outside of site perimeter including vehicles.	None to contain dust within site perimeter. Silt fence, Dandy bag inlet protection, and diversion berms installed for on-site runoff protection.

Table 1 Concrete Construction and Controls Observed/Discussed, con't.		
Site Visit and/or Contact	**Construction Operations Observed or Evaluated**	**Concrete Sediment and Water Control Methods Observed or Assessed**
Telephone Interview August 30, 2011 Ben Dalsing, P.E., Plant Engineer, Wells Concrete, Albany, MN	*Stucco* • Masonry surface treatment of rough troweled mortar to create textured appearance.	Truck washout, tool wash and mortar station for fines control.
	Stain • Colored aggregate incorporated into concrete to create colored appearance.	Truck washout for fines control.
Telephone Interview August 30, 2011 David Obyc, Estimator, Rampart Hydro Services, LP, Coraopolis, PA	*Hydro Demolition* • Use of high pressure water to demolish concrete and create small debris particles.	10,000 psi water spray can remove concrete and disintegrate particles to any depth. Control of pressure controls particle size. Requires observation and adjustment to achieve specific results. Reported as easy.
	Vacuum Capture • Use of high level vacuum to pick up concrete debris	Vacuum capture of debris done using hooded containment on hydraulic boom. Similar to vacuum truck or Shop Vac technology. Gravity separation of particles from airstream done by fabric baffles within vacuum.
	Capture of Concrete Sediments by Tornadic Vortex • Use of hydraulic vortex to separate particles from air or water streams	Rotary spin of flow causes particles to separate from hydraulic fluid. Small footprint, typically mounted on vacuum truck.
	Sweeping of Concrete Sediments • Use of mechanical street sweeper and brooms to collect or capture sediments from pavement surfaces.	Rotary broom to mechanically detach particles from pavement and collect. Typically incomplete, as finer particles do not easily dislodge from pavement.
	Filter Capture of Concrete Sediments • Use of fabric or membrane filtration to separate particles from air or water streams.	Commonly used with vacuum techniques. Similar to bag house for particulate capture in stack flows.

Table 1 Concrete Construction and Controls Observed/Discussed, con't.		
Site Visit and/or Contact	**Construction Operations Observed or Evaluated**	**Concrete Sediment and Water Control Methods Observed or Assessed**
Telephone Interview August 9, 2011 Robin Tiede, Chemist/Wastewater Specialist, Hubbard-Hall, Waterbury, CT	*Flocculent Sedimentation and Capture of Concrete Sediments* • Additional of chemical to cause particle aggregation and subsequent sedimentation.	Flocculent in use for concrete construction in Northwest states. Much use in mining water sediment control. Requires pH adjustment to neutral (pH = 7) prior to treatment. Mixing is critical to proper distribution of chemical for high effectiveness.
	Capture of Concrete Sediments Through Use of "Floc Log" • Flocculent soaked absorbent placed in surface water flow to provide treatment chemical application.	Mixing is poor and application of chemical incomplete. Does not age well/provide uniform application over time. Inability to control pH. Not recommended for construction site use.
Document/Report Searches of Internet Resources (http://constructionarticle.com/ shotcrete-gunite/ , downloaded October 11, 2011)	*Shotcrete* • Wet gunning: application of pre-mixed concrete using air propulsion.	Shotcrete is typically used for site work including stabilizing embankments, construction of retaining wall facings, etc. Assumes perimeter silt fence/hay bales to be sufficient. Containing shotcrete in building construction is not standard practice.
	Gunite • Dry gunning: application of cement-aggregate mixture using air propulsion with integrated water mixture.	Similar to shotcrete, gunite application assumes perimeter controls to be sufficient. Greater overspray and spatter to be expected with Gunite than shotcrete.

Table 2 Concrete Construction Practices and Potential for Stormwater Degradation

Construction Practice	Likely Byproducts	Relative Quantity[1]	Potential Byproduct Mobility	Risk[2] of Environmental Degradation
Concrete demolition by breaking and crushing	Cement-aggregate fines, widely graded	Truck loads	High	High
Saw cutting concrete	Cement-aggregate fines, uniform sized	Truck loads	High	High
Concrete pavement grinding	Cement-aggregate fines, uniform sized	Truck loads	High	High
Pouring concrete flatwork and curing	Cementitious water Unformed concrete (spillage)	Bucket load Wheel barrow loads	High Low	Moderate Low
Pouring concrete formwork and curing	Cementitious water Unformed concrete (spillage)	Wheel barrow loads Wheel barrow loads	High Low	Moderate Low
Pouring concrete formwork underwater	Cementitious water Unformed concrete (spillage)	Tankfuls Wheel barrow loads	Very high Moderate	High Low
Concrete or masonry repair (assuming reuse of facing elements)	Cementitious water Unformed concrete or mortar (spillage) Acid cleaners	Bucket load Wheel barrow loads Bucket load	High Moderate High	Moderate Low Moderate
Concrete placement by pump (flatwork or formwork)	Cementitious water Unformed concrete (spillage)	Bucket load Wheel barrow load	High Low	Moderate Low
Concrete truck, container or tool wash out	Cementitious water	Bucket load	High	Moderate

[1]Approximate quantities for relative comparison: Wheelbarrow load ~ 3 cubic feet; Bucket load ~ 3 cubic yards; Truck load ~ 20 cubic yards; Tankful ~ 5,000 gallons.

[2]Risk = Relative Quantity x Potential Mobility

Table 2 Concrete Construction Practices and Potential for Stormwater Degradation, con't.				
Construction Practice	**Likely Byproducts**	**Relative Quantity[1]**	**Potential Byproduct Mobility**	**Risk[2] of Environmental Degradation**
Saw Cutting Green Concrete	Cement-aggregate fines, uniform sized	Bucket loads	High	Moderate
Underwater Pour of Concrete by Tremie into Cofferdam or Drilled Shaft Casing	Cementitious water	Tankfuls	High	High
Bridge Pier Cap, Beams & Deck Pour	Cementitious water Unformed concrete (spillage)	Bucket loads	High	High
Super Sack Mortar Station	Cement dust Cementitious water	Wheelbarrow load	High	Moderate
Stucco	Unformed concrete (spillage) Cementitious water	Wheelbarrow load	Moderate	Moderate
Stain	Unformed concrete (spillage) Cementitious water	Wheelbarrow load	Moderate	Moderate
Hydro Demolition	Cement-aggregate fines, widely graded	Truck load	Moderate	High
Vacuum Capture	Cement-aggregate fines, widely graded	< Wheelbarrow load (bypassing capture)	Moderate	Low
Capture of Concrete Sediments by Tornadic Vortex	Cement-aggregate fines, widely graded	< Wheelbarrow load (bypassing capture)	Moderate	Low
Sweeping of Concrete Sediments	Cement-aggregate fines, widely graded	Bucket Load (bypassing capture)	High	Moderate

Table 2 Concrete Construction Practices and Potential for Stormwater Degradation, con't.				
Construction Practice	**Likely Byproducts**	**Relative Quantity[1]**	**Potential Byproduct Mobility**	**Risk[2] of Environmental Degradation**
Filter Capture of Concrete Sediments	Cement-aggregate fines, widely graded	< Wheelbarrow load (bypassing capture)	Moderate	Low
Flocculent Sedimentation and Capture of Concrete Sediments	Cement-aggregate fines, uniform sized	< Wheelbarrow load (bypassing capture) (assumes pH control and proper mixing)	High	Low (assumes pH control and proper mixing) High (if pH not controlled nor properly mixed)
Capture of Concrete Sediments Through Use of "Floc Log"	Cement-aggregate fines, uniform sized	Bucket loads or more	High	High, unless pH control and proper mixing installed
Shotcrete	Cement-aggregate fines, widely graded	Wheelbarrow load	Moderate	Moderate
Gunite	Cement-aggregate fines, widely graded	Wheelbarrow load	Moderate	Moderate

[1]Approximate quantities for relative comparison: Wheelbarrow load ~ 3 cubic feet; Bucket load ~ 3 cubic yards; Truck load ~ 20 cubic yards; Tankful ~ 5,000 gallons.

[2]Risk = Relative Quantity x Potential Mobility

Table 3 Concrete Sediment Control Techniques with Management and Maintenance Characteristics			
Sediment Control Technique	**Design Parameters**	**Installation**	**Maintenance Requirements**
Pavement Sweeping	Area of affected pavement Sweeper characteristics: broom speed; forward speed; bristle spacing, length and composition	Sweeper operation	Dumping of collected sediments Brush replacement
Excavation	Location Depth	Equipment operation	Transport of collected sediments
Silt Fence	Location Drainage area Design storm	Trench and stake	Excavation of collected sediments Replace when clogged
Inlet Protection – Rock Bag or Filter Log	Location	Placement anchorage or connection	Excavation of collected sediments Replace when clogged
Inlet Protection – Filter Bag	Location	Placement under grate	Excavation of collected sediments Replace when filled
Sedimentation Pond	Drainage area Area of pond Design storm Dike geometry and stability Freeboard Outfall stability/protection against erosion Sediment storage	Containment berm embankment Outfall construction and protection Mulch and seed embankment	Excavation of collected sediments

Table 3 Concrete Sediment Control Techniques with Management and Maintenance Characteristics, con't.			
Sediment Control Technique	**Design Parameters**	**Installation**	**Maintenance Requirements**
Cofferdam	Drainage area Dry area Design storm Cofferdam geometry and stability Freeboard Steam bypass capacity Outfall stability/protection against erosion	Cofferdam construction Outfall construction and protection	Excavation of collected sediments Dewatering fluid filtration and release
Lined Capture System (Polyethylene Sheeting)	Location Disposal method Repair method	Placement Anchorage or connection	Excavation or removal Protection from precipitation Protection from or replacement after damage
Filter Systems – Filter Sump, Zoned Filter System, or Check Dam	Grain size (effective opening size) comparison Hydraulic head loss evaluation Capture effectiveness	Filtration element construction	Removal of fines
Flocculants	Dosage Delivery and mixture Chemical composition / evaluation for effectiveness	Construction of dosing and mixing system	Management of dosing and mixing systems
Note: Mulch, seeding, cat tracking and similar sediment control techniques are not included here due to applicability to normal soil particles and only inadvertent control of concrete sediments.			

Chapter 3 Characterization of Concrete Erosion Products

An assessment was made of erosion products related to sediments and contact waters potentially released during concrete construction or demolition. Concrete and cementitious sediments originating from construction practices were previously identified and sampled as described in in Chapter 2. Laboratory tests conducted for this task included: hydrometer evaluation of grain size, microscopy for observation of grain shape, pH measurement of acidity, and stream flow bed and rainfall drop (drip) erosion tests. The results of this study are to be used to guide development of best management practices (BMPs) for control of concrete and cement sediments, slurries and contact waters.

Based on the observations made as part of the previous work, four concrete and cementitious sediments were selected for study:

- Bridge Deck Debris, obtained during deck removal as part of bridge reconstruction, Lasalle Avenue over Interstate 94, Minneapolis, MN, collected July 10, 2010;
- Saw Cut Slurry, obtained during concrete pavement rehabilitation, Highway 61, Maplewood, MN, collected July 28, 2010;
- Pavement Grindings, obtained from sediments disposed after profile grinding of concrete pavement, Interstate 35, Duluth, MN, collected September 14, 2010; and,
- Portland Cement (Type 1), obtained commercially (Holcin)

Two additional soil materials were used for various comparisons in this study:

- Minnesota River Silt, obtained from the Minnesota River west bank at Seven Mile Creek County Park, St. Peter, MN, collected July 10, 2010; and,
- Filter sand, obtained commercially (Quikrete Premium Play Sand, No. 1113)

3.1 Sediment Particle Size and Shape

Hydrometer evaluations (Figure 1) were performed on all materials except the filter sand using the methodology of ASTM D-422, with sample material that had been passed through a #40 sieve. Complete hydrometer results are presented in Appendix B, and are summarized in Table 4. Grain size and gradation characterizations are presented in Table 5, and material classifications are presented in Table 6.

Classification of each sediment indicated modest but highly significant differences between the sediments evaluated. Bridge deck debris are predominantly fine sand though widely distributed with substantial silt and clay proportions. Minnesota River Silt was similar but with a greater proportion of silt and less of sand. Widely distributed materials are less likely to erode, as large particles can armor the smaller particles while the smaller particles wedge in the larger particles. Saw cut slurry, pavement grindings and Portland cement are all clays with proportions of silt, uniform in both particle size and gradation. Uniform materials generally are high erodible.

Figure 1 Hydrometer testing of saw cut slurry sediments

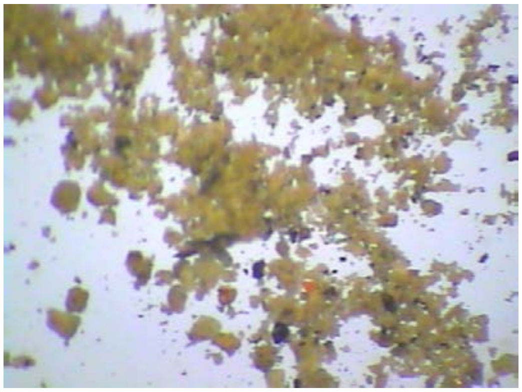
Table 4 Characteristic Particle Diameters Obtained From Hydrometer Testing					
Sediment	**Characteristic Particle Diameter, mm**				
	D_{85}	**D_{60}**	**D_{50}**	**D_{30}**	**D_{10}**
Bridge Deck Debris	*2*	*0.8*	*0.7*	*0.1*	0.0085
Saw Cut Slurry	*0.018*	*0.012*	0.0095	0.0034	0.0012
Pavement Grindings	0.017	0.012	0.0082	0.0036	0.00087
Portland Cement	0.012	0.0077	0.0065	0.0043	0.0018
Minnesota River Silt	*0.15*	*0.072*	0.054	0.024	0.0003

Notes: Specific gravity of particles assumed at 2.65 and 3.30 for aggregates and cement, respectively. Concrete sediments are assumed to consist of 85% aggregate and 15% cement for a overall specific gravity of 2.72. Estimated values in *italics*.

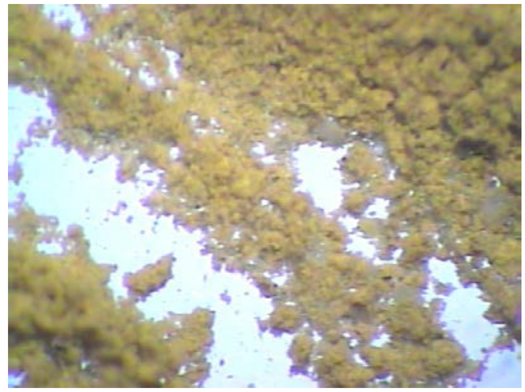
Table 5 Sediment Particle Size and Gradation Characterizations		
Sediment	**Uniformity Coefficient** $C_u = D_{60} / D_{10}$	**Gradation Coefficient** $C_g = D_{30}^2 / (D_{60} D_{10})$
Bridge Deck Debris	94	1.5
Saw Cut Slurry	10	0.8
Pavement Grindings	14	1.2
Portland Cement	4	1.3
Minnesota River Silt	240	27
Note: Values of D_{60}, D_{30} and D_{10} taken from Table 1.		

Table 6 Sediment Material Classification			
Sediment	**Overall Classification**	**Particle Size Characterization**	**Gradation Characterization**
Bridge Deck Debris	Sand, little Silt, little Clay	Widely distributed	Uniformly graded
Saw Cut Slurry	Clay with Silt	Moderately uniform	Uniformly graded
Pavement Grindings	Clay with Silt	Moderately uniform	Uniformly graded
Portland Cement	Clay, little Silt	Uniform	Uniformly graded
Minnesota River Silt	Silt with Sand, little Clay	Widely distributed	Well graded
Notes: Sand 2.0 to 0.07 mm; Silt 0.07 to 0.01 mm; Clay < 0.01 mm. Trace 0 – 10%, little 10 – 20%, some 20 – 30%, with 30 – 50%.			

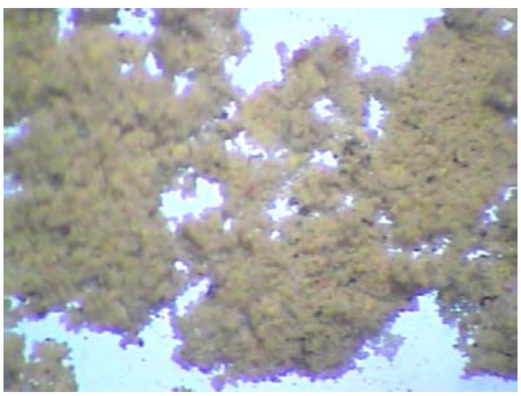
Photographs were taken of the sediments using a 40x reflecting light microscope (Figure 2). The uniformity or well-graded characteristic of each sediment may be observed in these photographs. Bridge deck debris, saw cut slurry, pavement grindings and Portland cement are all assumed to be angular or sub angular in shape, based on the lack of transport action that would round particles. This assumption was supported by transmitted light microscopy at 400x, in which particle angularity was identified (no photographs were obtained). Minnesota River silt and filter sand are observable in Figure 2 as generally sub rounded particles.



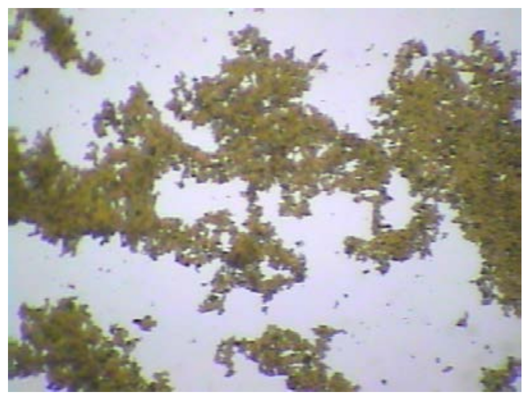
a) Bridge Deck Debris, D_{50} = 0.7 mm after scalping down to material passing 2.0 mm sieve opening (photograph predominated by material ~ 0.02 mm diameter)



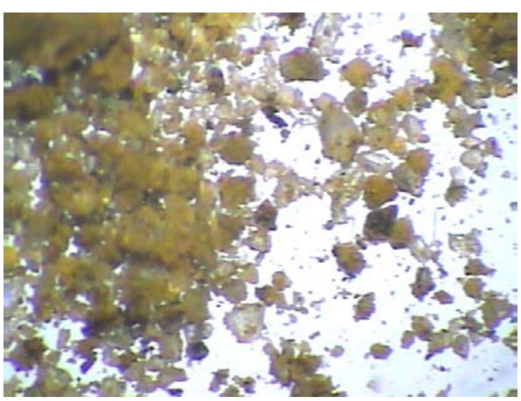
b) Saw Cut Slurry, D_{50} = 0.0095 mm



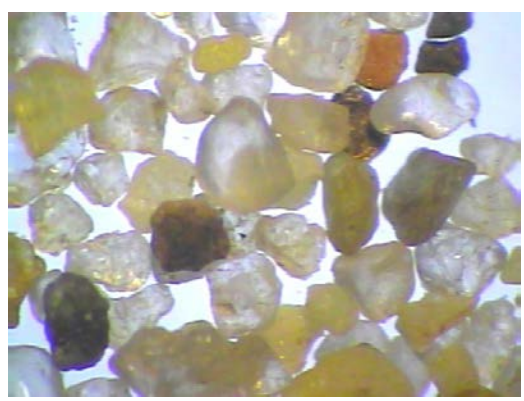
c) Pavement Grindings, D_{50} = 0.008 mm



d) Portland Cement D_{50} = 0.0065 mm



e) Minnesota River Silt, D_{50} = 0.054 mm



f) Sand, D_{50} = 0.1 mm

Figure 2 Microscope photographs of sediments selected for this study.

3.2 Acidity and Basicity of Sediments

Acidity contribution of the sediments to contact water was measured using a pH meter (Hach HQ40d meter with sensION probe), calibrated daily prior to use. Results are presented in Table 7, with distribution analysis provided in Appendix C. 10.00 g of sediment was placed in a borosilicate glass beaker with 50.0 mL of deionized water and allowed to remain for at least 24 hours until the pH stabilized. Acidity was determined using the definition of pH:

$$pH = -\log [H^+]$$

Therefore: $$[H^+] = 10^{-pH}$$

Basicity, the concentration of the hydronium ion, is determined through the dissociation constant of water:

$$K_w = 1 \times 10^{-14} = [H^+] [OH^-]$$

Therefore: $$[OH-] = 10^{(pH-14)}$$

Once the concentration of OH- is determined for the experimental condition, it can be related to the amount of sediment in the experiment as shown in Table 7. While equilibrium conditions are assumed in this calculation which may not be representative of a field situation where flowing water passes over the sediments without coming into equilibrium, the values can guide the amount of treatment additives for a BMP.

Table 7 Acidity and Basicity of Sediments

Sediment	pH	$[OH^-]$ moles per liter solute	$[OH^-]$ moles/g sediment	$[OH^-]$ mg/kg sediment
Bridge Deck Debris	12.54 ± 0.09	0.035 ± 0.008 (22.9%)	0.0035	59,500
Saw Cut Slurry	10.80 ± 0.38	0.00083 ± 0.0006 (67.3%)	0.000083	1,410
Pavement Grindings	9.39 ± 0.49	0.000037 ± 0.000031 (82.3%)	0.0000037	63
Portland Cement	12.86 ± 0.03	0.073 ± 0.006 (8.2%)	0.0073	124,100

Notes: Results reported as mean ± standard deviation with relative standard deviation reported as percentage where appropriate. Determination conducted using 7 replicates of 10.00 g sediment placed in solution for > 24 hr with 50.0 mL of deionized water as solute. OH^- has 17 g per mole molecular weight. Calculated concentrations assume equilibrium between sediments and OH^- in solution; moving water or water of greater volume would likely mobilize greater OH^- from sediment mass.

3.3 Sediment Erodibility

Relative erosion within a stream bed was evaluated using channel tests, as shown in Figure 3. Velocities within the channels were calibrated using dye tracer tests and slope adjustments; two velocities were selected for evaluation, 0.5 and 1.0 feet per second. These velocities represent medium and fast overland flow or stream velocities, respectively, and are indicative of conditions typical of roadway embankment side slopes or ditches in Minnesota. Channels were lined with 24 inches of washed fine gravel (Quikrete All-Purpose Washed Gravel, No. 1151), followed by 24 inches of sediment being evaluated, followed by 24 inches of more washed fine gravel. Clean deionized water, 1.00 liter in volume, was released at the top of the channel, to flow through and over the gravel in turbulent conditions, then to flow across the sediment deposit, then through and over the second gravel section, and finally collected at the end of the channel.

The entire sample of water collected was then completely mixed, and a 20 mL specimen analyzed for turbidity using an Oakton T-100 turbidity meter, calibrated immediately prior to use. The turbidity specimen was returned to the sample and the whole sample then filtered through a pre-weighed glass fiber filter (Hach 934-AH Filters, 47mm) (multiple filters were used for high-sediment samples).

To test Portland cement, a mortar paste was made using filter sand and washed fine gravel in the following proportion: 20.7% cement, 33.0% gravel, 33.5% sand, and 12.7% water. All other sediments were used as collected. Results are given in Table 8.

Figure 3 Stream flow bed erosion test apparatus, 0.5 feet per second velocity apparatus on left and 1.0 feet per second velocity apparatus on right. Note use of washed gravel up and down stream of sediment to prevent potential laminar flow conditions.

Table 8 Stream Flow Bed Erodibility of Sediments				
Sediment (initial mass placed in channel)	**Water Velocity of 0.5 Feet per Second**		**Water Velocity of 1.0 Feet per Second**	
	Sediment Eroded (RSD%) ***% of initial mass***	**Turbidity (NTU)**	**Sediment Eroded (RSD%)** ***% of initial mass***	**Turbidity (NTU)**
Bridge Deck Debris (650 g)	0.7 ± 0.1 g (14%) *0.1% of initial mass*	259	69.6 ± 49.7 g (71%) *11% of initial mass*	403 ± 119 (29%) (n = 3)
Saw Cut Slurry (300 g)	6.37 ± 2.44 g (38%) *2% of initial mass*	756 ± 199 (26%) (n = 3)	72.2 ± 20.7 g (29%) *24% of initial mass*	321 ± 207 (64%) (n = 3)
Pavement Grindings (300 g)	57.6 ± 5.3 g (9%) *19% of initial mass*	3.9 ± 4.2 (108%) (n = 3)	117.8 ± 1.8 g (1.5%) *39% of initial mass*	0.005 ± 0.007 (140%) (n = 2)
Portland Cement Mortar – 4 hours after hydration (800 g)	0.093 ± 0.03 g (32%) *0.01% of initial mass*	101 ± 49 (49%) (n = 3)	0.14 ± 0.06 g (43%) *0.02% of initial mass*	179 ± 89 (49%) (n = 3)
Portland Cement Mortar – 48 hours after hydration (800 g)	0.06 ± 0.01 g (17%) *0.008% of initial mass*	73.8 ± 4.1 (19%) (n = 3)	0.07 ± 0.006 g (8.6%) *0.009% of initial mass*	61.4 ± 8.0 (13%) (n = 3)
Notes: Sediment eroded measurements made with 3 replicates. All flows 1 liter in volume. Channel width 7.5 cm. Sediment depth approximately 1 cm. Water velocities calibrated using dye tracer tests. Number of turbidity determinations varied; results reported as mean ± standard deviation (relative standard deviation) (n = 2 or 3) when more than one measurement.				

Clearly, water velocity increased erosion of all sediments. Pavement grindings and saw cut slurry eroded substantially, then bridge deck debris less but still with significant amounts. Portland cement mortar of either 4 hours or 48 hours hydration time eroded little, and increasing hydration time decreased the amount eroded, small though it was.

Stream flow bed erosion test result distribution analyses and water velocity bivariate fit model analyses are included in Appendix D.

Rainfall drop erosion was modeled using a drip application apparatus, in which 1.00 liter of deionized water was dripped at a rate of approximately 100 mL/min from a height of 125 mm onto 5.00 g of sediment placed on a sand bed of approximately 10 g mass in a 25 mm diameter tube. Water was allowed to build up and pond to a maximum depth of ~75 mm prior to overflow into the sample collection container.

As in the previous experiment, the entire sample of water collected was then completely mixed, and a 20 mL specimen analyzed for turbidity using an Oakton T-100 turbidity meter, calibrated immediately prior to use. The turbidity specimen was returned to the sample and the whole sample then filtered through a pre-weighed 40 micron glass fiber filter. Results are provided in Table 9.

Table 9 Rainfall Drop (Drip) Erodibility of Sediments

Sediment	Number of Evaluations	Total Sediment Displaced (mg)	Turbidity of Water with Displaced Sediments (NTUs)
Bridge Deck Debris	39	3.7 ± 2.1 (57%)	1.25 ± 1.12 (90%)
Saw Cut Slurry	6	32.2 ± 49.0 (152%)	6.89 ± 7.04 (102%)
Pavement Grindings	4	525 ± 425 (81%)	91.6 ± 59.0 (64%)
Portland Cement	55	30.4 ± 29.3 (96%)	3.71 ± 3.42 (92%)

Notes: Results reported as mean ± standard deviation (relative standard deviation) for 1 liter of deionized water dripped from a 125 mm height onto 5.00 g of sediment placed on a ~10 g sand bed in a 25 mm diameter tube. Water was allowed to build up and pond to a maximum depth of ~75 mm prior to overflow into the sample collection container. Drip flow rate ~ 100 mL per minute.

The results for pavement slurry were similar to the streambed erosion experiment, as a substantial amount of sediment was measured after erosion (approximately 10% of the original sediment amount). However, neither saw cut slurry nor bridge deck debris were greatly eroded (each less than 1% of the original sediment amount). Portland cement was only lightly eroded, less than 1% of the original sediment amount, considering all results.

3.4 Effect of Hydration Time

The effects of hydration time on Portland cement were evaluated in this experiment, with results tabulated in Table 10. Hydration times of 0 to 48 hours were evaluated, with dramatic reduction in erosion observed with increased hydration time, as expected as the cement cured with time. These results were analyzed for bivariate fit and found to be significantly related of eroded sediment or turbidity as a function of hydration time with the following relationship:

Portland Cement Sediment (mg) = 36.84 – 1.356 x Hydration Time in hours, $p = 0.0203$

Portland Cement Turbidity (NTU) = 4.53 – 0.163 x Hydration Time in hours, $p = 0.0197$

As a check on the evaluation, the evaluation of hydration time effect was repeated with bridge deck debris using hydration times from 0 to 72 hours. These results were analyzed for bivariate fit and found to be significantly related of eroded sediment or turbidity as a function of hydration time with the following relationship:

Bridge Deck Debris Sediment (mg) = 4.43 – 0.0359 x Hydration Time in hours, p = 0.0078

Bridge Deck Debris Turbidity (NTU) = 1.759 – 0.0243 x Hydration Time in hours, p = 0.0004

Table 10 Rainfall Drop (Drip) Erodibility of Portland Cement Sediments by Hydration Time

Hydration Time (hrs)	**Number of Evaluations**	**Total Sediment Displaced (mg)**	**Turbidity of Water with Displaced Sediments (NTUs)**
0	9	53.9 ± 37.1 (69%)	5.59 ± 2.66 (48%)
0.5	11	53.1 ± 29.6 (56%)	8.01 ± 5.11 (64%)
1	3	13.6 ± 7.21 (53%)	3.11 ± 1.25 (40%)
2	14	28.0 ± 21.6 (77%)	3.31 ± 1.61 (49%)
4	11	17.3 ± 15.0 (87%)	2.20 ± 1.33 (60%)
8	3	9.73 ± 6.87 (71%)	0.78 ± 0.29 (37%)
16	1	0.7	0.32
48	1	0.6	0.07

Note that the distribution of bridge deck sediments was not tabulated here as no sediment result was greater than 10 mg. While statistically significant, the relationship with hydration time for bridge deck debris is a very small effect over the course of the experimental period of 72 hours. This behavior suggests some cementing or other armoring function of hydrated bridge deck debris sediments, though on a small scale.

Rainfall drop erosion test result distribution analyses and hydration time bivariate fit model analyses are included in Appendix E.

3.5 Summary

Sediments have factors characteristic of their source, relating grain size, uniformity and acidity to whether sediments were broken, cut or ground, or emanated from newly placed concrete prior to curing. Erodibility is strongly dependent upon time since original cement hydration, as the progression of the cement hydration process can result in sediments transitioning from erodible to bound. Erodibility is strongly influenced by sediment fineness and uniformity, similar to the well-defined characteristics of soil sediments.

Chapter 4 Capture and Containment Evaluation

An assessment was done of erosion products related to sediments and contact waters potentially released during concrete construction or demolition.

4.1 Sedimentation, with and without Flocculent

Hydrometer evaluations (Figure 1) were performed on all concrete sediments and the silt using the methodology of ASTM D-422, with sample material that had been passed through a #40 sieve. A flocculent, Biostar CH, was added to selected sediment mixtures at the completion of the mixing process and one last “over and back” mix of the graduated cylinder was done then the sedimentation timing begun (Figure 4). A flocculent rate of 100 uL/L of sediment and water mixture was used, following the dosing recommendations for the Biostar CH product. A flocculent rate of 50 uL/L was used for an additional pavement grindings sediment removal evaluation.

Complete hydrometer results are presented in Appendix F with both non-flocculated and flocculated results presented on the same graphs, and are summarized in Tables 2 and 3, respectively. Sedimentation time was estimated from the grain size distribution for the point representing 80% sediment removal from the fluid, defined as the time at which only 20% of particles remained in suspension.

Figure 4 Effect of flocculent addition (left), approximately 90 seconds after flocculent addition and mixing to a solution of Minnesota River silt in water.

Table 11 Estimated Time for 80% Sediment Removal.		
Sediment	**Estimated Time for 80% Removal (minutes)**	**Time Compared to Silt**
Bridge Deck Debris	1.5	1/30th
Saw Cut Slurry	300	6X
Pavement Grindings	800	16X
Portland Cement	200	4X
Minnesota River Silt	50	N/A
Notes: Removal times estimated from grain size distribution graph of hydrometer analysis.		

Table 12 Estimated Time for 80% Sediment Removal with Addition of Biostar CH Flocculent.		
Sediment	**Estimated Time for 80% Removal (minutes)**	**Estimated Time for 80% Removal (minutes) with Addition of 100 uL Biostar CH Flocculent**
Bridge Deck Debris	1.5	2
Saw Cut Slurry	300	1200
Pavement Grindings	800	800 (600 with 50 uL flocculent)
Portland Cement	200	DNT
Minnesota River Silt	50	4
Notes: Removal times estimated from grain size distribution graph of hydrometer analysis. DNT: Did not test.		

4.2 Infiltration

The reduction in infiltration rate caused by sediments was evaluated using a constant head infiltration test performed in the center ring of a double ring infiltrometer. The center ring was 12 inches in diameter. A constant hydraulic head of 12 inches was maintained for all tests. A bed of filter sand, 4 inches thick typically, was placed in the bottom of the center ring above a gravel drainage layer. To separate the sand from the gravel, a nonwoven geotextile (Geotex 401, Propex, Inc., Chattanooga, TN) with a minimum water flow rate of 140 gallons per minute per square foot was placed. The flow rate of the geotextile and the gravel drainage layer were greater than the sand alone, providing a test of the sand conductivity.

Tests were conducted by first establishing flow through the sand using a flow pumped from a receiving reservoir downstream of the infiltrometer. Application of ten aliquots of clear water, 14.00 L in volume, was then made at a rate that held the head level constant. The time required to infiltrate each aliquot was recorded and a conductivity rate determined. Effects of sediment loading on conductivity were then assessed by introducing measured amounts of sediment (dried and passed through a #20 sieve), allowing approximately 5 minutes for settlement, then measuring the time required for each of four aliquots of water, 1.00 L in volume, to infiltrate while maintaining the head level constant (Figure 5). To increase the sediment load, additional sediments were introduced and the steps repeated. At the end of the test, the infiltrometer was lifted off and the sand and sediment layers were inspected and checked for short circuiting (Figure 6). No appreciable amount of sediment of any type was passed through a sand layer.

Results are presented and graphed in Appendices G and H. Results are summarized in Table 13 by reduction in conductivity (average of four measurements) for each sediment, with comparison to the reduction caused by silt, at two loading rates.

Figure 5 Infiltration testing of sand filter challenged by sediments, using a known volume of water to keep a constant head condition.

Figure 6 Sand filter layer clogged by pavement grinding sediments.

Table 13 Reduction in Sand Filter Conductivity as a Function of Sediment Loading Rate.

Sediment	1 Pound/Square Foot Loading Rate		2 Pounds/Square Foot Loading Rate	
	Reduction in Conductivity	Reduction Relative to Silt	Reduction in Conductivity	Reduction Relative to Silt
Bridge Deck Debris	66%	0.87X	71%	0.81X
Saw Cut Slurry	62%	0.82X	77%	0.88X
Pavement Grindings	94%	1.24X	97%	1.10X
Portland Cement	66%	0.87X	90%	1.02X
Minnesota River Silt	76%	N/A	88%	N/A

Notes: Reduction calculated by comparison with flow rate established prior to sediment challenge.

4.3 Geotextile Infiltration

To assess the capture rate of sediments by a geotextile fabric, a sample of geotextile was stretched over the opening of a 5 gallon bucket. A known mass of sediment, previously dried and passed through a #20 sieve, of approximately 800 g mass was mixed with approximately 1 L of water and poured onto the geotextile (Figure 7). Clear water was used to rinse sediment from the mixing vessel. The dry mass of the geotextile before and the geotextile plus sediment after sediment application were measured, compared to the mass of sediment applied, and a capture rate calculated (Table 14). Four geotextile products were evaluated:

- Dandy Bag Inlet Protection (Dandy Products, Inc., Westerville, OH), a woven geotextile of unspecified composition;
- MnDOT Rock Bag, composed of Geotex 104 F woven geotextile (7 oz/sy, Propex, Inc., Chattanooga, TN);
- Geotex 401 non-woven needle punched geotextile (5 oz/sy, Propex, Inc.)
- Silt Fence, composed of Geotex 2127 woven geotextile (3 oz/sy, Propex, Inc.)

Figure 8 presents a bar chart of the sediment capture rate by sediment type and geotextile. Figures 9 through 12 present photographs the sediments on each of the four geotextiles, taken with 40X magnification, such that the sediment grains can be compared to the fibers or strands of the geotextile and the geotextile opening size.

Figure 7 Geotextile filtration of sediments.

Table 14 Geotextile Capture of Sediments.				
Sediment	**Sediment Capture**			
	Dandy Bag Sediment Capture Fabric	**MnDOT Rock Bag Material**	**Propex Geotex 401 Nonwoven Geotextile**	**Silt Fence Material**
Bridge Deck Debris	91.6%	91.7%	93.8%	Clogged
Saw Cut Slurry	62.9%	68.5%	95.5%	Clogged
Pavement Grindings	64.9%	55.4%	95.6%	Clogged
Minnesota River Silt	62.3%	77.8%	96.9%	Clogged
Notes: Clogged: Flow of water from the sediment/water mixture would not pass the geotextile within 48 hours.				

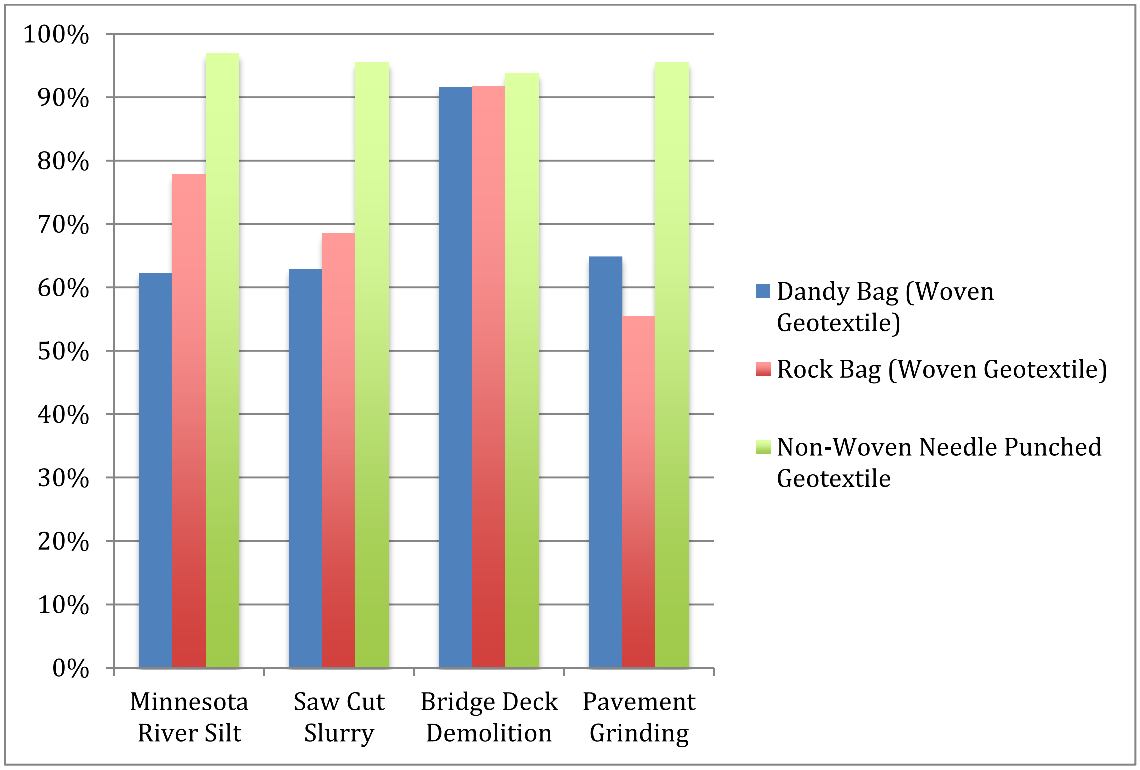
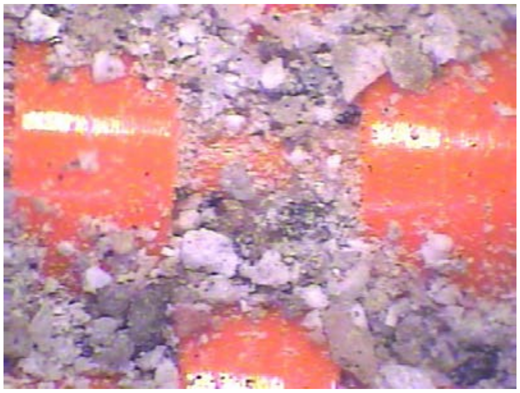
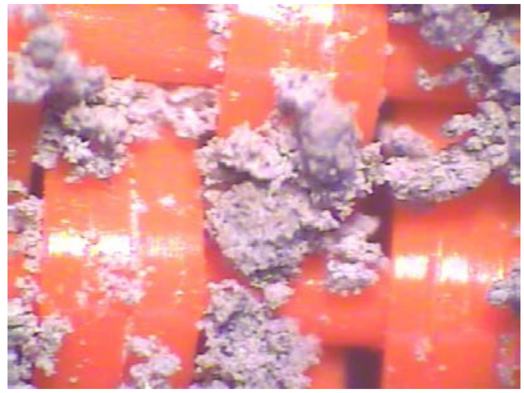


Figure 8 Bar chart of sediment capture rate by sediment and geotextile.

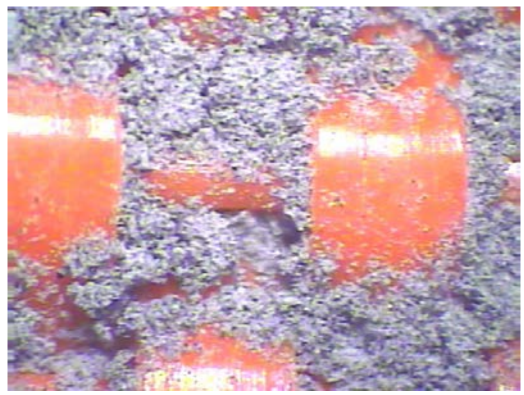


a) Bridge Deck Debris

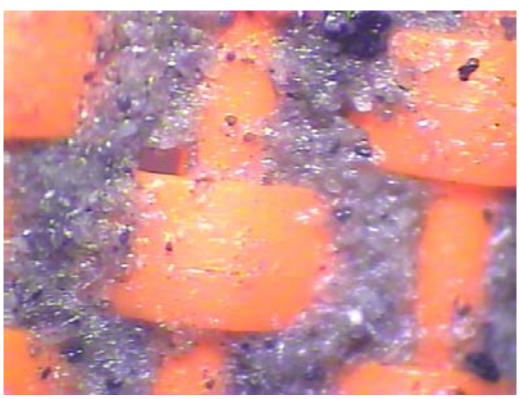


b) Saw Cut Slurry

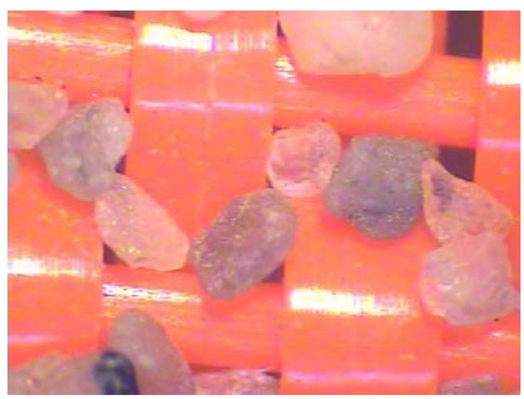
c) Pavement Grindings



d) Portland Cement

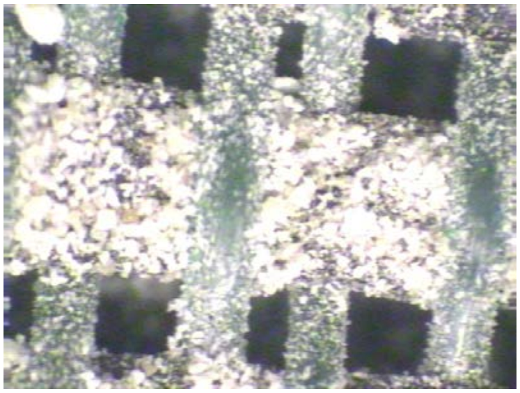


e) Minnesota River Silt



f) Sand

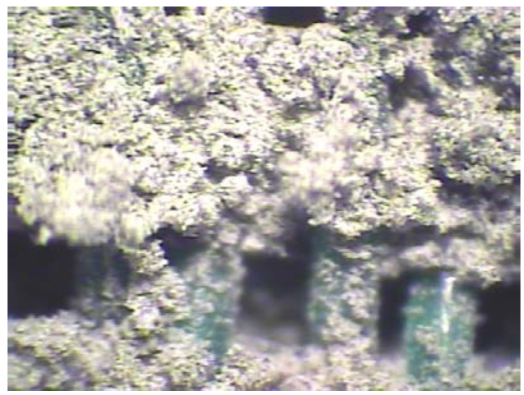
Figure 9 Microscope photographs of sediments filtered on Dandy Bag sediment capture fabric.



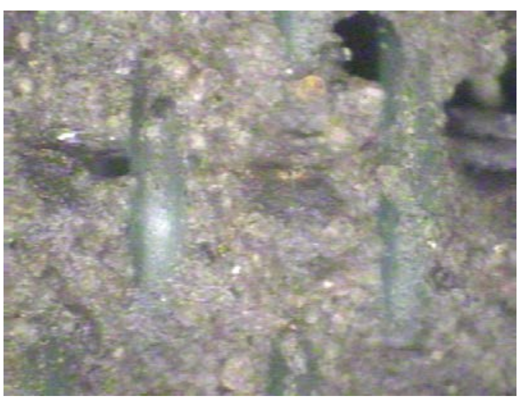
a) Bridge Deck Debris

b) Saw Cut Slurry

c) Pavement Grindings



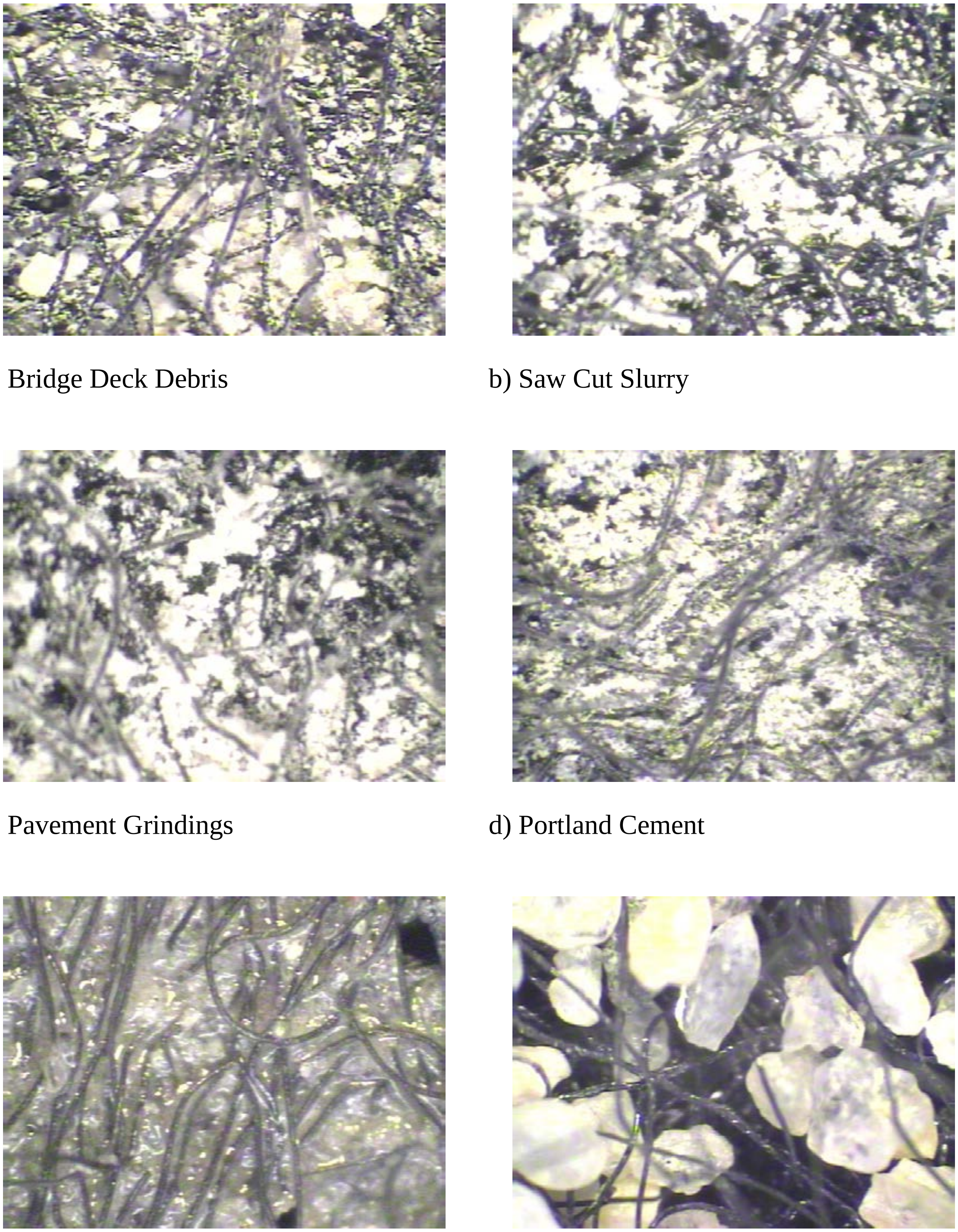
d) Portland Cement



e) Minnesota River Silt

f) Sand

Figure 10 Microscope photographs of sediments filtered on a MnDOT Rock Bag made of Propex Geotex 104 F woven geotextile.



a) Bridge Deck Debris

b) Saw Cut Slurry

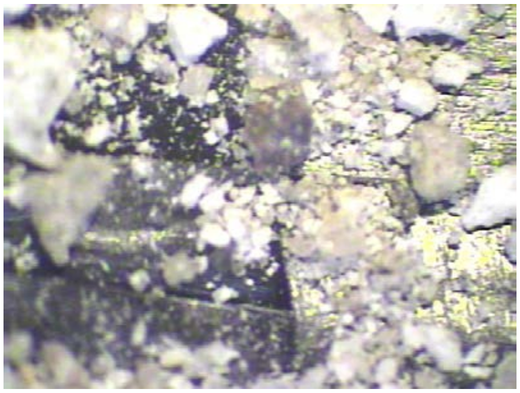
c) Pavement Grindings

d) Portland Cement

e) Minnesota River Silt

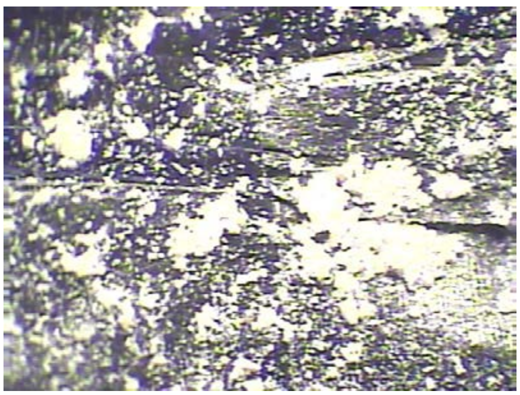
f) Sand

Figure 11 Microscope photographs of sediments filtered on Propex Geotex 401 nonwoven geotextile.



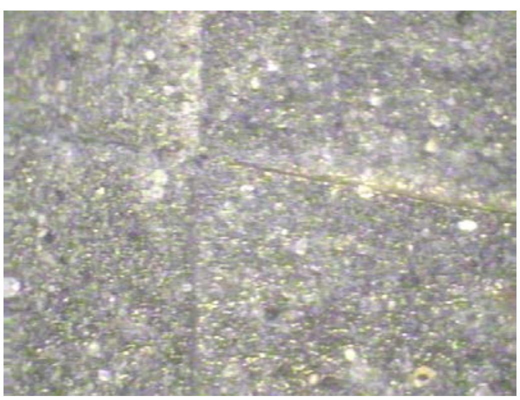
a) Bridge Deck Debris

b) Saw Cut Slurry



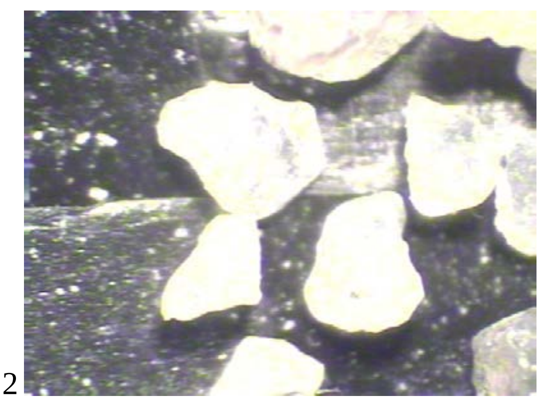
c) Pavement Grindings

d) Portland Cement



e) Minnesota River Silt

2



f) Sand

Figure 12 Microscope photographs of sediments filtered on silt fence material (Propex Geotex 2127 woven geotextile).

To further evaluate the effectiveness of geotextile filtering of concrete sediments, an additional round of experiments was conducted using selected geotextiles to filter approximately 1 g of selected sediment in about 100 mL of deionized water (Figures 13 and 14). Filtration was done with a 47 mm diameter glass filter holder with vacuum suction. All tests were done in triplicate for each combination of sediment and geotextile; results are provided in Table 15.

Figure 13 Deionized water stream being used to rinse all sediment from weigh dish during geotextile filter removal of approximately 1 g of bridge deck debris sediments in 100 mL of water through a 47 mm diameter glass filter apparatus with a rock bag woven geotextile above a 0.45 um glass fiber filter.

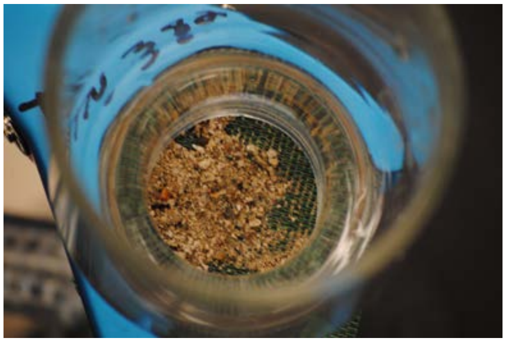
 

Figure 14 Geotextile filter removal of 1 g of bridge deck debris sediments in 100 mL of water through a 47 mm diameter glass filter apparatus. Left: coarser sediments retained by a rock bag woven geotextile, view down into the filter cone prior to disassembly. Right: finer sediments retained by a 0.45 um glass fiber filter from beneath the rock bag woven geotextile.

Table 15 Geotextile Filter Removal Effectiveness.

Concrete Sediment	**Filter Material**			
	Dandy Bag Woven Geotextile	**Rock Bag Woven Geotextile**	**4 oz/sy Non-Woven Geotextile**	**Silt Fence**
Bridge Deck Debris	81.3% ± 1.5% (1.9%)	83.7% ± 1.5% (1.8%)	87.7% ± 7.8% (8.9%)	96.7% ± 1.2% (1.2%)
Saw Cut Slurry	88.0% ± 1.0% (11.4%)	87.7% ± 0.6% (0.7%)	94.0% ± 0.0% (0.0%)	96.3% ± 0.6% (0.6%)
Pavement Grindings	79.0% ± 31.4% (39.8%)	61.3% ± 2.1% (3.4%)	78.7% ± 0.6% (0.7%)	105.3% ± 15.3% (14.5%)
Minnesota River Silt	54.3% ± 3.8% (7.0%)	66.7% ± 2.1% (3.1%)	93.3% ± 1.5% (1.3%)	95.7% ± 0.6% (0.6%)

Notes: Filtration done with 47 mm diameter glass filter holder with vacuum. All tests done in triplicate with results reported as Mean ± Standard Deviation (Relative Standard Deviation, %).

Geotextiles were generally effective at capturing concrete sediments via filtration. Bridge deck debris and saw cut slurry capture were over 80% for all geotextiles, with uniform test results. Capture of pavement grindings was both lower and more variable, though results were above 60% for all geotextiles. Minnesota river silt capture was much lower for both woven geotextiles tested, though the non-woven and silt fence geotextile performed well. Geotextile filtration test results are presented in Appendix I. Note that this test did not evaluate hydraulic flow rate of filtration.

4.4 pH Treatment

Acidity contribution of the sediments to contact water was measured using a pH meter (Hach HQ40d meter with sensION probe), calibrated daily prior to use. 10.00 g of sediment was placed in a borosilicate glass beaker with 50.0 mL of deionized water and allowed to remain for at least 24 hours until the pH stabilized. Treatment of the acidity to achieve a more neutral pH was modeled by the addition of a measured aliquot of 0.5 N Hydrochloric Acid (HCl) (Fisher Scientific, Inc., Pittsburgh, PA). Measurement of pH occurred at selected times following the treatment. The treated water remained in contact with the original sediments. Three replicates were generally tested.

Results are summarized in Table 16, with full results provided in Appendix J.

Table 16 Acidity Treatment and Change.

Sediment	Initial pH	0.5 N Hydrochloric Acid Added (mL)	Lowest pH Measured Immediately Following Acid Addition	Long Term pH Measured Following Acid Addition
Bridge Deck Debris	12.48	4600	1.92	11.97 (66 hrs)
	12.40	3600	1.85	11.94 (65 hrs)
	12.47	2600	2.14	12.14 (66 hrs)
Saw Cut Slurry	11.11	300	5.89	9.95 (46 hrs)
	10.91	250	5.95	10.01 (44 hrs)
	11.15	200	5.92	10.55 (45 hrs)
Pavement Grindings	8.62	100	2.63	DNT
	9.83	100	2.98	
	9.93	50	6.17	

Notes: Portland Cement and Minnesota River Silt were not tested. DNT: Did not test.

4.5 Summary

Review of the results presented in this report lead to the following conclusions:

- Removal of sediments by sedimentation process will vary by the time required for the sediments to fall out of suspension. Larger diameter particles such as bridge deck demolition debris fall quicker than silt, while smaller diameter particles such as saw cut slurry, pavement grindings and Portland cement fall much slower than silt.

- Flocculent of the type represented by Biostar CH do not help with the removal of concrete sediments, as the addition of flocculent causes concrete sediments to fall out of solution slower than without the flocculent. Flocculent addition did improve the removal of silt. Other flocculents with different ionic characteristics should be considered for the removal of concrete sediments.

- Sand filters provide excellent capture of concrete sediments, with a corresponding large reduction in sand conductivity similar to that caused by silt. However, for selected concrete sediments, the reduction in sand conductivity may be significantly higher; therefore each sediment should be evaluated individually if a minimum conductivity is a requirement of design.

- Geotextiles capture sediments in varying amounts, with woven products providing moderate capture while a non-woven geotextile provided excellent capture. The tight weave of silt fence, while a woven geotextile, provided excellent sediment capture but poor hydraulic flow when water was mixed with sediment.

- pH treatment of concrete sediment contact waters can be accomplished, but pH rebound will occur unless the water is removed from the presence of the sediments.

Chapter 5 Best Management Practices and Conclusion

This chapter presents methods of design and implementation for best management practices (BMPs) for the reduction, control and capture of erosion products related to sediments and contact waters potentially released during concrete construction or demolition. This assessment assumes full compliance with and adherence to the guidance of the Minnesota Stormwater Manual (2005) and requirements of MPCA General Permit MN R 100001, Authorization to Discharge Stormwater Associated with Construction Activity Under the National Pollution Discharge Elimination System. This assessment of BMPs for concrete sediments and contact waters primarily addresses what changes and/or adjustments may be required to adapt existing soil sediment BMPs.

5.1 Best Management Practices Overview

All sediments, including concrete and soil sediments alike, have significant potential to cause habitat loss, change waterway hydraulics, asphyxiate aquatic and benthic creatures, degrade navigation and plug drainage pipes and culverts. Construction sites are of particular concern due to the typical amount of disturbed ground, the stockpiles of earthen or particulate materials, the disturbance caused by construction equipment and operations, and the exposure to precipitation, sun and wind.

Preventing sediments from leaving a construction site requires a strategy built upon multiple lines of sediment control, if cost- and labor-efficiency is important. Such an approach provides flexibility for adjustment around both changing site operations and shifting seasonal weather, and can be strengthened through proactive maintenance. From the guidance provided in the Minnesota Stormwater Manual (2005), the following general classification of BMPs are suggested for construction sites:

- Diversion to limit run-on water;
- Reduction of erosional forces by surface water velocity reduction;
- Reduction of sediment development through sediment collection or anchoring;
- Sedimentation of mobilized sediments;
- Filtration of sediment-carrying flows;
- Collection of captured or contained sediments;
- Treatment of pH (hydronium and hydroxide);

- General housekeeping, including collection of trash and prevention of hazardous waste releases;
- Maintenance of erosion and sediment control devices/installations;
- Regular inspections; and,
- Recordkeeping.

Beyond guidance, erosion and sediment control are required by Minnesota regulation implanted through the requirements of MPCA General Permit MN R 100001, Authorization to Discharge Stormwater Associated with Construction Activity Under the National Pollution Discharge Elimination System

5.2 Best Management Practices for Concrete Sediments

Construction operations that involve mixing, pouring, finishing, grinding, saw cutting, or breaking concrete require special consideration for erosion and sediment control compared to soil sediments for several key attributes of concrete operations:

- The potential for concrete sediment mobility;
- The volume of potential sediments associated with larger concrete operations;
- The small size and uniformity of concrete sediments created by some construction operations;
- The angularity of concrete sediments; and,
- The chemical reactivity of concrete sediments.

These attributes were discussed and analyzed in the summary reports provided during the previous tasks. These attributes influence erosion and sediment control both in collection/capture feature design and in management of site operations.

Designing an erosion and sediment control strategy that addresses concrete sediments requires consideration of characteristics that may be different than for soil sediments. There are five specific characteristic differences between concrete sediments and typical soils, including:

1. Particle grain size;
2. Gradation distribution;
3. Material density;
4. pH; and,
5. Particle reactivity.

These characteristics must be defined or conservatively assumed in order to prepare a successful design.

Depending upon the construction process, additional operational factors may need to be addressed including: sediment volume, water velocity, concentration within water flows, and sediment location, including location during sediment generation, post-collection transport and any disposal/reuse on site. Table 17 provides specific listing of the characteristics required for BMP design, both the concrete sediment-specific and the operational characteristics.

5.3 Site Operations and Pre-Erosion Sediment Capture BMPs

Site operations can be affected by the characteristics of concrete sediments, particularly regarding pre-erosion sediment capture functions. Specifically, effectiveness of sweeping and vacuuming have been shown to be highly dependent upon the reactivity, grain size, gradation/distribution and density of the concrete sediments. Heavy, clay-sized or cemented sediments do not sweep or vacuum up at the same rate as sand or silt particles. Such operations may actually spread concrete sediments if not properly designed (Chapter 2). Note that design of street sweeping operations is not typically done in a formal procedure, but may need to be so addressed if depended upon for collection of concrete sediments. Design would encompass number of passes, direction of travel, moisture conditioning, broom type and bristle material, size and condition. Design would need to incorporate vendor recommendations as little formal information exists.

Design of pre-erosion sediment capture BMPs requires knowledge of the volume and location of the sediments to assess the overall BMP size. Density can be helpful to calculate the weight likely of the anticipated sediment volume, an important consideration for the excavation and haul of the sediments, particularly since the sediments are likely to weigh about 25% more than a similar volume of soil.

Reactivity can be an important factor in determining the “looseness” of sediments during removal and maintenance efforts. Sediments that are cemented together *en mass* may be more difficult to remove than sediments that remain distinct and sand- or silt-like. It should be noted that while cemented concrete sediments will erode less, they will continue to leach high pH (basicity) until removed from water contact.

Refer to Appendix K Figure A for a flow chart of concrete sediment control activities recommended for site operations.

5.4 Sedimentation BMPs

Sedimentation is the removal of particles by gravity processes. Sedimentation BMP design requires characterization of particle diameter, gradation and density in order to assess the capture for a given hydraulic retention time that forms the basis of the BMP size. This characterization is done through the hydrometer test, commonly used for determination of silt and clay particle size distribution (ASTM D-422; Chapter 3). The design of sedimentation basin involves selection of a volume that provides a hydraulic retention time (HRT) greater than the time required for the desired removal. The minimum sedimentation basin volume is calculated by multiplying the flow rate (Q, in cfs x 60 s/min) by the sedimentation time. The flow rate may come from the design storm (2 year, 24 hour storm, typically, as required by permit) or from the cumulative water use from the construction operations, if work would shut down in a rain event.

Table 17 Best Management Practices (BMPs), Functions and Required Sediment or Site Parameters for Concrete Sediment Erosion and Sediment Control Design.

Best Management Practice	Function[1]	Sediment or Site Parameters Required for Design[2]								
		Diameter	Distribution	Density	pH	Reactivity	Sediment Volume	Water Velocity	Sediment Concetnration	Sediment Location
Vegetated Buffer	Run on protection									X
Rock Construction Entrance	Pre-erosion sediment capture						X			X
Grade Breaks	Run on protection									X
Temporary Seeding	Erosion protection									X
Erosion Control Blanket	Erosion protection									X
Mulch/Hydraulic Mulch	Erosion protection									X
Temporary Pipe Downdrains	Run on protection									X
Silt Fence	Sedimentation	X	X	X		†	X	X	X	X
Fiber Log	Filtration, *sedimentation*	X	X			†	X	X	X	X
Floatation Silt Curtain	Sedimentation	X	X	X		†	X		X	X
Rock or Compost Bag	Sedimentation, *filtration*	X	X	X		†	X	X	X	X
Rock Check Dam	Sedimentation, *filtration, treatment*	X	X	X	†	†	X	X	X	X
Rip Rap	Erosion protection	X	X							X
Temporary Sediment Basin	Sedimentation, *treatment*	X	X	X		†	X	X	X	X
Filter Bag	Filtration, *treatment*	X	X		†	†	X	X	X	X
Chemical or Biological Treatment	Treatment	X	X	X	X	X			X	X
Filtration Devices	Filtration, *sedimentation*	X	X			†	X	X	X	X
Hydrodynamic Devices	Sedimentation	X	X	X		†	X	X	X	X
Tremie w/Water Balanced Withdraw	Pre-erosion sediment capture						X	X	X	X
CO_2 Sparge	Treatment				X	X	X	X	X	X

Cofferdam	Run on protection, erosion protection, pre-erosion sediment capture						X			X
Excavation	Pre-erosion sediment capture			X			X			X
Plastic Lining	Pre-erosion sediment capture			X			X			X
Entombment	Pre-erosion sediment capture						X			X
Vacuum	Pre-erosion sediment capture	X	X	X		X	X			X
Sweeping	Pre-erosion sediment capture	X	X	X		X	X			X
Dust Control	Pre-erosion sediment capture					X	X			X

[1]Potential or secondary functions are listed in *italics*.

[2]X = sediment or site parameter required for design. † = sediment or site parameter helpful for design.

Based on sedimentation basin design for wastewater, a 1.75 factor of safety should be placed on basins exposed to wind to negate the effects of wind-driven currents. For the pavement grindings result, for example, approximately 800 minutes is required to achieve an 80% removal (20% passing). Applying the 1.75 factor of safety, the basin should be designed to achieve a minimum hydraulic retention time of 1400 minutes, or 23.3 hours.

Table 18 provides the application of this calculation to sediment basin sizing assuming a flow of 5 cfs, for results obtained during Chapter 3.

Refer to Appendix K Figure B for a flow chart of concrete sediment control activities recommended for sedimentation and gravity removal. An alternative approach to evaluate removal effectiveness of fixed size sedimentation features is provided in a flow chart as Appendix K Figure C.

5.5 Filtration BMPs

Filtration BMP design requires definition of the particle diameters and gradation distribution to assess both the capture efficiency and the hydraulic capability of the filter, whether soil or geotextile based. Filtration BMP design also requires the definition of the filter material particle diameters and gradation distribution.

Table 18 Estimated Time and Volume Required for 80% Sediment Removal at 5 cfs Flow, Without and With a 1.75 Factor of Safety.			
Sediment	**Estimated Time for 80% Removal (minutes)**	**Volume Required for 5 cfs Flow (No Safety Factor)**	**Volume Required for 5 cfs Flow (1.75 Safety Factor)**
Bridge Deck Debris	1.5	450 cf	790 cf (0.02 acre ft)
Saw Cut Slurry	300	90,000 cf	158,000 cf (3.6 acre ft)
Pavement Grindings	800	240,000 cf	420,000 cf (9.6 acre ft)
Portland Cement	200	60,000 cf	105,000 cf (2.4 acre ft)
Minnesota River Silt	50	15,000 cf	26,000 cf (0.6 acre ft)
Notes: Removal times estimated from grain size distribution graph of hydrometer analysis.			

Using the US Army Corps of Engineers method for filter design, Cedegren (1989) suggests two requirements for selection of filter materials:

1) The filter material D_{15} (the size of which 15% of the filter material is smaller) be no smaller than five times the D_{15} of the sediment so that water freely flows from the sediment through the filter; and,
2) The filter material D_{15} be no larger than five times the sediment D_{85} (the size of which 85% of the sediment material is smaller) so that the sediment does not pass through the filter in a process termed piping.

Table 19 presents filter characteristic calculations for the five materials examined in Chapter 3. Because of the fineness of pavement grindings, Portland cement and saw cut slurry, the material necessary to filter these sediments is a silty sand, a material finer than normally used for construction site water management. Larger gravels may be needed as a second filter, to prevent the silty sand from piping. Such a multi-layered assemblage is known as a zoned filter and is commonly found in dewatering operations, embankment dams and levee structures.

Initially flow through the filter will control the hydraulic flow. As ripening occurs, in which the captured sediment fines build up and create a complete layer, the flow will slow down as the sediment fines control the rate (see Chapter 4 for measured values, and Table 20 for approximate values). When hydraulic flow is insufficient, it is time for filter cleaning and removal of sediments. For sediment filters,

Table 19 Filter Material Characteristic Calculation.

Sediment Characteristics			Filter Material Characteristics		
Material	**$D_{15\ Sediment}$ (mm)**	**$D_{85\ Sediment}$ (mm)**	**D_{15} (mm) No Smaller Than to Maintain Hydraulic Flow (5x $D_{15\ Sediment}$)**	**D_{15} (mm) No Larger Than to Prevent Piping (5x $D_{85\ Sediment}$)**	**Potential Classification of Filter Material**
Bridge Deck Debris	0.009	2.0	0.045 (#325 sieve)	10.0 (3/8 inch sieve)	Gravel, little Sand
Saw Cut Slurry	0.0018	0.018	0.009 (#400 sieve)	0.09 (#170 sieve)	Silty Sand
Pavement Grindings	0.0016	0.017	0.008 (#400 sieve)	0.085 (#200 sieve)	Silty Sand
Portland Cement	0.0024	0.012	0.012 (#400 sieve)	0.06 (#270 sieve)	Silty Sand
Minnesota River Silt	0.0060	0.15	0.030 (#400 sieve)	0.75 (#25 sieve)	Sand, well-graded

Note: Minimum sieve sizes specified are no smaller than #400 due to practicality. All sieve sizes provided are U.S. standard sieve numbers. Filter design based on the method of Cedergren (1989).

Table 20 Approximate Infiltration Values.			
Material	**Approximate Infiltration Rate**	**Infiltration Rate at a Gradient = 1.0**	**Approximate Area Required for 1 gpm Flow with Gradient = 1.0**
Bridge Deck Debris	0.02 cm/s	0.3 gpm/sf	3 sf
Saw Cut Slurry	0.01 cm/s	0.15 gpm/sf	7 sf
Pavement Grindings	0.002 cm/s	0.03 gpm/sf	30 sf
Portland Cement	0.004 cm/s	0.06 gpm/sf	16 sf
Minnesota River Silt	0.01 cm/s	0.15 gpm/sf	7 sf
Note: values developed from infiltration tests described in the Task 3 Summary Report			

cleaning is usually done by scraping or excavating until the sediments are removed and sufficient filter material remains or is replaced.

Note that some sediment control BMPs that are generally applicable to sedimentation can be converted to filtration BMPs if properly designed and maintained (i.e., silt fence). In this function, the filtration typically involves the clarified supernatant above the sediment capture zone. Infiltration rate at a gradient of 1.0, provided in Table 6, is recommended for use when designing geotextile filtration flow rates.

Refer to Appendix K Figure D for a flow chart of concrete sediment control activities recommended for filtration.

5.6 Treatment BMPs

Treatment BMP design addresses the fine particles that are slow to settle by gravity sedimentation. A chemical flocculent is added to the water and vigorously mixed for typically 30 seconds, then sedimentation is allowed to progress. The flocculent works by encouraging attraction between particles such that they aggrade and become grouped. The sediment groups are then heavy enough to increase their downward velocity and rate of sedimentation. Sediment groups will bump into more particles while sinking, continuing the group growth through a process termed “sweep floc” (i.e., sweeping the water clean). See Figure 4 for an illustration of this behavior.

Flocculent addition is often done to waters contained in roll-off boxes, dumpsters or frac tanks so that mixing can be done in a controlled mode. Either batch-mode (single dose, no influent or effluent until treatment done) or continuous-mode treatment and mixing may be done. Mixing can be done with powered mixers, hand-operated paddles or hydraulic (pump) recirculation, if sufficient turbulence is achieved.

Successful flocculation requires the water to be treated to have a pH between 6 and 9. Therefore, treatment BMP design also addresses the high pH of the concrete sediment contact waters; it assumes that the sediments have been removed from the water by either filtration or sedimentation. Not to do so would only neutralize the treatment then regenerate high pH from continued sediment contact. However, the rate of high pH regeneration may be slow enough such that flocculent-based chemical settling can be done to remove the concrete sediment fines and decant the water prior to pH regeneration.

pH, the measure of acidity, is related to the concentration (noted by the brackets, [ ], and in units of moles per liter) of the hydronium ion by the following identity:

$$pH = -\log [H^+]$$

Therefore: $$[H^+] = 10^{-pH}$$

Basicity, the concentration of the hydroxide ion, is determined through the dissociation constant of water:

$$K_w = 1 \times 10^{-14} = [H^+]\,[OH^-]$$

Therefore: $$[OH-] = 10^{(pH-14)}$$

Once the concentration of OH- is determined for the experimental condition, the amount of acid needed to neutralize it can be calculated. For example, to use 0.3N (0.3 mole/liter) muriatic (hydrochloric) acid to neutralize water that had been in contact with concrete bridge deck debris, it is necessary to recognize that normality is similar to efficiency, in that a normality less than 1.0 is not as efficient a neutralizer due to dilution.

$$V_{acid} / V_{contact\ water} = [H^+] / N$$; units of liter of acid per liter of contact water

Substituting: $$V_{acid} / V_{contact\ water} = 10^{-pH} / N$$

This relationship is developed for the four concrete sediments analyzed in Chapter 3 and presented in Table 21. For example, to calculate the volume of 0.3N (0.3 mole/liter) muriatic (hydrochloric) acid required to neutralize 800 gallons of water that had been in contact with concrete bridge deck debris, 115 mL of acid would be applied to each liter of contact water. It may be convenient to convert this dosing rate to mL of acid (measured by a syringe or graduated cylinder) per gallon of contact water, gallons being a common field measure. In the example situation, 800 gallons of contact water would be treated at a dosing rate of 450 mL/gal, so that 360 liters of 0.3N muriatic acid, or 93 gallons, would be required.

Alternatively, carbon dioxide gas may be sparged (bubbled) into water for pH adjustment in a process known as recarbonation, often employed for wastewater treatment. There are two aspects of the sparging method that are key to high effective pH adjustment: the bubbles should be fine (i.e., nozzle holes less than 1/8 inch diameter), and the depth of carbon dioxide injection should be as deep as practical. Fine nozzles create small bubbles that increases the contact area, as smaller bubbles have higher overall surface area for the same volume of gas. Deeper injection creates a longer contact time, as bubbles rise to the surface.

Note that the carbon dioxide flow rate required for pH adjustment of concrete sediment waters by recarbonation is typically assessed experimentally, using a trial and error approach, because of the numerous factors involved. For a given nozzle and tank set up, typical application factors will include sparge time, gas pressure, water temperature and initial pH. However, recarbonation by carbon dioxide sparge may quickly change the pH and hold it long enough for flocculation to be effective (typically 3 to 5 minutes) such that the clarified water can be released prior to pH rebound due to sediment contact.

Refer to Appendix K Figure E for a flow chart of concrete sediment control activities recommended for chemical settlement, including pH adjustment.

Table 21 Acidity and Basicity of Sediments.

Sediment	pH	$[OH^-]$ Moles per Liter of Solute	$[H^+]$ Moles per Liter Required to Neutralize	Volume of 0.3N Muriatic Acid Required for Neutralization
Bridge Deck Debris	12.54	0.035	0.035	115 mL/L (450 mL/gal)
Saw Cut Slurry	10.80	0.00083	0.00083	3.3 mL/L (13 mL/gal)
Pavement Grindings	9.39	0.000037	0.000037	115 uL/L (0.45 mL/gal)
Portland Cement	12.86	0.073	0.073	250 mL/L (950 mL/gal)

Notes: Neutralization is treating to a pH = 7.0, at which acidity equals basicity. pH values taken from the results presented in the Task 2 Summary Report; only average values are shown, variation from the average was observed at differing levels. Buffering effects not addressed.

5.7 BMP Combinations

Combinations of BMPs are likely to be amenable to most constructing sites, as space limitations and other operational constraints may limit the size of a single BMP. This approach is akin to a treatment train, a sequence of treatment operations, commonly used for drinking water treatment optimization and cost efficiency. BMPs to be combined will likely consist of BMPs listed above, placed in order of treatment by cost efficiency or site space minimization. To illustrate this concept, Table 22 presents example combined-BMP applications, listed by concrete sediment source or construction operation.

Refer to Appendix K Figures F and G for overview flow charts of concrete sediment control activities recommended in general for all concrete sediment sites and concrete sediment sites with water. These flow charts may be used as initiation plans as they incorporate all previous flow charts through the use of reference points.

Table 22 BMP Application By Concrete Sediment Source/Construction Operation.

Construction Operation	Masonry	Truck Washout, Flatwork Tool Wash	Saw Cutting	Pavement Grinding	Demolition	Caisson Slurry Pour
Concrete Sediment Characteristics	- Medium to small volume - Reactive and cementitious - High solids content	- Medium volume per truck - Reactive and cementitious - Medium solids content	- Medium volume per saw - Highly uniform particle sizes - High solids content	- Large volume - Highly uniform particle sizes - High solids content	- Large volume - Wide range of particle sizes - High solids content	- Large volume - Reactive and cementitious - Low solids content
Applicable BMPs	• Run on prevention • Capture & contain • Excavate	• Run on prevention • Capture & contain • Gravity settle • Decant • Filter • Excavate sludge	• Run on prevention • Vacuum • Excavate • Gravity settle • Filter • Sweep • Tire clean/wash	• Run on prevention • Vacuum • Excavate • Gravity settle • Filter • Sweep • Tire clean/wash	• Run on prevention • Vacuum • Excavate • Filter • Sweep • Tire clean/wash	• Run on prevention • Gravity settle • Chemical settle • Filter • Excavate sludge
Operations & Maintenance	- Maintenance of run on controls - Disposal of solids	- Maintenance of run on controls - Inspection of clarified water - Excavation of settled sludge - Excavation of filtrate solids - Disposal of solids	- Maintenance of run on controls - Inspection of pavement sweeping - Excavation of settled sludge - Excavation of filtrate solids - Excavation of solids removed from tires - Disposal of solids	- Maintenance of run on controls - Inspection of pavement sweeping - Excavation of settled sludge - Excavation of filtrate solids - Excavation of solids removed from tires - Disposal of solids	- Maintenance of run on controls - Inspection of pavement sweeping - Excavation of filtrate solids - Excavation of solids removed from tires - Disposal of solids	- Maintenance of run on controls - Inspection of clarified water - Maintenance of pH adjustment and flocculent addition processes - Excavation of settled sludge - Excavation of filtrate solids - Disposal of solids

5.8 Conclusions

Review of the results presented in this report lead to the following conclusions:

- Concrete sediment characteristics of particle grain size, gradation distribution, material density, pH; and particle reactivity must be defined or conservatively assumed prior to design.

- Control of concrete sediments requires attention to operational factors as well as sediment characteristics when designing the sediment and erosion control plan.

- Removal of sediments by sedimentation process requires hydrometer analysis of the sediments then sizing of the sedimentation basin for the desired removal percentage and the hydraulic flow.

- Filter material may be designed around the principals of maintaining sufficient hydraulic flow and prevention of particle movement through the filter material using the grain size characteristics of the concrete sediment and the filter material.

- Chemical sedimentation or flocculation may be effective in removing suspended concrete sediments, if pH is adjusted to a range of between 6 and 9.

- Treatment of the high pH in concrete sediment contact water requires either recarbonation with carbon dioxide or acid addition. Calculation of acid volume for the measured pH and the normality of the proposed acid is proposed if acid addition is proposed.

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Appendix A
Site Visit Summaries

Bridge Deck Demolition

Construction Project: LaSalle Avenue Bridge over Interstate 94 Bridge Deck Reconstruction
State Project No. 2781-414
Location: Minneapolis, MN
Date: July 10, 2010
Met With: Tom Villar, Mn/DOT and Justin Gabrielson, Ames Construction
Concrete Activities Observed: Removal of the bridge deck, in preparation for deck replacement. On-site concrete crushing and reinforcing bar removal prior to load out.
SWPPP Controls Observed: Silt fence, inlet protection, rock bag, inlet filter bag (Dandy bag)
Observations : Sand and silt sized fines produced during concrete breaking and crushing, comprising approximately 20-40% of total volume. Inlet protection methods of rock bag and Dandy bag appear effective at trapping concrete sediment mobilized by dust-control water, if not overfilled.

Figure 1: Removal of concrete deck by hand operated air hammers and equipment mounted hoe-ram, with water application for dust control.

Figure 2: Excavator-mounted jaws performing concrete crushing to allow for reinforcing bar removal prior to load out. Note sand protective layer below concrete rubble.

Figure 3: Debris pile, ready for load out. Note mixture of fines with course particles and slab chunks.

Figure 4: Debris dropped from deck breaking operations.

Figure 5: Woven geotextile catch basin liner (Dandy Bag) placed along I-94 gutter line, approximately 250 feet down slope from concrete debris pile. Note dust control water, sand and concrete sediments, plus urban sediments on both sides of the catch basin.

Figure 6: Filtration log placed along gutter line of Lasalle Avenue, approximately 30 feet down slope from deck being removed.   Note concrete sediments both wet and dry.

Figure 7: Filtration log and woven geotextile catch basin liner (Dandy Bag) placed in combination along gutter line of Lasalle Avenue. Note clarification of flow by filtration log with small amount of sediments trapped before the catch basin.

Concrete Pavement Repair

Construction Project: Highway 61 Resurfacing
State Project No. 6222-161
Location: Maplewood, MN
Date: July 28, 2010
Met With: Eric Rustad, Mn/DOT
Concrete Activities Observed: Saw cutting, drilling, excavation of debris, collection of saw cut sediment, placement of rapid set concrete.
SWPPP Controls Observed: Inlet basin protection, sweeping (described, not directly observed).
Observations: Saw cut sediment is very fine, highly uniform, full of cooling water. Quantity of sediment appeared to be several gallons per lane-cross cut. No releases were observed at the time, although the risk of sediment release would be high if rain occurred during operations or after incomplete collection. Fugitive dust from drilling operations was not contained.

Figure 1: Concrete pavement repairs consisting of saw cutting, removal of damaged concrete, preparation of base, dowel connection to adjacent pavement slabs and replacement of pavement with quick set concrete.

Figure 2: Saw cutting prior to removal of damaged concrete using a fleet of saws.

Figure 3: Saw cut debris management by screed prior to collection.

Figure 4: Saw cut debris sampling. Note open shoulder of roadway towards ramp gore.

Figure 5: Epoxy and dowel installation in drill holes.

Figure 6: Drilling holes for inter-slab dowels using backhoe mounted air percussion drill, with fugitive dust and concrete sediment.

Figure 7: Air percussion drill in operation.

Figure 8: Repair sections prepared for rapid set concrete placement. Note disturbed median, set apart from roadway by existing curb.

Pavement Profile Grinding

Construction Project: Interstate 35 Duluth Mega Project
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Pavement profile grinding, parapet breaking and demolition (activities done prior to date of visit)
SWPPP Controls Observed: Sweeping, catch basin inlet protection.
Observations: Sediments generally picked up but significant amount was remaining as residual. Sediments are very fine grained, uniform, and appear to be easily mobilized by surface water. Fugitive dust not caught.

Figure 1: Elevated highway pavement profiled by grinding (grooving) adjacent to bridge parapet (yet to be poured), showing residual fines after sweeping.

Figure 2: Concrete pavement after profile grinding, with residual fines on surface.

Figure 3: Concrete pavement after profile grinding, adjacent to bridge parapet being reconstructed.

Figure 4: Concrete pavement grinding sediments remaining after incomplete sweeping effort (note: water in gutter is due to concrete washout activities).

Figure 5: Sweeper for concrete pavement grinding fines management (parked).

Figure 6: Concrete pavement grinding sediments remaining after incomplete sweeping effort (view up ramp towards location in Figure 4).

Figure 7: Catch basin protection (Dandy bag and rock filter log) overwhelmed by sediment at bottom of ramp in Figures 4 and 6.

Figure 8: Concrete pavement grinding sediment bypassing catch basin following gutter line onto local street (bottom of ramp shown in Figures 4 and 6).

Figure 9: Concrete debris and fugitive pavement grinding sediment below elevated highway (below location of Figure 4), dropped to ground surface with no stormwater controls (perhaps awaiting follow up excavation).

Figure 10: Fugitive concrete pavement grinding sediment dropped from elevated highway with no stormwater control (adjacent to ramp of Figure 6).

Figure 11: Concrete pavement grinding sediment dropped from elevated highway and formed into basin shape in location adjacent to scupper drain and catch basin.

Bridge Deck Pour

Construction Project: Interstate 35 Duluth Mega Project
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Concrete delivery, pumping, placement on deck, power screeding.
SWPPP Controls Observed: Inlet protection, silt fence, mulch, pavement sweeping (assumed but not observed).
Observations: Fugitive cement sediment and contact water emanate from vicinity of concrete pumping. However, concentrations that reach water are considerably smaller than with other options compared to the size of pond.

Figure 1: Concrete pumping and delivery to deck pour of elevated highway.

Figure 2: Concrete delivery for deck pour.

Figure 3: Concrete ready mix truck delivering to concrete pump hopper, with water and sediment on grade in vicinity of hopper.

Figure 4: Water and sediment on grade adjacent to ready mix truck and concrete pump.

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Figure 5: Cement sediment draining to pavement approximately 50 feet from concrete pump.

Bridge Parapet Pour

Construction Project: Interstate 35 Duluth Mega Project
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Placement of concrete bridge parapet with curing compound application.
SWPPP Controls Observed: None – adjacent controls assumed as perimeter out of sight.
Observations: No fugitive sediment produced during observation, though other activities, such as dowel hole drilling, adjacent pavement profiling and concrete wash out, may have caused some sediment.

Figure 1: Parapet wall pour with traveling form machine and delivery of concrete by ready mix truck.

Figure 2: Parapet reinforcement epoxied into drill holes adjacent to recently ground pavement.

Figure 3: Curing compound application to newly poured parapet.

On Site Wash Out

Construction Project: Interstate 35 Duluth Mega Project
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Ready mix truck wash out.
SWPPP Controls Observed: Sedimentation pond with filter berms.
Observations: Release of recently hydrated cement sediments, fine aggregate and cement contact water after incomplete filtration due to apparent hydraulic failure of filter.

Figure 1: Washout of ready mix truck on elevated highway into bermed sediment filter sump.

Figure 2: Liquid pool within bermed sediment filter sump, at or near capacity.

Figure 3: Sediment and incompletely filtered water released from bermed sediment filter sump in roadway gutter approximately 25 feet down slope.

Figure 4: Sediment and incompletely filtered water released from bermed sediment filter sump in roadway gutter approximately 50 feet down slope.

High Mast Light Foundation Installation

Construction Project: Interstate 35 Duluth Mega Project
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Foundation construction, including concrete placement and form removal (all activities occurred prior to site observation).
SWPPP Controls Observed: Mulch, inlet protection, silt fence (note: all missing or in significant disrepair).
Observations: Concrete spillage not collected. Significant disregard of requirements.

Figure 1: High mast light pole foundation adjacent to new embankment nest to tied back sheet pile wall. Note disturbed ground with disrupted sediment control measures.

Figure 2: Ground surface immediately down slope of high mast light pole foundation showing disturbed ground and lack of inlet protection.

Figure 3: Concrete debris left on ground surface adjacent to high mast light pole foundation.

Figure 4: Concrete debris left on curb adjacent to high mast light pole foundation.

Figure 5: Concrete debris left on ground surface adjacent to high mast light pole foundation.

Bridge Pier Cap Pour

Construction Project: Interstate 35 Duluth Mega Project
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Form work and prior placement of concrete for bridge pier, with associated earthwork.
SWPPP Controls Observed: Sedimentation pond with filtration prior to discharge.
Observations: Hydraulically difficult, but no apparent escaping sediment observed.

Figure 1: Excavation bank, existing elevated highway and newly constructed bridge piers above sedimentation pond and filtration system.

Figure 2: Sediment pond dike, mulched, with outlet pipe.

Figure 3: Sediment pond outlet pipe and four zone filter comprised of wood chips and vertical steel sheet baffles, set for underflow, in a roll off box.

Figure 4: Filter box, compartments 1 and 2, showing wood chip filter media in compartment, inlet pipe and emergency overflow bypass weir, trough and outlet.

Figure 5: Filter compartment 4 with wood chip filter media, end screen, effluent trough and outlet pipe. Note trace of organic sediments in trough but no build up around outlet.

Pavement Grinding Lagoon Disposal

Construction Project: Interstate 35 Duluth Mega Project
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Disposal of concrete pavement grinding sediments.
SWPPP Controls Observed: Sediment pond disposal, cat tracking.
Observations: Size, stiffness, uniformity of pavement grinding sediments. Lack of free water. Initially apparent turbidity followed by thixotropic firming. Contact waster control failure, after containment pond dike failure.

Figure 1: Concrete pavement grinding sediment disposal lagoon with current estimated depth of 10 to 15 feet.

Figure 2: Concrete pavement grinding sediment disposal lagoon influent pipe discharge, adjacent to truck dump station.

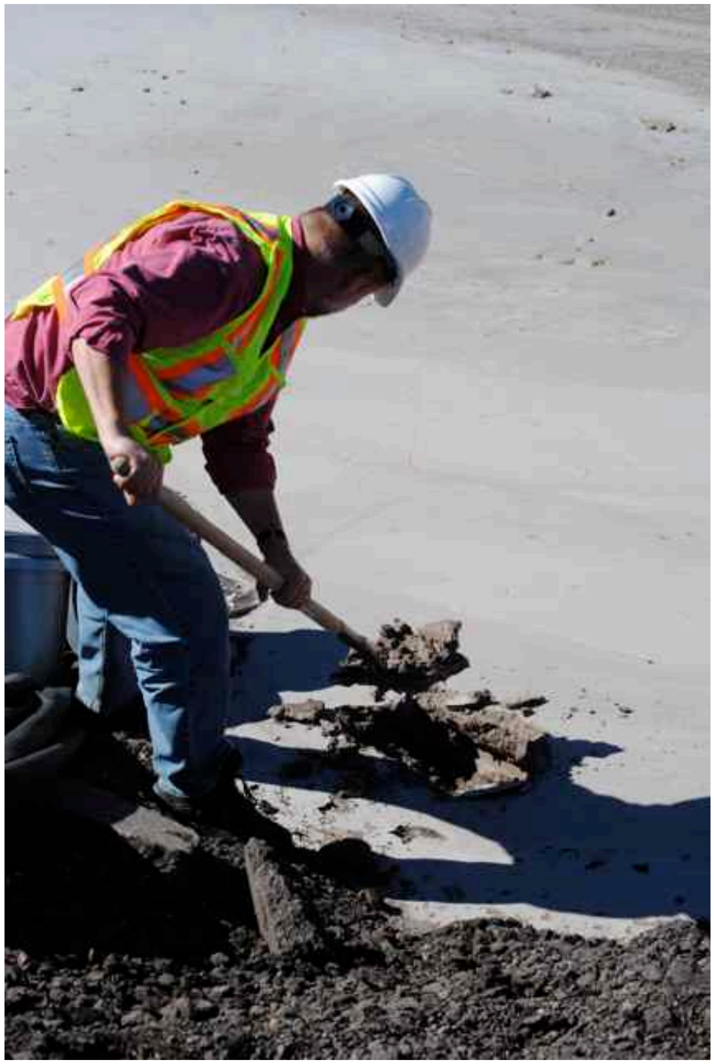


Figure 3: Sampling of concrete pavement grinding sediment disposal lagoon.

Figure 4: Second concrete pavement grinding sediment disposal lagoon.

Figure 5: Containment dike failure, second concrete pavement grinding sediment disposal lagoon.

Figure 6: Containment dike failure, second concrete pavement grinding sediment disposal lagoon.

Figure 7: Receiving pond below containment dike failure, second concrete pavement grinding sediment disposal lagoon.

Bridge Masonry Repair

Construction Project: Highway 61 Lester River Bridge
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Mortar mixing, material storage piles, joint repointing, block cleaning, and block placement.
SWPPP Controls Observed: Plastic sheeting collection, solid waste disposal.
Observations: When working, plastic sheeting collection could work well. However, the system had large gaps and breaches that could let sediments enter the underlying stream.

Figure 1: Masonry facing and parapet repairs being made from scaffolding, with chemical and debris catch system made of plastic sheeting on both the ground next to the abutment wing wall and on the scaffolding.

Figure 2: Chemical and debris catch system with discontinuities, view from below.

Figure 3: Chemical and debris catch system with discontinuities, view from below.

Figure 4: Accumulation and on-site storage of concrete and mortar debris plus solid waste.

Figure 5: Mortar mixer with adjacent debris pile and sediment on grade.

Figure 6: Chemical and debris catch system disposal bags in storage beneath bridge.

Culvert Wing Wall Reconstruction

Construction Project: Miller Trunk Hwy (US Hwy 53/Hwy 194) between Trinity and Haines Roads
Location: Duluth, MN
Date: September 14, 2010
Met With: Dwayne Stenlund, Mn/DOT
Concrete Activities Observed: Form and place concrete wing walls for existing box culvert.
SWPPP Controls Observed: Temporary stream diversion between lined cofferdam berms.
Observations: No cement sediment observed. Any potential sediment likely caught within cofferdam, to be removed prior to cofferdam removal.

Figure 1: Concrete wing wall form removal after concrete curing and initial backfill casting.

Figure 2: Lined stone berm cofferdam with corrugated HDPE bypass pipe inlet, upstream of culvert.

Figure 3: Bypass pipe exiting from culvert adjacent to new concrete wing walls.

Figure 4: Bypass pipe discharge to streambed over downstream cofferdam.

Figure 5: Culvert interior, view downstream.

Figure 6: Upstream wing wall formwork and bracing, placed around bypass pipe and cofferdam.

Figure 7: Wing wall formwork with end cap removed showing recently placed concrete.

Concrete Ready Mix Water Capture, Washout and Treatment

Construction Project: Central Concrete Ready Mix Plant
Location: Mankato, MN
Date: December 7, 2009
Met With: Dennis Jorgenson
Concrete Activities Observed: Washout capture and primary treatment.
SWPPP Controls Observed: Grit chamber, sedimentation basin, desander and washout capture.
Observations: Concrete contact water, aggregate and cement sediment contained by process, if used.

Figure 1: Ready mix truck with pony axle-mounted wash water capture tank that drains back to mixer upon raising.

Figure 2: Truck washout discharge station, with desander screen and conveyor.

Cofferdam Contained Bridge Repair

Construction Project: Reconstruction of Stone Arch Trail Bridge over Round Lake Outlet to Lake Phalen (Bridge No. L8560)
Location: St. Paul, MN
Date: September 9, 2010
Met With: Mark Daubenberger and Matt Wassman, TKDA
Concrete Activities Observed: Excavation in preparation for foundation installation.
SWPPP Controls Observed: Cofferdam, dewatering, dewatering fluid filtering, mulch, silt curtain.
Observations: Capture appears complete of potential debris, mortar, masonry repair chemicals and contact water, assuming excavation of streambed prior to cofferdam removal.

Figure 1: Concrete arch bridge with underlying stream bed cofferdammed off to allow for foundation excavation prior to reinforcing arch member placement.

Figure 2: Silt curtain, concrete block and liner cofferdam, dewatering pump pit and dewatering discharge filter.

Figure 3: Foundation excavation.

Figure 4: Wing wall and arch fascia masonry prior to repair grouting and repointing with localized removal for abutment repairs.

Saw Cutting Green Concrete

Construction Project: TH 610
Location: Maple Grove, Mn
Date: June 16th, 2011

Met With: Bob Rabine project supervisor and Juan Podesta field inspector, Mn/DOT.
Concrete Activities Observed: Cutting of concrete after approximately 8 hours of curing.
SWPPP Controls Observed: Sediments passively absorbed in the aggregate shoulder. No run off was observed leaving the shoulder, which was subject to later finishes.
Observations: Presumed fine silt sized particles produced during concrete sawing collected on site and integrated into shoulder base material.

Figure 1: Wet sawing of green concrete.

Figure 2: Saw cut edge showing slurring generation.

Figure 3: Sampling of saw cut slurry directly after completed cut with flow indicative of maximum generated from cut. Samples taken here later settled and cured into 1" thick coalesced specimen with moderate structural strength.

Underwater Pour of Concrete by Tremie into Cofferdam or Drilled Shaft Casing

Construction Project: Lowry Avenue Bridge over Mississippi River
Location: Minneapolis, Mn
Date: June 16, 2011
Met With: Paul Backer, Resident Engineer, Hennepin County
Concrete Activities Observed: In river pier construction including cofferdam, excavation and tremie pour. Drilled shaft construction for bridge approach that included polymer slurry excavation support. Work partially completed prior to visit.
SWPPP Controls Observed: Pump and hose system for control of slurry from excavation support. Treatment of slurry in onshore lined tank using baffles for clarification and biodegradation for removal of polymer and deposition of sediments. Release to sedimentation pond and surface filtration system prior to outfall discharge.

Figure 1: Drilled shaft for onshore bridge pier at a depth of 75' below ground surface. Polymer slurry used to stabilize the sides of the shaft excavation. Water and slurry mixture is being pumped out of the piling in preparation for tremie placement of concrete.

Figure 2: Polymer slurry mixture pumped from the shaft excavation (shown in Figure 1) entering treatment system located in a lined roll off box. Treatment consists of clarification of larger solids and biodegradation of the polymer.

Figure 3: Upon completion of biodegradation process described in Figure 2, water is placed in sediment pond to flow though filter logs and rock bags then discharged.

Figure 4: Sheet pilings in the river were used to create cofferdam that separates the river flows from the concrete pour. Note pile supported form work that also provides debris containment related to the bridge pier cap, beams and deck construction.

Figure 5: View from the top of the sheet piles on the cofferdam perimeter showing the recently poured concrete pier.

Super Sack Mortar Station

Construction Project: Residence Hall, Minnesota State University Mankato
Location: Mankato, Mn
Date: September 26, 2011
Concrete Activities Observed: Mortar super sack batch plant in operation. Silo system accommodates 3000-pound bulk cement bags and provides cement metering for mortar mixing.
SWPPP Controls Observed: Silt fence, Dandy bag inlet protection, rock construction entrance and diversion berms.
Observations: Dust and sediments leaving site and settling beyond project limits on nearby areas and vehicles.

Figure 1: Super sack silo system and batch mortar mixers.

Figure 2: Dust cloud emerging during use of metering of cement for mortar mixing.

Figure 3: Super sack mortar station location in relationship to street. Note dust accumulating on vehicles.

Appendix B
Hydrometer Analyses

Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

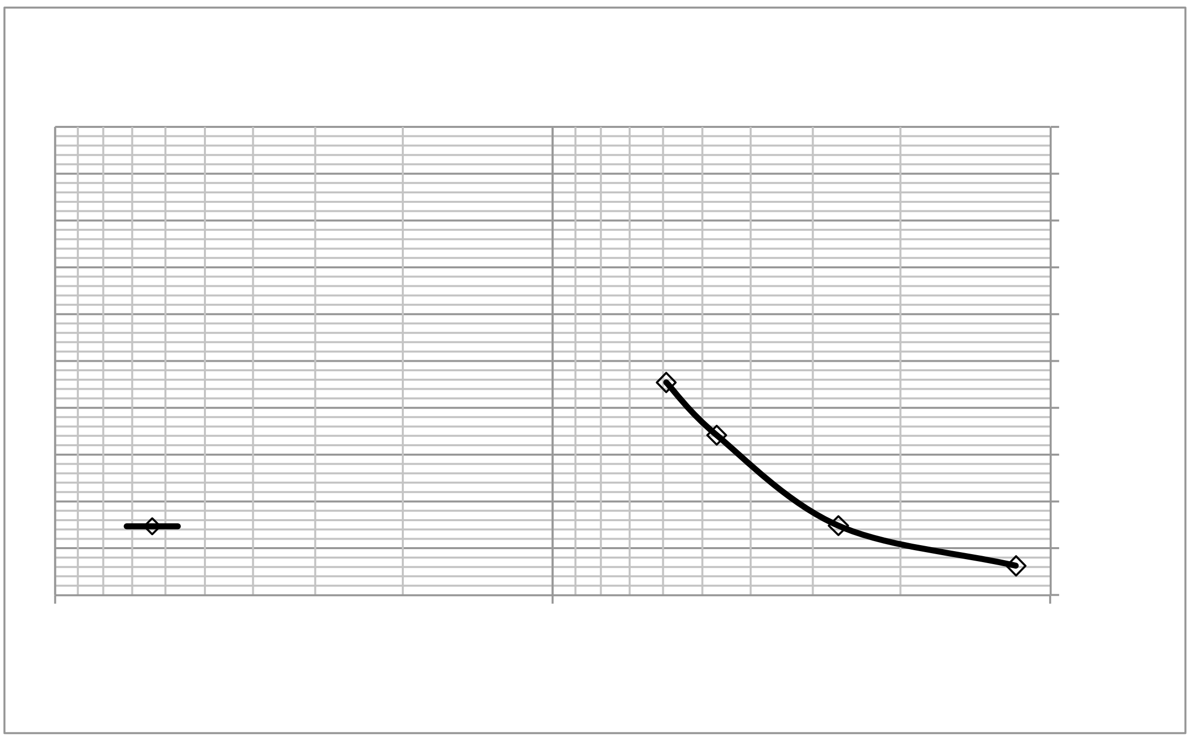
Material	Portland Cement	Sample Mass	100.0004 g
Sample Date	July 10, 2010		
Sample Location	Bag		

From ASTM D422

Estimated Gs =	3.15	
Gs Corr, a =	0.9	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01145	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L) + 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	0			
5	0			
15	0			
30	50.5	8.01	0.005917543	45.4%
60	38	10.06	0.004689136	34.2%
250	16.5	13.59	0.002669492	14.8%
1440	7	15.15	0.001174322	6.3%



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

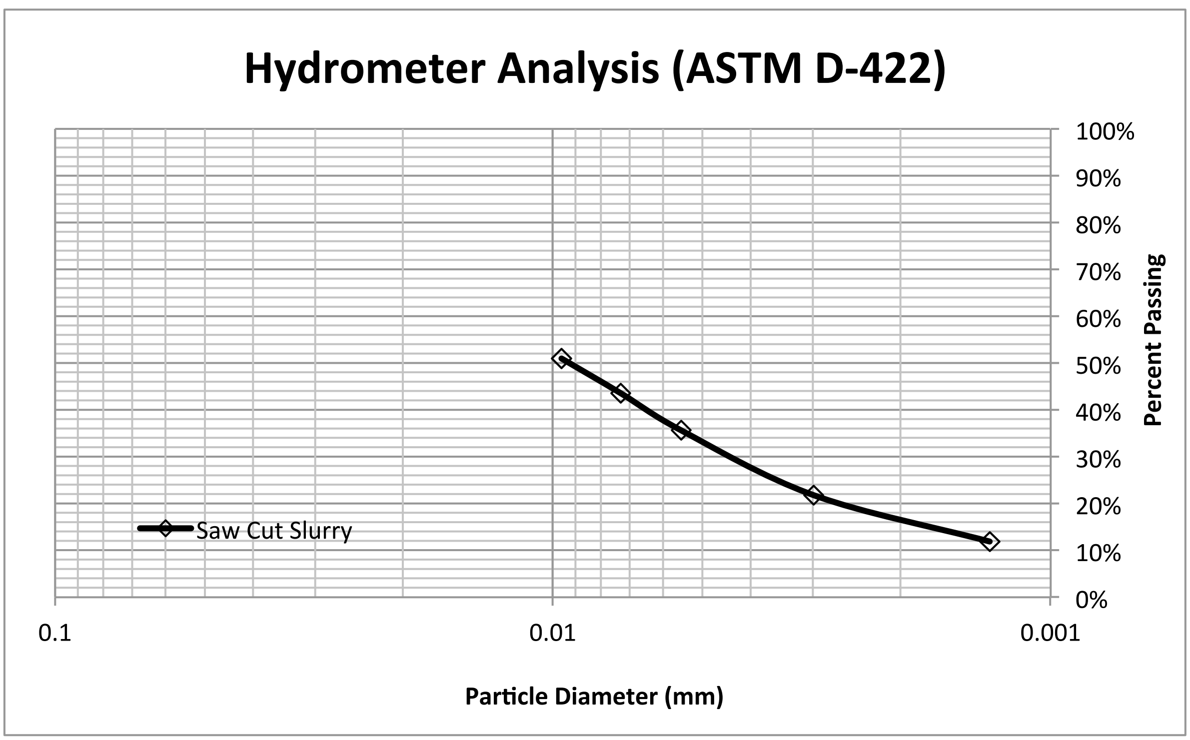
Material	Saw Cut Slurry	Sample Mass	100.0007	g
Sample Date	July 28, 2010			
Sample Location	TH 61 Maplewood			

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L)
+ 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	0			
5	0			
15	51.5	7.85	0.009606355	51.0%
30	44	9.08	0.007305595	43.6%
60	36	10.39	0.005526502	35.6%
250	22	12.69	0.002991623	21.8%
1440	12	14.33	0.001324628	11.9%



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

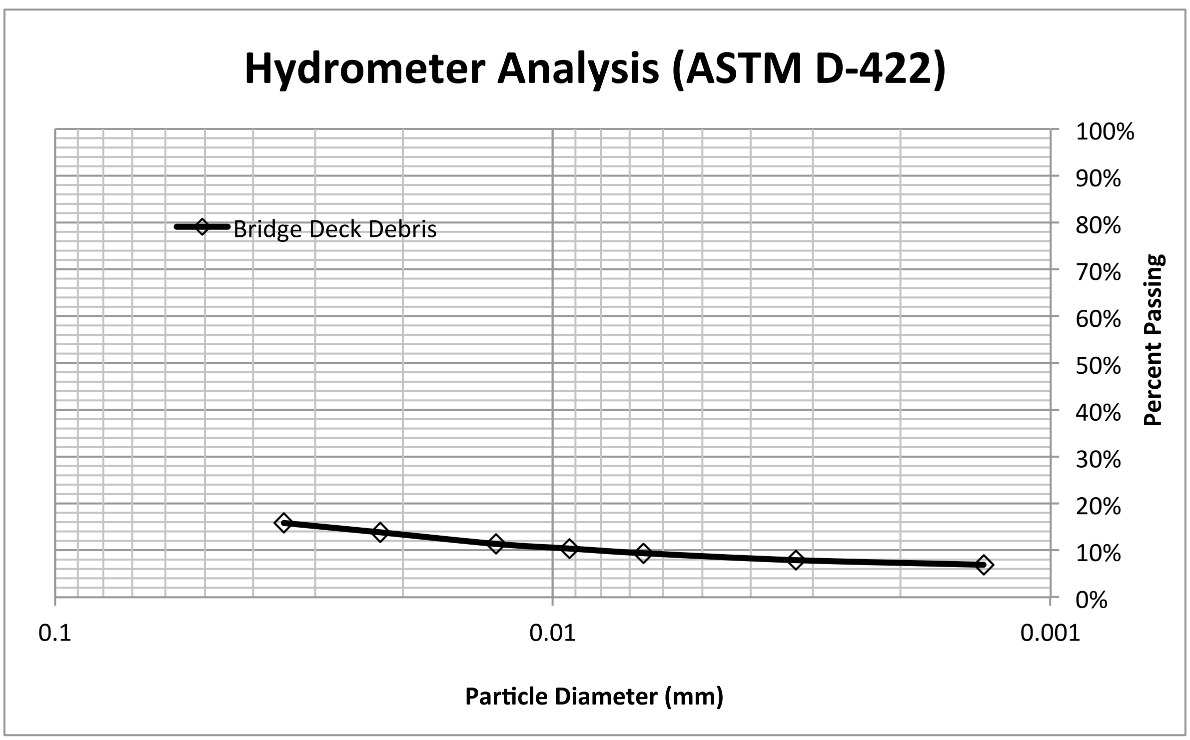
Material	Bridge Deck Debris	Sample Mass	100.0012 g
Sample Date	July 10, 2010		
Sample Location	LaSalle Ave over I-94		

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L) + 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	16	13.67	0.034720234	15.8%
5	14	14.00	0.022220868	13.9%
15	11.5	14.41	0.013015739	11.4%
30	10.5	14.57	0.009255745	10.4%
60	9.5	14.74	0.006581524	9.4%
250	8	14.98	0.003251075	7.9%
1440	7	15.15	0.001362008	6.9%



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

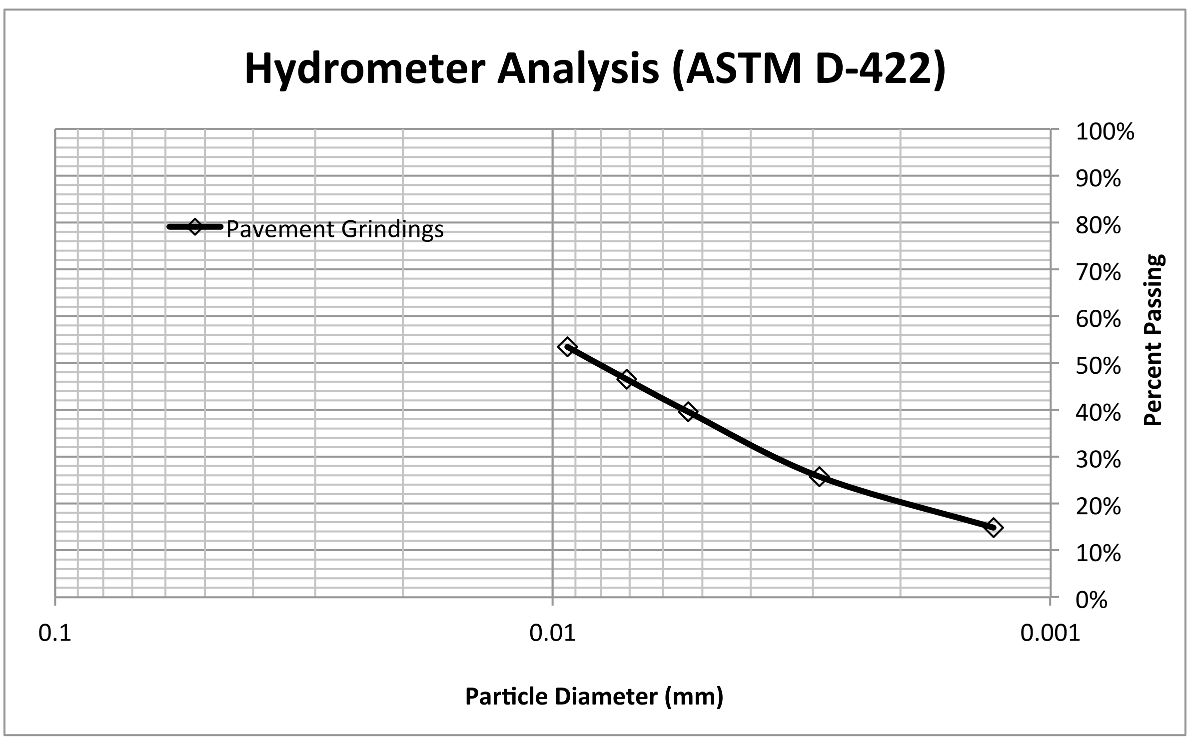
Material	Pavement Grindings	Sample Mass	100	g
Sample Date	September 14, 2010			
Sample Location	Duluth			

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L)
+ 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	0			
5	0			
15	54	7.44	0.00935209	53.5%
30	47	8.59	0.007104889	46.5%
60	40	9.73	0.00534921	39.6%
250	26	12.03	0.002913254	25.7%
1440	15	13.83	0.001301685	14.9%



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

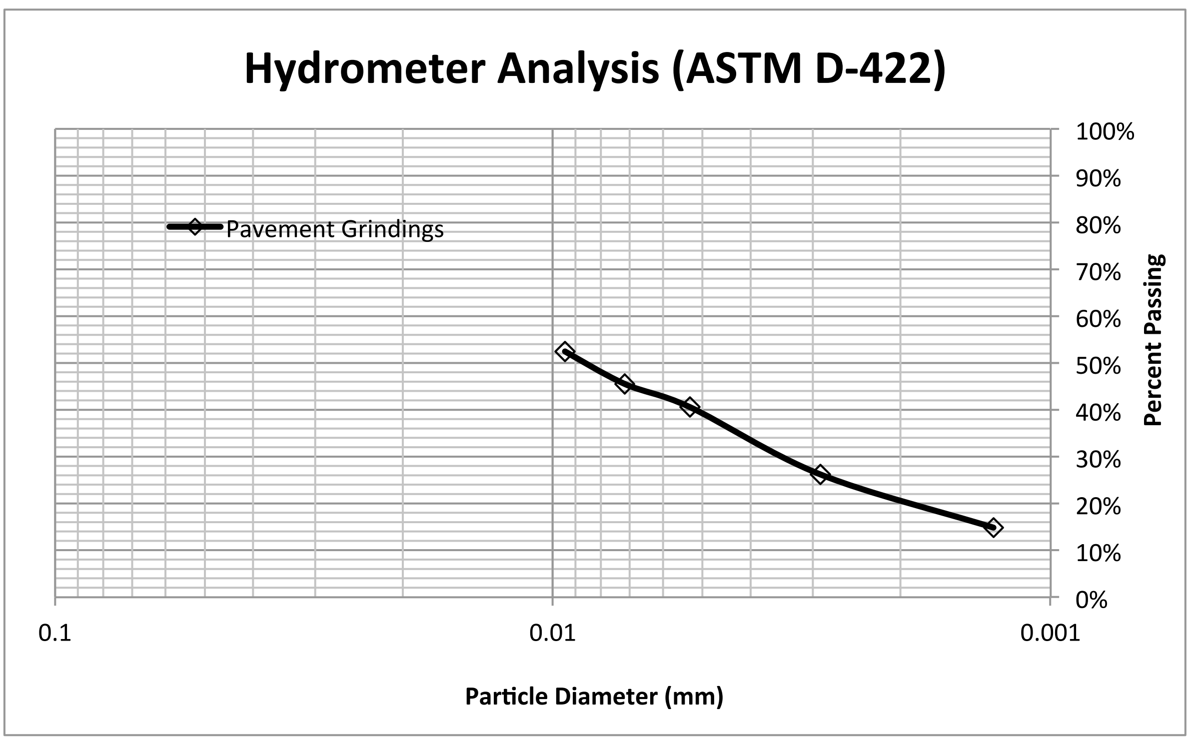
Material	Pavement Grindings	Sample Mass	100	g
Sample Date	September 14, 2010			
Sample Location	Duluth			

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L) + 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	0			
5	0			
15	53	7.60	0.009454616	52.5%
30	46	8.75	0.007172415	45.5%
60	41	9.57	0.005303961	40.6%
250	26.5	11.95	0.002903309	26.2%
1440	15	13.83	0.001301685	14.9%



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

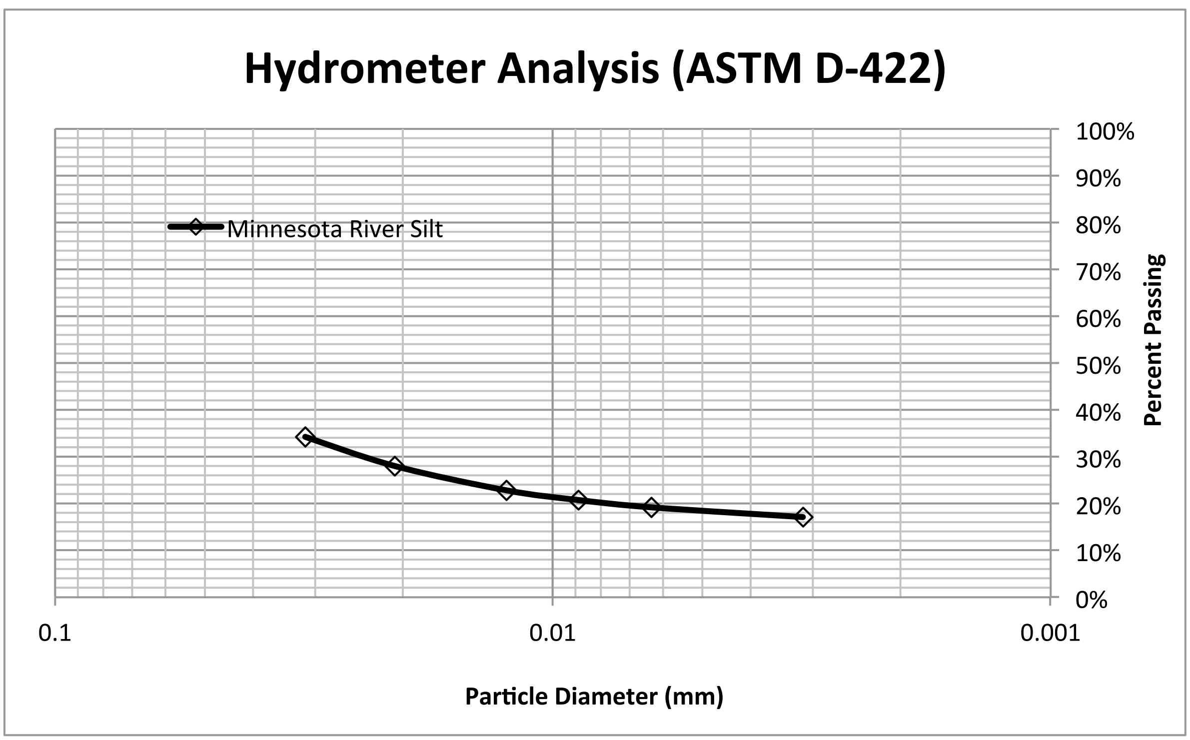
Material	Minnesota River Silt	Sample Mass	96.3861	g
Sample Date	July 10, 2010			
Sample Location	Seven Mile Creek Park			

From ASTM D422

Estimated Gs =	2.65	
Gs Corr, a =	1.00	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01348	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L)
+ 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	33	10.88	0.031444775	34.2%
5	27	11.87	0.020767045	28.0%
15	22	12.69	0.012397186	22.8%
30	20	13.01	0.008878728	20.7%
60	18.5	13.26	0.006337264	19.2%
250	16.5	13.59	0.003142773	17.1%
1440	0			



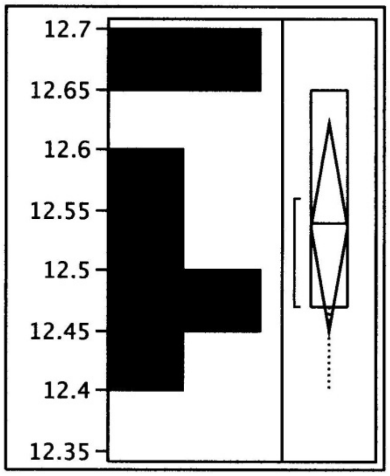
Appendix C
pH Statistical Analyses

pH Concrete Sed

	Sediment	Equilibrium pH	[OH-] (Moles per liter)
1	Bridge Deck	12.48	0.03019952
2	Bridge Deck	12.4	0.02511886
3	Bridge Deck	12.47	0.02951209
4	Bridge Deck	12.54	0.03467369
5	Bridge Deck	12.56	0.03630781
6	Bridge Deck	12.65	0.04466836
7	Bridge Deck	12.65	0.04466836
8	Saw Cut Slurry	11.11	0.00128825
9	Saw Cut Slurry	10.91	0.00081283
10	Saw Cut Slurry	11.15	0.00141254
11	Saw Cut Slurry	11.16	0.00144544
12	Saw Cut Slurry	10.38	0.00023988
13	Saw Cut Slurry	10.63	0.00042658
14	Saw Cut Slurry	10.24	0.00017378
15	Pavement Grindings	8.62	0.00000417
16	Pavement Grindings	9.83	0.00006761
17	Pavement Grindings	9.93	0.00008511
18	Pavement Grindings	9.52	0.00003311
19	Pavement Grindings	8.91	0.00000813
20	Pavement Grindings	9.66	0.00004571
21	Pavement Grindings	9.24	0.00001738
22	Portland Cement	12.88	0.07585776
23	Portland Cement	12.86	0.0724436
24	Portland Cement	12.85	0.07079458
25	Portland Cement	12.83	0.0676083
26	Portland Cement	12.85	0.07079458
27	Portland Cement	12.93	0.0851138
28	Portland Cement	12.83	0.0676083

Distributions Sediment=Bridge Deck

Equilibrium pH



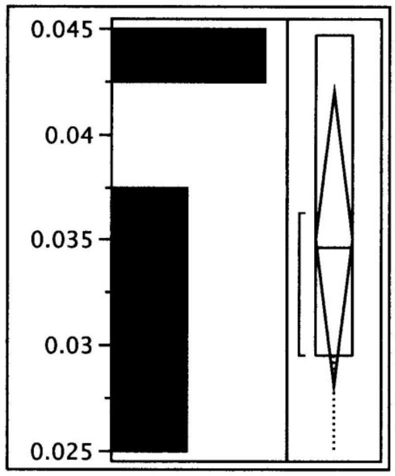
Quantiles

100.0%	maximum	12.65
99.5%		12.65
97.5%		12.65
90.0%		12.65
75.0%	quartile	12.65
50.0%	median	12.54
25.0%	quartile	12.47
10.0%		12.4
2.5%		12.4
0.5%		12.4
0.0%	minimum	12.4

Moments

Mean	12.535714
Std Dev	0.093605
Std Err Mean	0.0353794
Upper 95% Mean	12.622285
Lower 95% Mean	12.449144
N	7

[OH-] (Moles per liter)



Quantiles

100.0%	maximum	0.04467
99.5%		0.04467
97.5%		0.04467
90.0%		0.04467
75.0%	quartile	0.04467
50.0%	median	0.03467
25.0%	quartile	0.02951
10.0%		0.02512
2.5%		0.02512
0.5%		0.02512
0.0%	minimum	0.02512

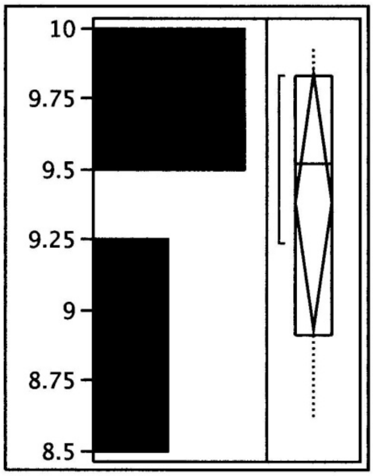
Moments

Mean	0.0350212
Std Dev	0.0075229
Std Err Mean	0.0028434
Upper 95% Mean	0.0419788
Lower 95% Mean	0.0280637
N	7

Distributions Sediment=Pavement Grindings

Distributions Sediment=Pavement Grindings

Equilibrium pH



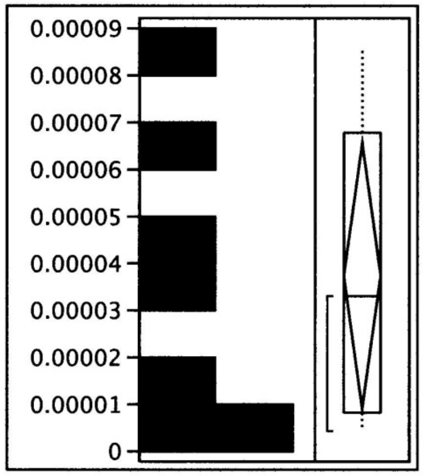
Quantiles

100.0%	maximum	9.93
99.5%		9.93
97.5%		9.93
90.0%		9.93
75.0%	quartile	9.83
50.0%	median	9.52
25.0%	quartile	8.91
10.0%		8.62
2.5%		8.62
0.5%		8.62
0.0%	minimum	8.62

Moments

Mean	9.3871429
Std Dev	0.4866112
Std Err Mean	0.1839218
Upper 95% Mean	9.8371832
Lower 95% Mean	8.9371025
N	7

[OH-] (Moles per liter)



Quantiles

100.0%	maximum	8.51e-5
99.5%		8.51e-5
97.5%		8.51e-5
90.0%		8.51e-5
75.0%	quartile	6.76e-5
50.0%	median	3.31e-5
25.0%	quartile	8.13e-6
10.0%		4.17e-6
2.5%		4.17e-6
0.5%		4.17e-6
0.0%	minimum	4.17e-6

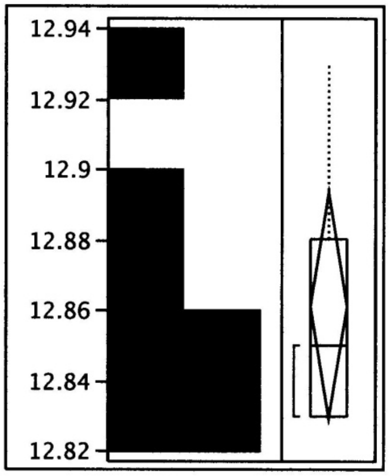
Moments

Mean	3.7317e-5
Std Dev	3.0654e-5
Std Err Mean	1.1586e-5
Upper 95% Mean	6.5668e-5
Lower 95% Mean	8.9668e-6
N	7

Distributions Sediment=Portland Cement

Distributions Sediment=Portland Cement

Equilibrium pH



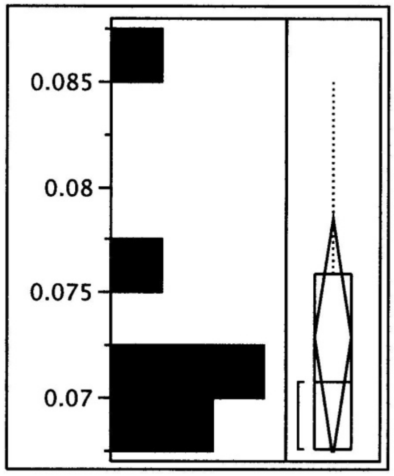
Quantiles

100.0%	maximum	12.93
99.5%		12.93
97.5%		12.93
90.0%		12.93
75.0%	quartile	12.88
50.0%	median	12.85
25.0%	quartile	12.83
10.0%		12.83
2.5%		12.83
0.5%		12.83
0.0%	minimum	12.83

Moments

Mean	12.861429
Std Dev	0.0348466
Std Err Mean	0.0131708
Upper 95% Mean	12.893656
Lower 95% Mean	12.829201
N	7

[OH-] (Moles per liter)



Quantiles

100.0%	maximum	0.08511
99.5%		0.08511
97.5%		0.08511
90.0%		0.08511
75.0%	quartile	0.07586
50.0%	median	0.07079
25.0%	quartile	0.06761
10.0%		0.06761
2.5%		0.06761
0.5%		0.06761
0.0%	minimum	0.06761

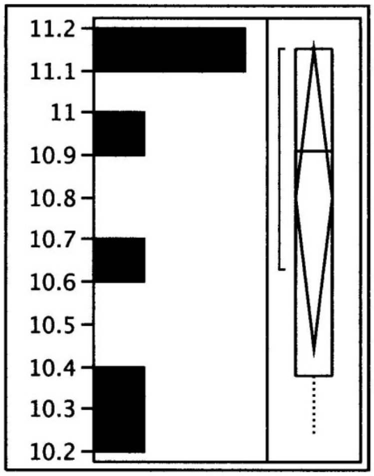
Moments

Mean	0.0728887
Std Dev	0.0060965
Std Err Mean	0.0023043
Upper 95% Mean	0.078527
Lower 95% Mean	0.0672504
N	7

Distributions Sediment=Saw Cut Slurry

Distributions Sediment=Saw Cut Slurry

Equilibrium pH



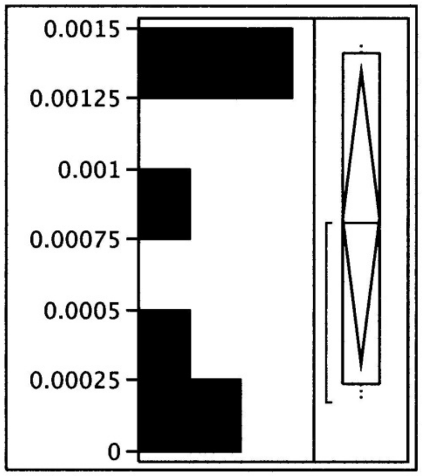
Quantiles

100.0%	maximum	11.16
99.5%		11.16
97.5%		11.16
90.0%		11.16
75.0%	quartile	11.15
50.0%	median	10.91
25.0%	quartile	10.38
10.0%		10.24
2.5%		10.24
0.5%		10.24
0.0%	minimum	10.24

Moments

Mean	10.797143
Std Dev	0.3827843
Std Err Mean	0.1446789
Upper 95% Mean	11.151159
Lower 95% Mean	10.443126
N	7

[OH-] (Moles per liter)



Quantiles

100.0%	maximum	0.00145
99.5%		0.00145
97.5%		0.00145
90.0%		0.00145
75.0%	quartile	0.00141
50.0%	median	0.00081
25.0%	quartile	0.00024
10.0%		0.00017
2.5%		0.00017
0.5%		0.00017
0.0%	minimum	0.00017

Moments

Mean	0.0008285
Std Dev	0.0005583
Std Err Mean	0.000211
Upper 95% Mean	0.0013448
Lower 95% Mean	0.0003122
N	7

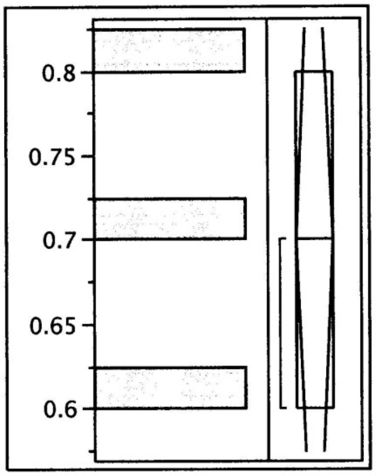
Appendix D
Stream Flow Bed Erosion Statistical Analyses

Erodibility Test Concrete Sediments 021711

	Sediment	Water Velocity (feet per second)	Sediments Derived (g)	Sediments Originally Placed in Channel (g)	Sediment Proportion Derived	Turbidity (NTU)
1	Bridge Deck	0.5	0.7	650	0.0011	259
2	Bridge Deck	0.5	0.8	650	0.0012	.
3	Bridge Deck	0.5	0.6	650	0.0009	.
4	Bridge Deck	1	117.9	650	0.1814	538
5	Bridge Deck	1	72.2	650	0.1111	360
6	Bridge Deck	1	18.7	650	0.0288	312
7	Saw Cut Slurry	0.5	3.6	300	0.012	949
8	Saw Cut Slurry	0.5	7.3	300	0.0243	551
9	Saw Cut Slurry	0.5	8.2	300	0.0273	769
10	Saw Cut Slurry	1	61.9	300	0.2063	202
11	Saw Cut Slurry	1	96	300	0.32	201
12	Saw Cut Slurry	1	58.7	300	0.1957	560
13	Pavement Grindings	0.5	61.4	300	0.2047	0.01
14	Pavement Grindings	0.5	59.9	300	0.1997	3.36
15	Pavement Grindings	0.5	51.6	300	0.172	8.33
16	Pavement Grindings	1	118.9	300	0.3963	0
17	Pavement Grindings	1	118.9	300	0.3963	.
18	Pavement Grindings	1	115.7	300	0.3857	0.01
19	Portland Cement - 4 hr	0.5	0.08	800	0.0001	60
20	Portland Cement - 4 hr	0.5	0.07	800	0.0001	86.8
21	Portland Cement - 4 hr	0.5	0.13	800	0.0002	155
22	Portland Cement - 4 hr	1	0.19	800	0.0002	272
23	Portland Cement - 4 hr	1	0.08	800	0.0001	95.6
24	Portland Cement - 4 hr	1	0.16	800	0.0002	170
25	Portland Cement - 48 hr	0.5	0.06	800	0.0001	90
26	Portland Cement - 48 hr	0.5	0.05	800	0.0001	64
27	Portland Cement - 48 hr	0.5	0.07	800	0.0001	67.4
28	Portland Cement - 48 hr	1	0.06	800	0.0001	52.2
29	Portland Cement - 48 hr	1	0.07	800	0.0001	66.5
30	Portland Cement - 48 hr	1	0.07	800	0.0001	65.4

Distributions Sediment=Bridge Deck, Water Velocity (feet per second)=0.5

Sediments Derived (g)



Quantiles

100.0%	maximum	0.8
99.5%		0.8
97.5%		0.8
90.0%		0.8
75.0%	quartile	0.8
50.0%	median	0.7
25.0%	quartile	0.6
10.0%		0.6
2.5%		0.6
0.5%		0.6
0.0%	minimum	0.6

Moments

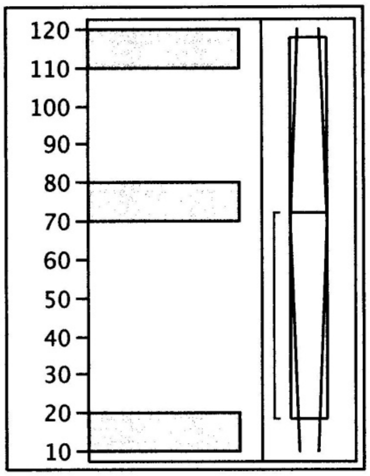
Mean	0.7
Std Dev	0.1
Std Err Mean	0.057735
Upper 95% Mean	0.9484138
Lower 95% Mean	0.4515862
N	3

Distributions Sediment=Bridge Deck, Water Velocity (feet per second)=1

Sediments Derived (g)

Distributions Sediment=Bridge Deck, Water Velocity (feet per second)=1

Sediments Derived (g)



Quantiles

100.0%	maximum	117.9
99.5%		117.9
97.5%		117.9
90.0%		117.9
75.0%	quartile	117.9
50.0%	median	72.2
25.0%	quartile	18.7
10.0%		18.7
2.5%		18.7
0.5%		18.7
0.0%	minimum	18.7

Moments

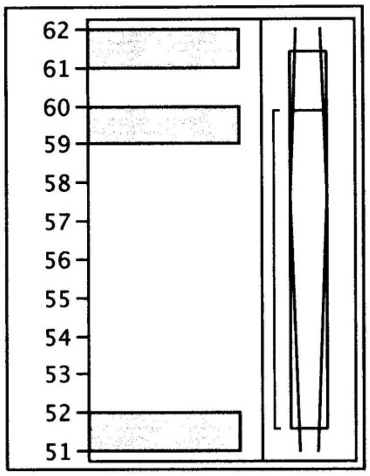
Mean	69.6
Std Dev	49.651083
Std Err Mean	28.666066
Upper 95% Mean	192.94013
Lower 95% Mean	-53.74013
N	3

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=0.5

Sediments Derived (g)

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=0.5

Sediments Derived (g)



Quantiles

100.0%	maximum	61.4
99.5%		61.4
97.5%		61.4
90.0%		61.4
75.0%	quartile	61.4
50.0%	median	59.9
25.0%	quartile	51.6
10.0%		51.6
2.5%		51.6
0.5%		51.6
0.0%	minimum	51.6

Moments

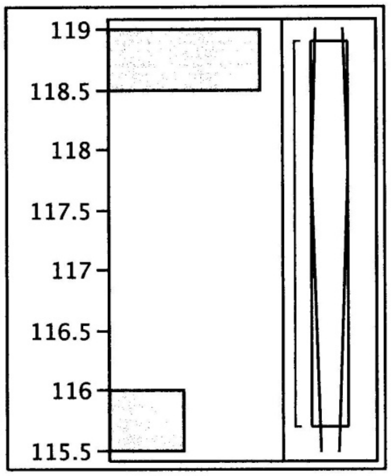
Mean	57.633333
Std Dev	5.278573
Std Err Mean	3.0475856
Upper 95% Mean	70.746036
Lower 95% Mean	44.520631
N	3

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=1

Sediments Derived (g)

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=1

Sediments Derived (g)



Quantiles

100.0%	maximum	118.9
99.5%		118.9
97.5%		118.9
90.0%		118.9
75.0%	quartile	118.9
50.0%	median	118.9
25.0%	quartile	115.7
10.0%		115.7
2.5%		115.7
0.5%		115.7
0.0%	minimum	115.7

Moments

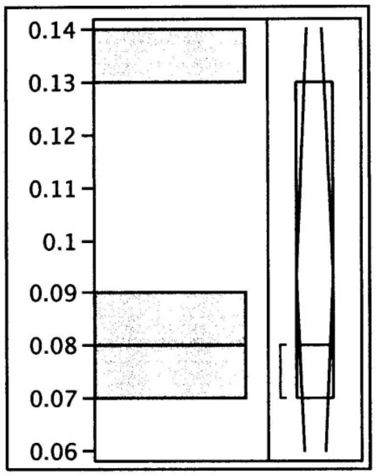
Mean	117.83333
Std Dev	1.8475209
Std Err Mean	1.0666667
Upper 95% Mean	122.42283
Lower 95% Mean	113.24384
N	3

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=0.5

Sediments Derived (g)

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=0.5

Sediments Derived (g)



Quantiles

100.0%	maximum	0.13
99.5%		0.13
97.5%		0.13
90.0%		0.13
75.0%	quartile	0.13
50.0%	median	0.08
25.0%	quartile	0.07
10.0%		0.07
2.5%		0.07
0.5%		0.07
0.0%	minimum	0.07

Moments

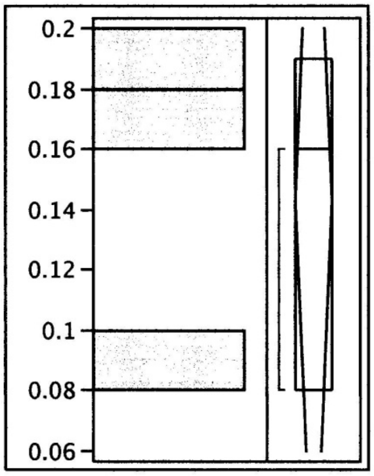
Mean	0.0933333
Std Dev	0.0321455
Std Err Mean	0.0185592
Upper 95% Mean	0.1731872
Lower 95% Mean	0.0134795
N	3

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=1

Sediments Derived (g)

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=1

Sediments Derived (g)



Quantiles

100.0%	maximum	0.19
99.5%		0.19
97.5%		0.19
90.0%		0.19
75.0%	quartile	0.19
50.0%	median	0.16
25.0%	quartile	0.08
10.0%		0.08
2.5%		0.08
0.5%		0.08
0.0%	minimum	0.08

Moments

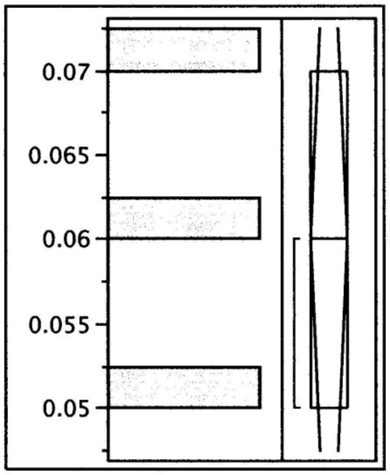
Mean	0.1433333
Std Dev	0.0568624
Std Err Mean	0.0328295
Upper 95% Mean	0.2845874
Lower 95% Mean	0.0020793
N	3

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=0.5

Sediments Derived (g)

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=0.5

Sediments Derived (g)



Quantiles

100.0%	maximum	0.07
99.5%		0.07
97.5%		0.07
90.0%		0.07
75.0%	quartile	0.07
50.0%	median	0.06
25.0%	quartile	0.05
10.0%		0.05
2.5%		0.05
0.5%		0.05
0.0%	minimum	0.05

Moments

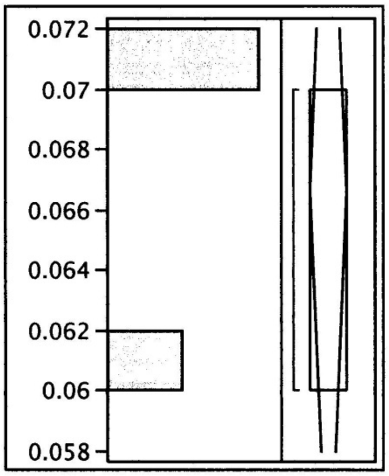
Mean	0.06
Std Dev	0.01
Std Err Mean	0.0057735
Upper 95% Mean	0.0848414
Lower 95% Mean	0.0351586
N	3

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=1

Sediments Derived (g)

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=1

Sediments Derived (g)



Quantiles

100.0%	maximum	0.07
99.5%		0.07
97.5%		0.07
90.0%		0.07
75.0%	quartile	0.07
50.0%	median	0.07
25.0%	quartile	0.06
10.0%		0.06
2.5%		0.06
0.5%		0.06
0.0%	minimum	0.06

Moments

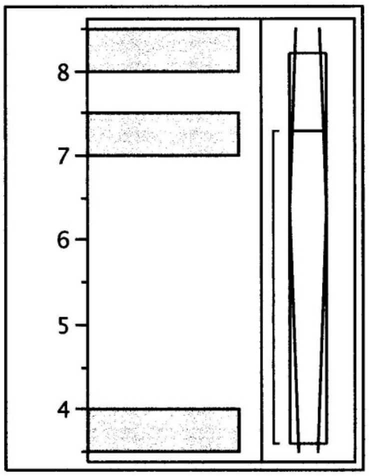
Mean	0.0666667
Std Dev	0.0057735
Std Err Mean	0.0033333
Upper 95% Mean	0.0810088
Lower 95% Mean	0.0523245
N	3

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=0.5

Sediments Derived (g)

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=0.5

Sediments Derived (g)



Quantiles

100.0%	maximum	8.2
99.5%		8.2
97.5%		8.2
90.0%		8.2
75.0%	quartile	8.2
50.0%	median	7.3
25.0%	quartile	3.6
10.0%		3.6
2.5%		3.6
0.5%		3.6
0.0%	minimum	3.6

Moments

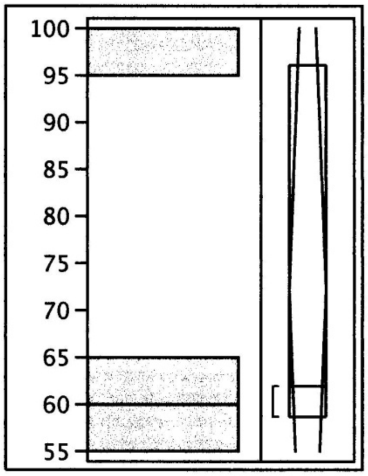
Mean	6.3666667
Std Dev	2.4378953
Std Err Mean	1.4075195
Upper 95% Mean	12.422734
Lower 95% Mean	0.3105991
N	3

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=1

Sediments Derived (g)

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=1

Sediments Derived (g)



Quantiles

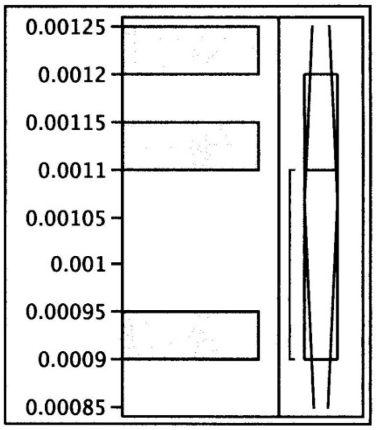
100.0%	maximum	96
99.5%		96
97.5%		96
90.0%		96
75.0%	quartile	96
50.0%	median	61.9
25.0%	quartile	58.7
10.0%		58.7
2.5%		58.7
0.5%		58.7
0.0%	minimum	58.7

Moments

Mean	72.2
Std Dev	20.673413
Std Err Mean	11.9358
Upper 95% Mean	123.5556
Lower 95% Mean	20.844395
N	3

Distributions Sediment=Bridge Deck, Water Velocity (feet per second)=0.5

Sediment Proportion Derived



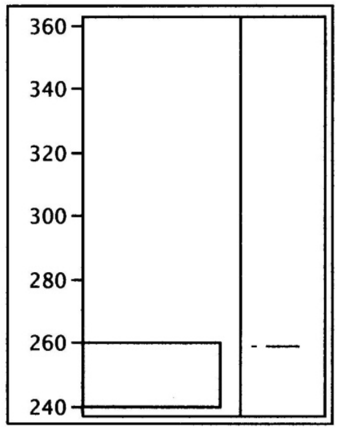
Quantiles

100.0%	maximum	0.0012
99.5%		0.0012
97.5%		0.0012
90.0%		0.0012
75.0%	quartile	0.0012
50.0%	median	0.0011
25.0%	quartile	0.0009
10.0%		0.0009
2.5%		0.0009
0.5%		0.0009
0.0%	minimum	0.0009

Moments

Mean	0.0010667
Std Dev	0.0001528
Std Err Mean	0.0000882
Upper 95% Mean	0.0014461
Lower 95% Mean	0.0006872
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	259
99.5%		259
97.5%		259
90.0%		259
75.0%	quartile	259
50.0%	median	259
25.0%	quartile	259
10.0%		259
2.5%		259
0.5%		259
0.0%	minimum	259

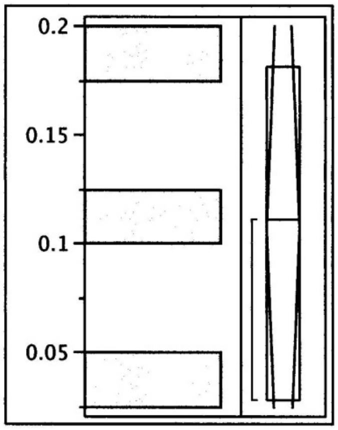
Moments

Mean	259
Std Dev	.
Std Err Mean	.
Upper 95% Mean	.
Lower 95% Mean	.
N	1

Distributions Sediment=Bridge Deck, Water Velocity (feet per second)=1

Distributions Sediment=Bridge Deck, Water Velocity (feet per second)=1

Sediment Proportion Derived



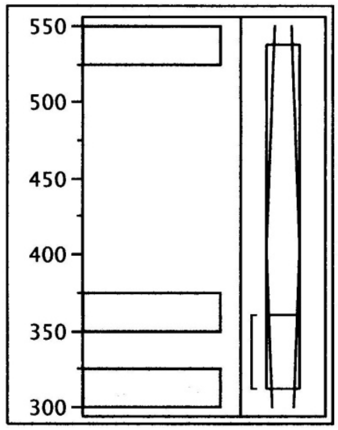
Quantiles

100.0%	maximum	0.1814
99.5%		0.1814
97.5%		0.1814
90.0%		0.1814
75.0%	quartile	0.1814
50.0%	median	0.1111
25.0%	quartile	0.0288
10.0%		0.0288
2.5%		0.0288
0.5%		0.0288
0.0%	minimum	0.0288

Moments

Mean	0.1071
Std Dev	0.0763786
Std Err Mean	0.0440972
Upper 95% Mean	0.296835
Lower 95% Mean	-0.082635
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	538
99.5%		538
97.5%		538
90.0%		538
75.0%	quartile	538
50.0%	median	360
25.0%	quartile	312
10.0%		312
2.5%		312
0.5%		312
0.0%	minimum	312

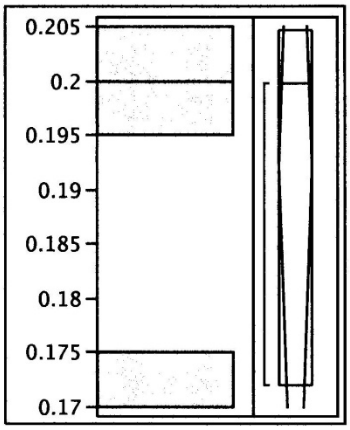
Moments

Mean	403.33333
Std Dev	119.06861
Std Err Mean	68.744293
Upper 95% Mean	699.11615
Lower 95% Mean	107.55051
N	3

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=0.5

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=0.5

Sediment Proportion Derived



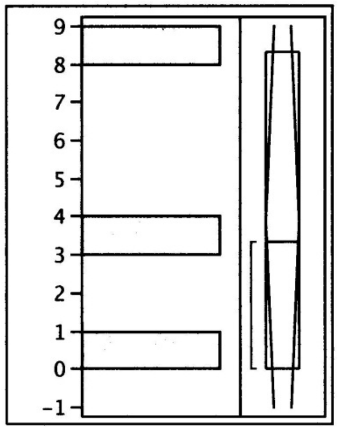
Quantiles

100.0%	maximum	0.2047
99.5%		0.2047
97.5%		0.2047
90.0%		0.2047
75.0%	quartile	0.2047
50.0%	median	0.1997
25.0%	quartile	0.172
10.0%		0.172
2.5%		0.172
0.5%		0.172
0.0%	minimum	0.172

Moments

Mean	0.1921333
Std Dev	0.0176143
Std Err Mean	0.0101696
Upper 95% Mean	0.2358897
Lower 95% Mean	0.148377
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	8.33
99.5%		8.33
97.5%		8.33
90.0%		8.33
75.0%	quartile	8.33
50.0%	median	3.36
25.0%	quartile	0.01
10.0%		0.01
2.5%		0.01
0.5%		0.01
0.0%	minimum	0.01

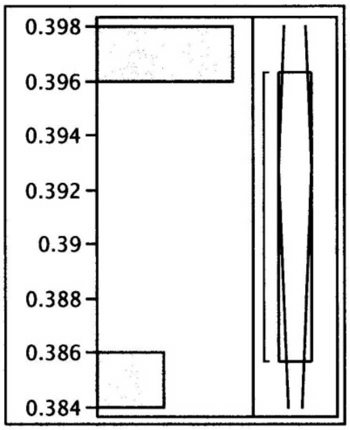
Moments

Mean	3.9
Std Dev	4.1862035
Std Err Mean	2.4169057
Upper 95% Mean	14.299106
Lower 95% Mean	-6.499106
N	3

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=1

Distributions Sediment=Pavement Grindings, Water Velocity (feet per second)=1

Sediment Proportion Derived



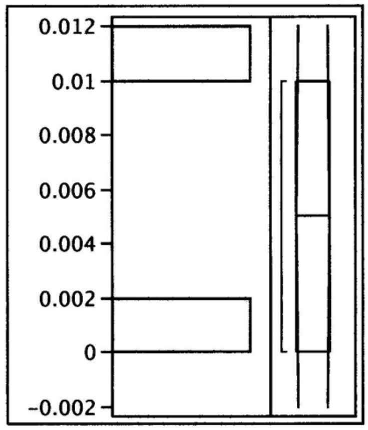
Quantiles

100.0%	maximum	0.3963
99.5%		0.3963
97.5%		0.3963
90.0%		0.3963
75.0%	quartile	0.3963
50.0%	median	0.3963
25.0%	quartile	0.3857
10.0%		0.3857
2.5%		0.3857
0.5%		0.3857
0.0%	minimum	0.3857

Moments

Mean	0.3927667
Std Dev	0.0061199
Std Err Mean	0.0035333
Upper 95% Mean	0.4079694
Lower 95% Mean	0.377564
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	0.01
99.5%		0.01
97.5%		0.01
90.0%		0.01
75.0%	quartile	0.01
50.0%	median	0.005
25.0%	quartile	0
10.0%		0
2.5%		0
0.5%		0
0.0%	minimum	0

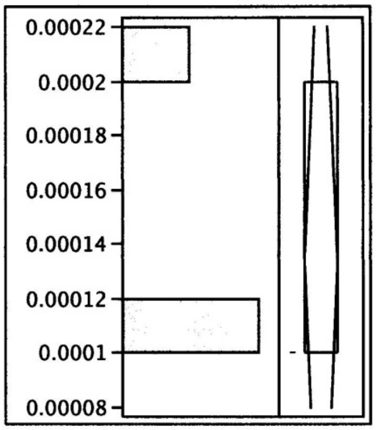
Moments

Mean	0.005
Std Dev	0.0070711
Std Err Mean	0.005
Upper 95% Mean	0.068531
Lower 95% Mean	-0.058531
N	2

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=0.5

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=0.5

Sediment Proportion Derived



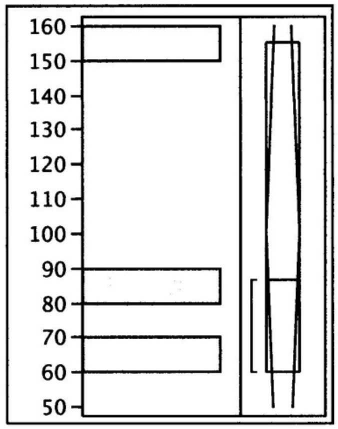
Quantiles

100.0%	maximum	0.0002
99.5%		0.0002
97.5%		0.0002
90.0%		0.0002
75.0%	quartile	0.0002
50.0%	median	0.0001
25.0%	quartile	0.0001
10.0%		0.0001
2.5%		0.0001
0.5%		0.0001
0.0%	minimum	0.0001

Moments

Mean	0.0001333
Std Dev	5.7735e-5
Std Err Mean	3.3333e-5
Upper 95% Mean	0.0002768
Lower 95% Mean	-0.00001
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	155
99.5%		155
97.5%		155
90.0%		155
75.0%	quartile	155
50.0%	median	86.8
25.0%	quartile	60
10.0%		60
2.5%		60
0.5%		60
0.0%	minimum	60

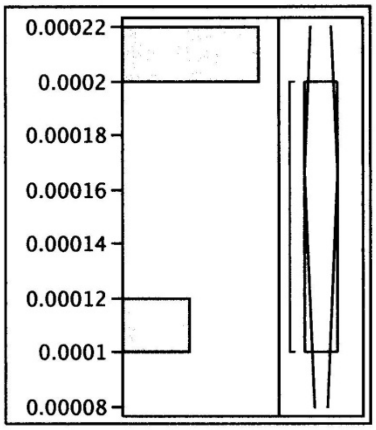
Moments

Mean	100.6
Std Dev	48.980404
Std Err Mean	28.27885
Upper 95% Mean	222.27407
Lower 95% Mean	-21.07407
N	3

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=1

Distributions Sediment=Portland Cement - 4 hr, Water Velocity (feet per second)=1

Sediment Proportion Derived



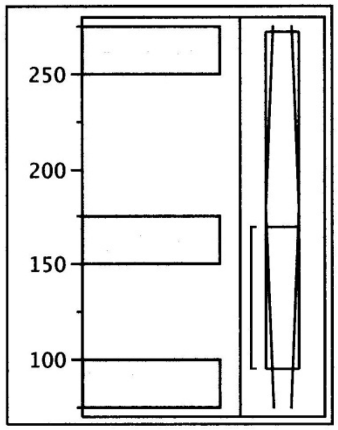
Quantiles

100.0%	maximum	0.0002
99.5%		0.0002
97.5%		0.0002
90.0%		0.0002
75.0%	quartile	0.0002
50.0%	median	0.0002
25.0%	quartile	0.0001
10.0%		0.0001
2.5%		0.0001
0.5%		0.0001
0.0%	minimum	0.0001

Moments

Mean	0.0001667
Std Dev	5.7735e-5
Std Err Mean	3.3333e-5
Upper 95% Mean	0.0003101
Lower 95% Mean	2.3245e-5
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	272
99.5%		272
97.5%		272
90.0%		272
75.0%	quartile	272
50.0%	median	170
25.0%	quartile	95.6
10.0%		95.6
2.5%		95.6
0.5%		95.6
0.0%	minimum	95.6

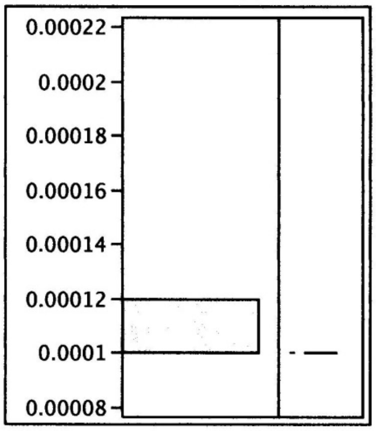
Moments

Mean	179.2
Std Dev	88.559133
Std Err Mean	51.129639
Upper 95% Mean	399.19308
Lower 95% Mean	-40.79308
N	3

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=0.5

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=0.5

Sediment Proportion Derived



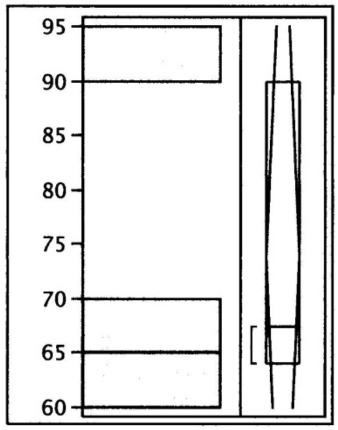
Quantiles

100.0%	maximum	0.0001
99.5%		0.0001
97.5%		0.0001
90.0%		0.0001
75.0%	quartile	0.0001
50.0%	median	0.0001
25.0%	quartile	0.0001
10.0%		0.0001
2.5%		0.0001
0.5%		0.0001
0.0%	minimum	0.0001

Moments

Mean	0.0001
Std Dev	0
Std Err Mean	0
Upper 95% Mean	0.0001
Lower 95% Mean	0.0001
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	90
99.5%		90
97.5%		90
90.0%		90
75.0%	quartile	90
50.0%	median	67.4
25.0%	quartile	64
10.0%		64
2.5%		64
0.5%		64
0.0%	minimum	64

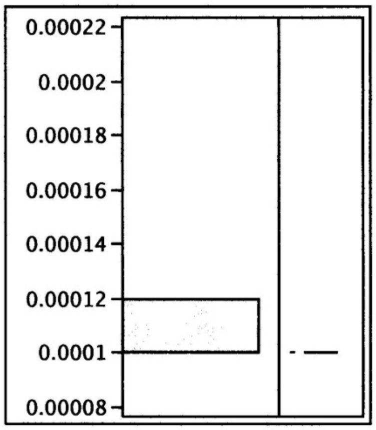
Moments

Mean	73.8
Std Dev	14.132233
Std Err Mean	8.1592483
Upper 95% Mean	108.90641
Lower 95% Mean	38.693588
N	3

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=1

Distributions Sediment=Portland Cement - 48 hr, Water Velocity (feet per second)=1

Sediment Proportion Derived



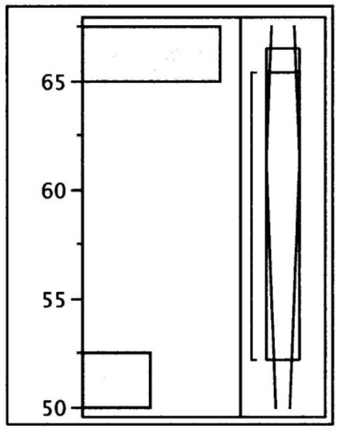
Quantiles

100.0%	maximum	0.0001
99.5%		0.0001
97.5%		0.0001
90.0%		0.0001
75.0%	quartile	0.0001
50.0%	median	0.0001
25.0%	quartile	0.0001
10.0%		0.0001
2.5%		0.0001
0.5%		0.0001
0.0%	minimum	0.0001

Moments

Mean	0.0001
Std Dev	0
Std Err Mean	0
Upper 95% Mean	0.0001
Lower 95% Mean	0.0001
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	66.5
99.5%		66.5
97.5%		66.5
90.0%		66.5
75.0%	quartile	66.5
50.0%	median	65.4
25.0%	quartile	52.2
10.0%		52.2
2.5%		52.2
0.5%		52.2
0.0%	minimum	52.2

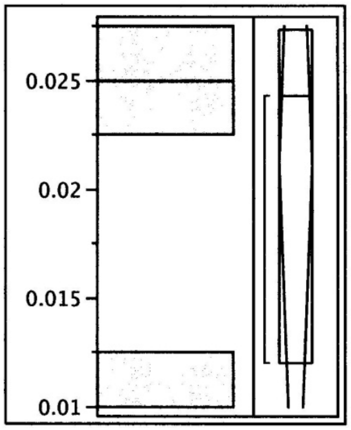
Moments

Mean	61.366667
Std Dev	7.957596
Std Err Mean	4.5943202
Upper 95% Mean	81.134431
Lower 95% Mean	41.598902
N	3

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=0.5

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=0.5

Sediment Proportion Derived



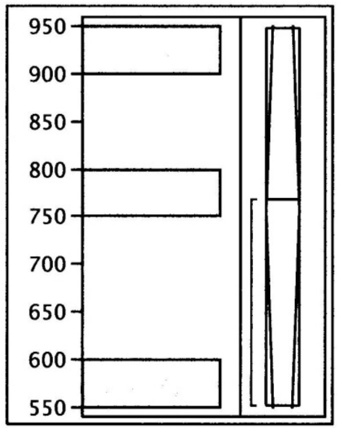
Quantiles

100.0%	maximum	0.0273
99.5%		0.0273
97.5%		0.0273
90.0%		0.0273
75.0%	quartile	0.0273
50.0%	median	0.0243
25.0%	quartile	0.012
10.0%		0.012
2.5%		0.012
0.5%		0.012
0.0%	minimum	0.012

Moments

Mean	0.0212
Std Dev	0.0081074
Std Err Mean	0.0046808
Upper 95% Mean	0.0413399
Lower 95% Mean	0.0010601
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	949
99.5%		949
97.5%		949
90.0%		949
75.0%	quartile	949
50.0%	median	769
25.0%	quartile	551
10.0%		551
2.5%		551
0.5%		551
0.0%	minimum	551

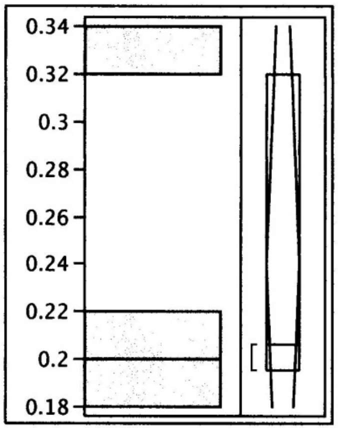
Moments

Mean	756.33333
Std Dev	199.30212
Std Err Mean	115.06713
Upper 95% Mean	1251.4272
Lower 95% Mean	261.23943
N	3

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=1

Distributions Sediment=Saw Cut Slurry, Water Velocity (feet per second)=1

Sediment Proportion Derived



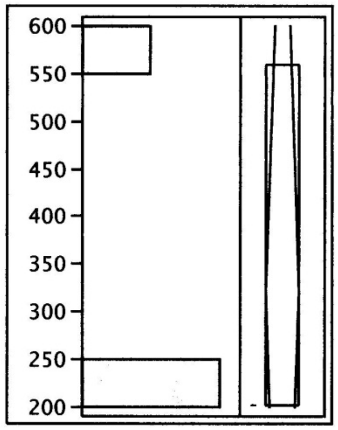
Quantiles

100.0%	maximum	0.32
99.5%		0.32
97.5%		0.32
90.0%		0.32
75.0%	quartile	0.32
50.0%	median	0.2063
25.0%	quartile	0.1957
10.0%		0.1957
2.5%		0.1957
0.5%		0.1957
0.0%	minimum	0.1957

Moments

Mean	0.2406667
Std Dev	0.0689088
Std Err Mean	0.0397845
Upper 95% Mean	0.4118456
Lower 95% Mean	0.0694877
N	3

Turbidity (NTU)



Quantiles

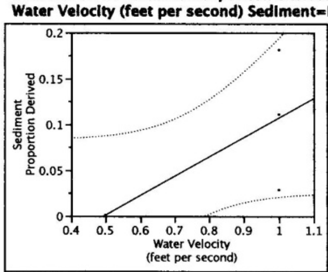
100.0%	maximum	560
99.5%		560
97.5%		560
90.0%		560
75.0%	quartile	560
50.0%	median	202
25.0%	quartile	201
10.0%		201
2.5%		201
0.5%		201
0.0%	minimum	201

Moments

Mean	321
Std Dev	206.98068
Std Err Mean	119.50035
Upper 95% Mean	835.1685
Lower 95% Mean	-193.1685
N	3

Fit Y by X Group

Bivariate Fit of Sediment Proportion Derived By Water Velocity (feet per second) Sediment=Bridge Deck



Linear Fit

Linear Fit

Sediment Proportion Derived = -0.104967 + 0.2120667*Water Velocity (feet per second)

Summary of Fit

RSquare	0.591076
RSquare Adj	0.488845
Root Mean Square Error	0.054008
Mean of Response	0.054083
Observations (or Sum Wgts)	6

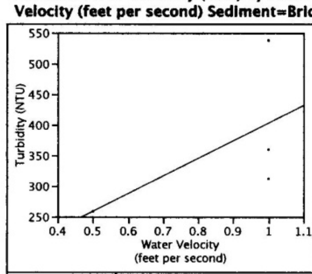
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.01686460	0.016865	5.7818
Error	4	0.01166743	0.002917	Prob > F
C. Total	5	0.02853203		0.0740

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.104967	0.069724	-1.51	0.2067
Water Velocity (feet per second)	0.2120667	0.088195	2.40	0.0740

Bivariate Fit of Turbidity (NTU) By Water Velocity (feet per second) Sediment=Bridge Deck



Linear Fit

Linear Fit

Turbidity (NTU) = 114.66667 + 288.66667*Water Velocity (feet per second)

Summary of Fit

RSquare	0.355264
RSquare Adj	0.032897
Root Mean Square Error	119.0686
Mean of Response	367.25
Observations (or Sum Wgts)	4

Analysis of Variance

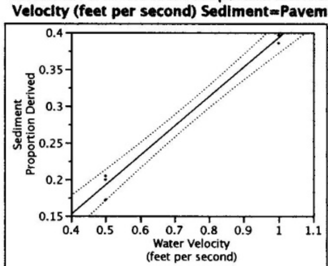
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	15624.083	15624.1	1.1020
Error	2	28354.667	14177.3	Prob > F
C. Total	3	43978.750		0.4040

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	114.66667	247.8611	0.46	0.6891
Water Velocity (feet per second)	288.66667	274.9772	1.05	0.4040

Fit Y by X Group

Bivariate Fit of Sediment Proportion Derived By Water Velocity (feet per second) Sediment=Pavement Grindings



Linear Fit

Linear Fit

Sediment Proportion Derived = -0.0085 + 0.4012667*Water Velocity (feet per second)

Summary of Fit

RSquare	0.988614
RSquare Adj	0.985767
Root Mean Square Error	0.013186
Mean of Response	0.29245
Observations (or Sum Wgts)	6

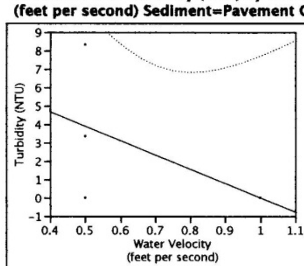
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.06038060	0.060381	347.2977
Error	4	0.00069543	0.000174	Prob > F
C. Total	5	0.06107603		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.0085	0.017022	-0.50	0.6438
Water Velocity (feet per second)	0.4012667	0.021532	18.64	<.0001*

Bivariate Fit of Turbidity (NTU) By Water Velocity (feet per second) Sediment=Pavement Grindings



Linear Fit

Linear Fit

Turbidity (NTU) = 7.795 - 7.79*Water Velocity (feet per second)

Summary of Fit

RSquare	0.341857
RSquare Adj	0.122476
Root Mean Square Error	3.418023
Mean of Response	2.342
Observations (or Sum Wgts)	5

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	18.205230	18.2052	1.5583
Error	3	35.048650	11.6829	Prob > F
C. Total	4	53.253880		0.3005

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7.795	4.628025	1.68	0.1907
Water Velocity (feet per second)	-7.79	6.240428	-1.25	0.3005

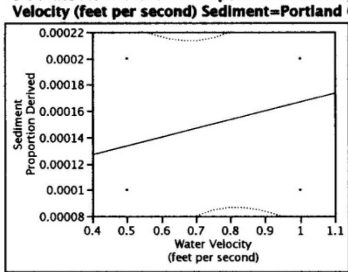
Fit Y by X Group

Bivariate Fit of Sediment Proportion Derived By Water Velocity (feet per second) Sediment=Portland Cement - 4 hr

Bivariate Fit of Turbidity (NTU) By Water Velocity (feet per second) Sediment=Portland Cement - 4 hr

Fit Y by X Group

Bivariate Fit of Sediment Proportion Derived By Water Velocity (feet per second) Sediment=Portland Cement - 4 hr



Linear Fit

Linear Fit

Sediment Proportion Derived = 0.0001 + 6.6667e-5*Water Velocity (feet per second)

Summary of Fit

RSquare	0.111111
RSquare Adj	-0.11111
Root Mean Square Error	5.774e-5
Mean of Response	0.00015
Observations (or Sum Wgts)	6

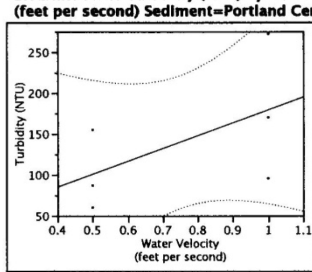
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.66667e-9	1.6667e-9	0.5000
Error	4	1.33333e-8	3.3333e-9	Prob > F
C. Total	5	1.5e-8		0.5185

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0001	7.454e-5	1.34	0.2508
Water Velocity (feet per second)	6.6667e-5	9.428e-5	0.71	0.5185

Bivariate Fit of Turbidity (NTU) By Water Velocity (feet per second) Sediment=Portland Cement - 4 hr



Linear Fit

Linear Fit

Turbidity (NTU) = 22 + 157.2*Water Velocity (feet per second)

Summary of Fit

RSquare	0.311488
RSquare Adj	0.13936
Root Mean Square Error	71.56046
Mean of Response	139.9
Observations (or Sum Wgts)	6

Analysis of Variance

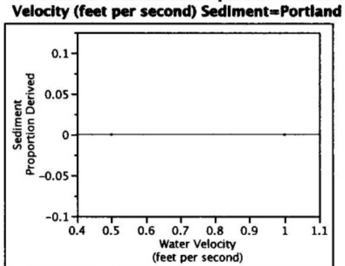
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	9266.940	9266.94	1.8096
Error	4	20483.600	5120.90	Prob > F
C. Total	5	29750.540		0.2498

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	22	92.38416	0.24	0.8235
Water Velocity (feet per second)	157.2	116.8577	1.35	0.2498

Fit Y by X Group

Bivariate Fit of Sediment Proportion Derived By Water Velocity (feet per second) Sediment=Portland Cement - 48 hr



Linear Fit

Linear Fit

Sediment Proportion Derived = 0.0001 - 1.446e-19*Water Velocity (feet per second)

Summary of Fit

RSquare	.
RSquare Adj	.
Root Mean Square Error	0
Mean of Response	0.0001
Observations (or Sum Wgts)	6

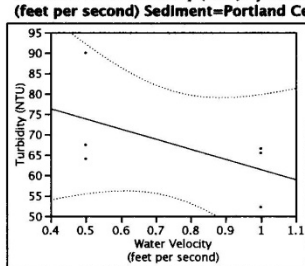
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0	0	.
Error	4	0	0	Prob > F
C. Total	5	-1.323e-23		.

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0001	0	.	.
Water Velocity (feet per second)	-1.45e-19	0	.	.

Bivariate Fit of Turbidity (NTU) By Water Velocity (feet per second) Sediment=Portland Cement - 48 hr



Linear Fit

Linear Fit

Turbidity (NTU) = 86.233333 - 24.866667*Water Velocity (feet per second)

Summary of Fit

RSquare	0.305925
RSquare Adj	0.132407
Root Mean Square Error	11.46829
Mean of Response	67.58333
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	231.88167	231.882	1.7631
Error	4	526.08667	131.522	Prob > F
C. Total	5	757.96833		0.2549

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	86.233333	14.8055	5.82	0.0043*
Water Velocity (feet per second)	-24.86667	18.72764	-1.33	0.2549

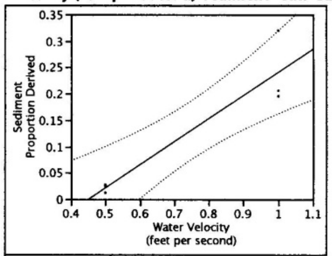
Fit Y by X Group

Bivariate Fit of Sediment Proportion Derived By Water Velocity (feet per second) Sediment=Saw Cut Slurry

Bivariate Fit of Turbidity (NTU) By Water Velocity (feet per second) Sediment=Saw Cut Slurry

Fit Y by X Group

Bivariate Fit of Sediment Proportion Derived By Water Velocity (feet per second) Sediment=Saw Cut Slurry



Linear Fit

Sediment Proportion Derived = -0.198267 + 0.4389333*Water Velocity (feet per second)

Summary of Fit

RSquare	0.882405
RSquare Adj	0.853006
Root Mean Square Error	0.049062
Mean of Response	0.130933
Observations (or Sum Wgts)	6

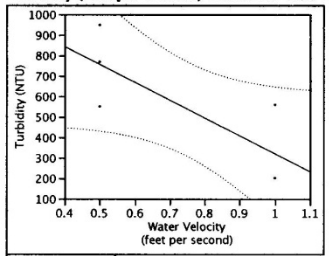
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.07224843	0.072248	30.0150
Error	4	0.00962831	0.002407	Prob > F
C. Total	5	0.08187673		0.0054*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-0.198267	0.063339	-3.13	0.0352*
Water Velocity (feet per second)	0.4389333	0.080118	5.48	0.0054*

Bivariate Fit of Turbidity (NTU) By Water Velocity (feet per second) Sediment=Saw Cut Slurry



Linear Fit

Turbidity (NTU) = 1191.6667 - 870.66667*Water Velocity (feet per second)

Summary of Fit

RSquare	0.632564
RSquare Adj	0.540705
Root Mean Square Error	203.1777
Mean of Response	538.6667
Observations (or Sum Wgts)	6

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	284272.67	284273	6.8863
Error	4	165124.67	41281	Prob > F
C. Total	5	449397.33		0.0585

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1191.6667	262.3012	4.54	0.0105*
Water Velocity (feet per second)	-870.6667	331.7878	-2.62	0.0585

Appendix E
Rainfall Drop Erosion Statistical Analyses

Drip Test Results 021711

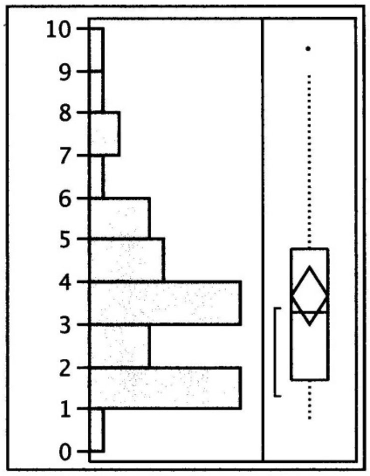
	Date of Test	Concrete Sediments	Hydration Time (hrs)	Test Type	Sediment (mg)	Turbidity (NTU)
1	07/20/2010	Bridge Deck Debris	2	Drip test	8.9	1.61
2	07/20/2010	Bridge Deck Debris	2	Drip test	6.3	2.8
3	07/20/2010	Bridge Deck Debris	2	Drip test	4.3	2.18
4	07/20/2010	Bridge Deck Debris	2	Drip test	4	1.8
5	07/20/2010	Bridge Deck Debris	2	Drip test	4.1	3.25
6	07/20/2010	Bridge Deck Debris	4	Drip test	7.6	3.55
7	07/20/2010	Bridge Deck Debris	4	Drip test	5.9	1.86
8	07/20/2010	Bridge Deck Debris	4	Drip test	3.8	1.46
9	07/20/2010	Bridge Deck Debris	4	Drip test	3	1.99
10	07/20/2010	Bridge Deck Debris	4	Drip test	3.3	1.69
11	07/20/2010	Bridge Deck Debris	6	Drip test	2.3	1.11
12	07/20/2010	Bridge Deck Debris	8	Drip test	2.4	0.98
13	07/20/2010	Bridge Deck Debris	8	Drip test	1.5	0.67
14	07/20/2010	Bridge Deck Debris	8	Drip test	1.6	1.13
15	07/20/2010	Bridge Deck Debris	8	Drip test	3.4	5.02
16	07/21/2010	Bridge Deck Debris	24	Drip test	1.3	0.28
17	07/21/2010	Bridge Deck Debris	24	Drip test	3.4	0.1
18	07/21/2010	Bridge Deck Debris	24	Drip test	1.5	0.18
19	07/21/2010	Bridge Deck Debris	24	Drip test	1.7	0.07
20	07/21/2010	Bridge Deck Debris	24	Drip test	1.7	0.19
21	07/22/2010	Bridge Deck Debris	48	Drip test	3.2	0.05
22	07/22/2010	Bridge Deck Debris	48	Drip test	3.8	0.78
23	07/22/2010	Bridge Deck Debris	48	Drip test	3.3	0.56
24	07/22/2010	Bridge Deck Debris	48	Drip test	2.9	0.57
25	07/22/2010	Bridge Deck Debris	48	Drip test	2.8	0.52
26	07/23/2010	Bridge Deck Debris	72	Drip test	1.6	0.22
27	07/23/2010	Bridge Deck Debris	72	Drip test	4.8	1.31
28	07/23/2010	Bridge Deck Debris	72	Drip test	1.5	0.05
29	07/23/2010	Bridge Deck Debris	72	Drip test	1	0.3
30	07/23/2010	Bridge Deck Debris	72	Drip test	1.9	0.22
31	08/02/2010	Bridge Deck Debris	1	Drip test	5.3	2.19
32	08/02/2010	Bridge Deck Debris	1	Drip test	9.5	2.38
33	08/02/2010	Bridge Deck Debris	1	Drip test	3.1	2.47
34	08/02/2010	Bridge Deck Debris	2	Drip test	0.67	1.06
35	08/02/2010	Bridge Deck Debris	2	Drip test	7	1.58
36	08/02/2010	Bridge Deck Debris	2	Drip test	4.4	0.92
37	08/02/2010	Bridge Deck Debris	8	Drip test	5.7	0.45
38	08/02/2010	Bridge Deck Debris	8	Drip test	5.2	0.64
39	08/02/2010	Bridge Deck Debris	8	Drip test	3.7	0.48
40	10/12/2010	Pavement Grindings	1	Drip test	1088.8	154
41	10/12/2010	Pavement Grindings	1	Drip test	915.3	163
42	10/12/2010	Pavement Grindings	1	Drip test	643.6	97.8
43	11/04/2010	Pavement Grindings	2	Drip test	309.8	74.2
44	11/04/2010	Pavement Grindings	2	Drip test	42.9	14.14
45	11/04/2010	Pavement Grindings	2	Drip test	149.9	46.4
46	06/04/2010	Portland Cement	0.5	Drip test	62.2	13.26
47	06/04/2010	Portland Cement	2	Drip test	17.5	3.18
48	06/04/2010	Portland Cement	4	Drip test	3.4	1.8
49	06/04/2010	Portland Cement	6	Drip Test	3.4	1.75
50	06/07/2010	Portland Cement	0.5	Drip Test	80.6	14.27
51	06/07/2010	Portland Cement	2	Drip Test	2.4	.
52	06/07/2010	Portland Cement	4	Drip test	1.3	0.65
53	06/07/2010	Portland Cement	16	Drip Test	0.7	0.32
54	06/07/2010	Portland Cement	48	Drip Test	0.6	0.07
55	06/22/2010	Portland Cement	0	Drip test	127.4	.
56	06/22/2010	Portland Cement	0.5	Drip test	67	.
57	06/22/2010	Portland Cement	2	Drip test	51.7	.
58	06/22/2010	Portland Cement	4	Drip test	8.1	.
59	06/23/2010	Portland Cement	0	Drip test	35.8	.
60	06/23/2010	Portland Cement	0	Drip test	72.6	3.96

Drip Test Results 021711

	Date of Test	Concrete Sediments	Hydration Time (hrs)	Test Type	Sediment (mg)	Turbidity (NTU)
61	06/23/2010	Portland Cement	0.5	Drip test	39.5	.
62	06/23/2010	Portland Cement	0.5	Drip test	74.6	3.68
63	06/23/2010	Portland Cement	2	Drip test	67.7	.
64	06/23/2010	Portland Cement	2	Drip test	49.3	2.06
65	06/23/2010	Portland Cement	4	Drip test	36.3	2.07
66	06/23/2010	Portland Cement	4	Drip test	40.1	1.22
67	06/24/2010	Portland Cement	0	Drip test	88.8	9.59
68	06/24/2010	Portland Cement	0	Drip test	22.3	4.6
69	06/24/2010	Portland Cement	0.5	Drip test	58.8	.
70	06/24/2010	Portland Cement	0.5	Drip test	39	5.15
71	06/24/2010	Portland Cement	2	Drip test	45.9	2.66
72	06/24/2010	Portland Cement	2	Drip test	26.9	3.69
73	06/24/2010	Portland Cement	4	Drip test	33	3.3
74	06/24/2010	Portland Cement	4	Drip test	23	4.36
75	06/25/2010	Portland Cement	0	Drip test	59.4	9.33
76	06/25/2010	Portland Cement	0	Drip test	24.6	3.38
77	06/25/2010	Portland Cement	0	Drip test	41.5	4.14
78	06/25/2010	Portland Cement	0.5	Drip test	103.7	14.1
79	06/25/2010	Portland Cement	0.5	Drip test	44.4	7.851
80	06/25/2010	Portland Cement	0.5	Drip test	10.7	3.21
81	06/25/2010	Portland Cement	2	Drip test	52.1	6.15
82	06/25/2010	Portland Cement	2	Drip test	20.7	6.32
83	06/25/2010	Portland Cement	2	Drip test	24.4	3.52
84	06/25/2010	Portland Cement	4	Drip test	3.2	1.06
85	06/25/2010	Portland Cement	4	Drip test	27.5	3.88
86	06/25/2010	Portland Cement	4	Drip test	13.2	2.8
87	06/30/2010	Portland Cement	0	Drip test	12.9	4.14
88	06/30/2010	Portland Cement	0.5	Drip test	4	2.59
89	06/30/2010	Portland Cement	2	Drip test	2.7	1.88
90	06/30/2010	Portland Cement	3	Drip test	3.9	0.92
91	06/30/2010	Portland Cement	4	Drip test	1.6	0.82
92	06/30/2010	Portland Cement	5	Drip test	1.6	0.75
93	06/30/2010	Portland Cement	6	Drip test	1.1	0.69
94	08/05/2010	Portland Cement	1	Drip test	7.4	4.52
95	08/05/2010	Portland Cement	1	Drip test	11.8	2.12
96	08/05/2010	Portland Cement	1	Drip test	21.5	2.7
97	08/05/2010	Portland Cement	2	Drip test	6.9	1.83
98	08/05/2010	Portland Cement	2	Drip test	3.6	1.8
99	08/05/2010	Portland Cement	2	Drip test	20.8	3.37
100	08/05/2010	Portland Cement	8	Drip test	13.6	0.92
101	08/05/2010	Portland Cement	8	Drip test	13.8	0.97
102	08/05/2010	Portland Cement	8	Drip test	1.8	0.45
103	08/04/2010	Saw Cut Slurry	1	Drip test	11	5.8
104	08/04/2010	Saw Cut Slurry	1	Drip test	12.2	4.88
105	08/04/2010	Saw Cut Slurry	1	Drip test	15.4	5.36
106	08/04/2010	Saw Cut Slurry	2	Drip test	11.1	4.06
107	08/04/2010	Saw Cut Slurry	2	Drip test	6.4	3.13
108	08/04/2010	Saw Cut Slurry	2	Drip test	62.1	10.12
109	08/04/2010	Saw Cut Slurry	8	Drip test	154.4	24.5
110	08/04/2010	Saw Cut Slurry	8	Drip test	4	1.94
111	08/04/2010	Saw Cut Slurry	8	Drip test	13.7	2.2

Distributions Concrete Sediments=Bridge Deck Debris

Sediment (mg)



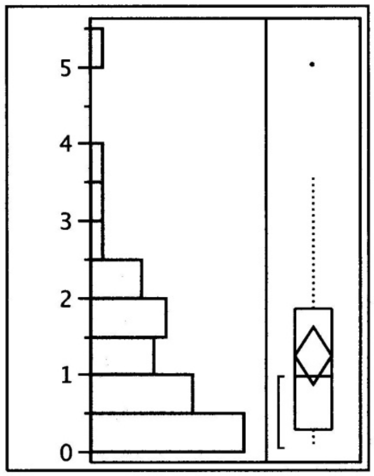
Quantiles

100.0%	maximum	9.5
99.5%		9.5
97.5%		9.5
90.0%		7
75.0%	quartile	4.8
50.0%	median	3.3
25.0%	quartile	1.7
10.0%		1.5
2.5%		0.67
0.5%		0.67
0.0%	minimum	0.67

Moments

Mean	3.6761538
Std Dev	2.1337435
Std Err Mean	0.3416724
Upper 95% Mean	4.3678335
Lower 95% Mean	2.9844742
N	39

Turbidity (NTU)



Quantiles

100.0%	maximum	5.02
99.5%		5.02
97.5%		5.02
90.0%		2.8
75.0%	quartile	1.86
50.0%	median	0.98
25.0%	quartile	0.3
10.0%		0.1
2.5%		0.05
0.5%		0.05
0.0%	minimum	0.05

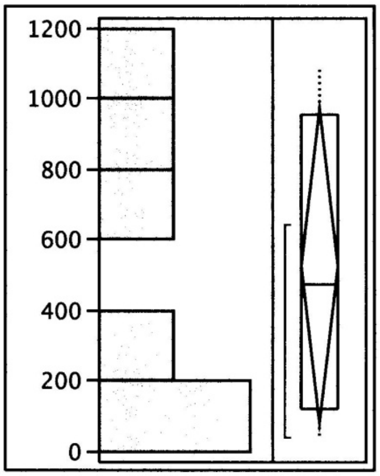
Moments

Mean	1.2479487
Std Dev	1.1219724
Std Err Mean	0.1796594
Upper 95% Mean	1.6116501
Lower 95% Mean	0.8842473
N	39

Distributions Concrete Sediments=Pavement Grindings

Distributions Concrete Sediments=Pavement Grindings

Sediment (mg)



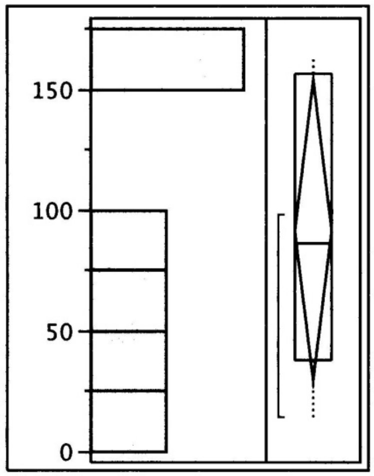
Quantiles

100.0%	maximum	1088.8
99.5%		1088.8
97.5%		1088.8
90.0%		1088.8
75.0%	quartile	958.675
50.0%	median	476.7
25.0%	quartile	123.15
10.0%		42.9
2.5%		42.9
0.5%		42.9
0.0%	minimum	42.9

Moments

Mean	525.05
Std Dev	425.13573
Std Err Mean	173.56093
Upper 95% Mean	971.20258
Lower 95% Mean	78.897416
N	6

Turbidity (NTU)



Quantiles

100.0%	maximum	163
99.5%		163
97.5%		163
90.0%		163
75.0%	quartile	156.25
50.0%	median	86
25.0%	quartile	38.335
10.0%		14.14
2.5%		14.14
0.5%		14.14
0.0%	minimum	14.14

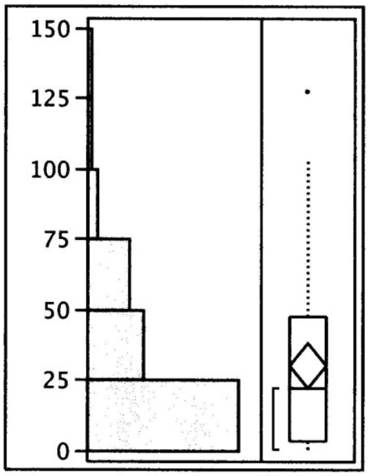
Moments

Mean	91.59
Std Dev	58.950846
Std Err Mean	24.066582
Upper 95% Mean	153.45512
Lower 95% Mean	29.724882
N	6

Distributions Concrete Sediments=Portland Cement

Distributions Concrete Sediments=Portland Cement

Sediment (mg)



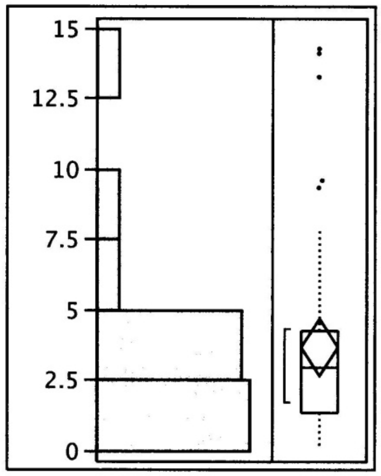
Quantiles

100.0%	maximum	127.4
99.5%		127.4
97.5%		116.735
90.0%		73
75.0%	quartile	47.6
50.0%	median	22.3
25.0%	quartile	3.95
10.0%		1.6
2.5%		0.645
0.5%		0.6
0.0%	minimum	0.6

Moments

Mean	30.426316
Std Dev	29.256651
Std Err Mean	3.8751381
Upper 95% Mean	38.18915
Lower 95% Mean	22.663481
N	57

Turbidity (NTU)



Quantiles

100.0%	maximum	14.27
99.5%		14.27
97.5%		14.2318
90.0%		9.356
75.0%	quartile	4.305
50.0%	median	2.99
25.0%	quartile	1.3525
10.0%		0.686
2.5%		0.12625
0.5%		0.07
0.0%	minimum	0.07

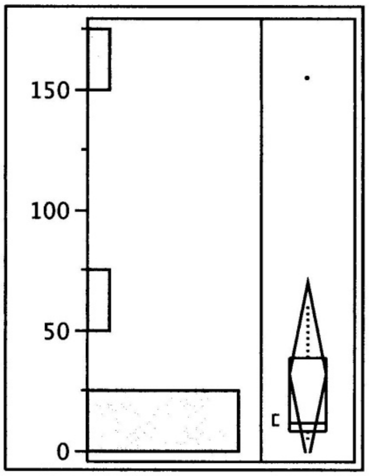
Moments

Mean	3.7052292
Std Dev	3.4193993
Std Err Mean	0.4935478
Upper 95% Mean	4.6981192
Lower 95% Mean	2.7123391
N	48

Distributions Concrete Sediments=Saw Cut Slurry

Distributions Concrete Sediments=Saw Cut Slurry

Sediment (mg)



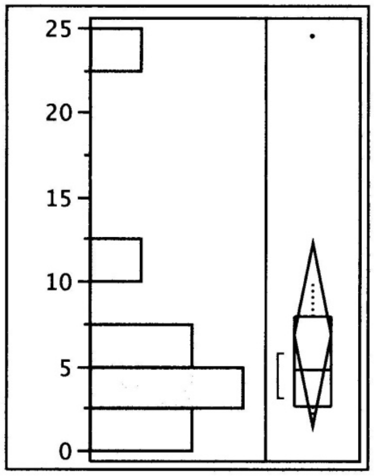
Quantiles

100.0%	maximum	154.4
99.5%		154.4
97.5%		154.4
90.0%		154.4
75.0%	quartile	38.75
50.0%	median	12.2
25.0%	quartile	8.7
10.0%		4
2.5%		4
0.5%		4
0.0%	minimum	4

Moments

Mean	32.255556
Std Dev	48.998523
Std Err Mean	16.332841
Upper 95% Mean	69.919155
Lower 95% Mean	-5.408043
N	9

Turbidity (NTU)



Quantiles

100.0%	maximum	24.5
99.5%		24.5
97.5%		24.5
90.0%		24.5
75.0%	quartile	7.96
50.0%	median	4.88
25.0%	quartile	2.665
10.0%		1.94
2.5%		1.94
0.5%		1.94
0.0%	minimum	1.94

Moments

Mean	6.8877778
Std Dev	7.0423643
Std Err Mean	2.3474548
Upper 95% Mean	12.301018
Lower 95% Mean	1.4745374
N	9

Drip Test Portland Cement Hydration Time 022011

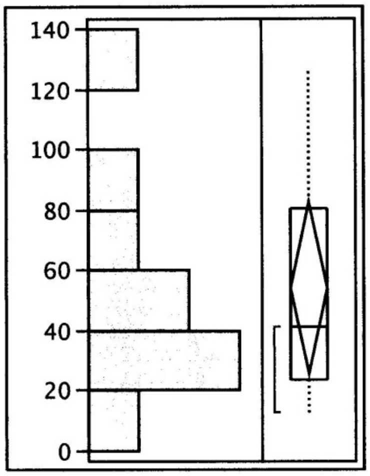
	Date	Sediment Material	Hydration Time (hrs)	Test Type	Sediment (mg)	Turbidity (NTU)
1	06/04/2010	Portland Cement	0.5	Drip test	62.2	13.26
2	06/04/2010	Portland Cement	2	Drip test	17.5	3.18
3	06/04/2010	Portland Cement	4	Drip test	3.4	1.8
4	06/07/2010	Portland Cement	0.5	Drip Test	80.6	14.27
5	06/07/2010	Portland Cement	2	Drip Test	2.4	.
6	06/07/2010	Portland Cement	4	Drip test	1.3	0.65
7	06/07/2010	Portland Cement	16	Drip Test	0.7	0.32
8	06/07/2010	Portland Cement	48	Drip Test	0.6	0.07
9	06/22/2010	Portland Cement	0	Drip test	127.4	.
10	06/22/2010	Portland Cement	0.5	Drip test	67	.
11	06/22/2010	Portland Cement	2	Drip test	51.7	.
12	06/22/2010	Portland Cement	4	Drip test	8.1	.
13	06/23/2010	Portland Cement	0	Drip test	35.8	.
14	06/23/2010	Portland Cement	0	Drip test	72.6	3.96
15	06/23/2010	Portland Cement	0.5	Drip test	39.5	.
16	06/23/2010	Portland Cement	0.5	Drip test	74.6	3.68
17	06/23/2010	Portland Cement	2	Drip test	67.7	.
18	06/23/2010	Portland Cement	2	Drip test	49.3	2.06
19	06/23/2010	Portland Cement	4	Drip test	36.3	2.07
20	06/23/2010	Portland Cement	4	Drip test	40.1	1.22
21	06/24/2010	Portland Cement	0	Drip test	88.8	9.59
22	06/24/2010	Portland Cement	0	Drip test	22.3	4.6
23	06/24/2010	Portland Cement	0.5	Drip test	58.8	.
24	06/24/2010	Portland Cement	0.5	Drip test	39	5.15
25	06/24/2010	Portland Cement	2	Drip test	45.9	2.66
26	06/24/2010	Portland Cement	2	Drip test	26.9	3.69
27	06/24/2010	Portland Cement	4	Drip test	33	3.3
28	06/24/2010	Portland Cement	4	Drip test	23	4.36
29	06/25/2010	Portland Cement	0	Drip test	59.4	9.33
30	06/25/2010	Portland Cement	0	Drip test	24.6	3.38
31	06/25/2010	Portland Cement	0	Drip test	41.5	4.14
32	06/25/2010	Portland Cement	0.5	Drip test	103.7	14.1
33	06/25/2010	Portland Cement	0.5	Drip test	44.4	7.851
34	06/25/2010	Portland Cement	0.5	Drip test	10.7	3.21
35	06/25/2010	Portland Cement	2	Drip test	52.1	6.15
36	06/25/2010	Portland Cement	2	Drip test	20.7	6.32
37	06/25/2010	Portland Cement	2	Drip test	24.4	3.52
38	06/25/2010	Portland Cement	4	Drip test	3.2	1.06
39	06/25/2010	Portland Cement	4	Drip test	27.5	3.88
40	06/25/2010	Portland Cement	4	Drip test	13.2	2.8
41	06/30/2010	Portland Cement	0	Drip test	12.9	4.14
42	06/30/2010	Portland Cement	0.5	Drip test	4	2.59
43	06/30/2010	Portland Cement	2	Drip test	2.7	1.88
44	06/30/2010	Portland Cement	4	Drip test	1.6	0.82

Drip Test Portland Cement Hydration Time 022011

	Date	Sediment Material	Hydration Time (hrs)	Test Type	Sediment (mg)	Turbidity (NTU)
45	08/05/2010	Portland Cement	1	Drip test	7.4	4.52
46	08/05/2010	Portland Cement	1	Drip test	11.8	2.12
47	08/05/2010	Portland Cement	1	Drip test	21.5	2.7
48	08/05/2010	Portland Cement	2	Drip test	6.9	1.83
49	08/05/2010	Portland Cement	2	Drip test	3.6	1.8
50	08/05/2010	Portland Cement	2	Drip test	20.8	3.37
51	08/05/2010	Portland Cement	8	Drip test	13.6	0.92
52	08/05/2010	Portland Cement	8	Drip test	13.8	0.97
53	08/05/2010	Portland Cement	8	Drip test	1.8	0.45

Distributions Hydration Time (hrs)=0

Sediment (mg)



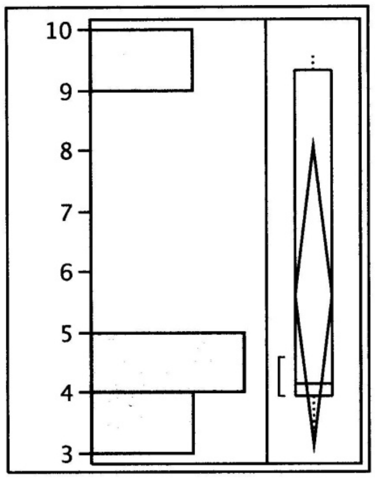
Quantiles

100.0%	maximum	127.4
99.5%		127.4
97.5%		127.4
90.0%		127.4
75.0%	quartile	80.7
50.0%	median	41.5
25.0%	quartile	23.45
10.0%		12.9
2.5%		12.9
0.5%		12.9
0.0%	minimum	12.9

Moments

Mean	53.922222
Std Dev	37.11404
Std Err Mean	12.371347
Upper 95% Mean	82.450599
Lower 95% Mean	25.393846
N	9

Turbidity (NTU)



Quantiles

100.0%	maximum	9.59
99.5%		9.59
97.5%		9.59
90.0%		9.59
75.0%	quartile	9.33
50.0%	median	4.14
25.0%	quartile	3.96
10.0%		3.38
2.5%		3.38
0.5%		3.38
0.0%	minimum	3.38

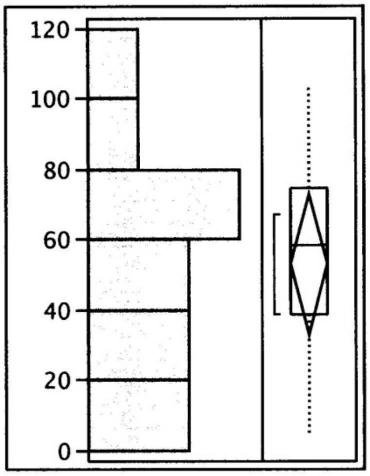
Moments

Mean	5.5914286
Std Dev	2.6681356
Std Err Mean	1.0084605
Upper 95% Mean	8.0590424
Lower 95% Mean	3.1238147
N	7

Distributions Hydration Time (hrs)=0.5

Distributions Hydration Time (hrs)=0.5

Sediment (mg)



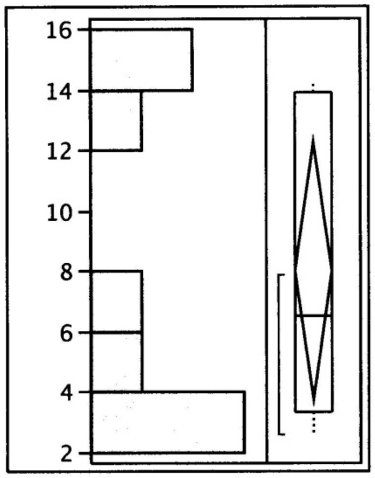
Quantiles

100.0%	maximum	103.7
99.5%		103.7
97.5%		103.7
90.0%		99.08
75.0%	quartile	74.6
50.0%	median	58.8
25.0%	quartile	39
10.0%		5.34
2.5%		4
0.5%		4
0.0%	minimum	4

Moments

Mean	53.136364
Std Dev	29.589501
Std Err Mean	8.9215701
Upper 95% Mean	73.014861
Lower 95% Mean	33.257867
N	11

Turbidity (NTU)



Quantiles

100.0%	maximum	14.27
99.5%		14.27
97.5%		14.27
90.0%		14.27
75.0%	quartile	13.89
50.0%	median	6.5005
25.0%	quartile	3.3275
10.0%		2.59
2.5%		2.59
0.5%		2.59
0.0%	minimum	2.59

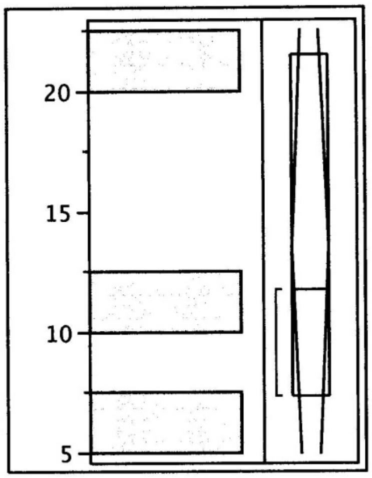
Moments

Mean	8.013875
Std Dev	5.1159172
Std Err Mean	1.8087499
Upper 95% Mean	12.290889
Lower 95% Mean	3.7368612
N	8

Distributions Hydration Time (hrs)=1

Distributions Hydration Time (hrs)=1

Sediment (mg)



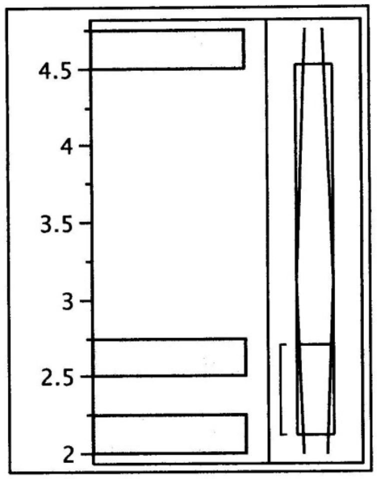
Quantiles

100.0%	maximum	21.5
99.5%		21.5
97.5%		21.5
90.0%		21.5
75.0%	quartile	21.5
50.0%	median	11.8
25.0%	quartile	7.4
10.0%		7.4
2.5%		7.4
0.5%		7.4
0.0%	minimum	7.4

Moments

Mean	13.566667
Std Dev	7.2141066
Std Err Mean	4.1650664
Upper 95% Mean	31.487501
Lower 95% Mean	-4.354167
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	4.52
99.5%		4.52
97.5%		4.52
90.0%		4.52
75.0%	quartile	4.52
50.0%	median	2.7
25.0%	quartile	2.12
10.0%		2.12
2.5%		2.12
0.5%		2.12
0.0%	minimum	2.12

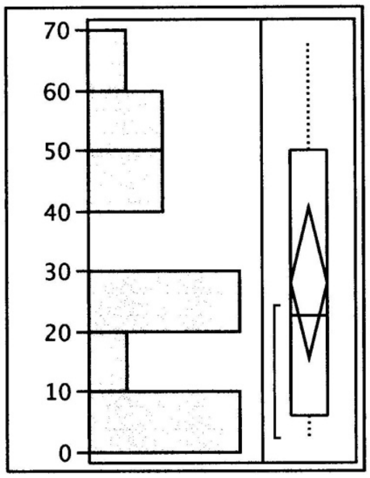
Moments

Mean	3.1133333
Std Dev	1.2522513
Std Err Mean	0.7229876
Upper 95% Mean	6.224098
Lower 95% Mean	0.0025686
N	3

Distributions Hydration Time (hrs)=2

Distributions Hydration Time (hrs)=2

Sediment (mg)



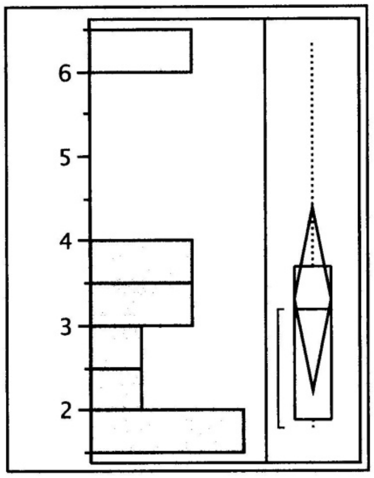
Quantiles

100.0%	maximum	67.7
99.5%		67.7
97.5%		67.7
90.0%		59.9
75.0%	quartile	49.9
50.0%	median	22.6
25.0%	quartile	6.075
10.0%		2.55
2.5%		2.4
0.5%		2.4
0.0%	minimum	2.4

Moments

Mean	28.042857
Std Dev	21.587451
Std Err Mean	5.7694888
Upper 95% Mean	40.50708
Lower 95% Mean	15.578634
N	14

Turbidity (NTU)



Quantiles

100.0%	maximum	6.32
99.5%		6.32
97.5%		6.32
90.0%		6.286
75.0%	quartile	3.69
50.0%	median	3.18
25.0%	quartile	1.88
10.0%		1.806
2.5%		1.8
0.5%		1.8
0.0%	minimum	1.8

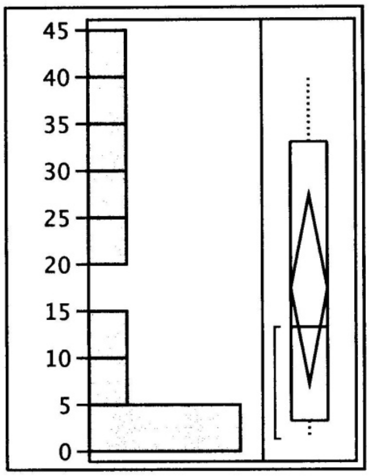
Moments

Mean	3.3145455
Std Dev	1.607323
Std Err Mean	0.4846261
Upper 95% Mean	4.3943597
Lower 95% Mean	2.2347312
N	11

Distributions Hydration Time (hrs)=4

Distributions Hydration Time (hrs)=4

Sediment (mg)



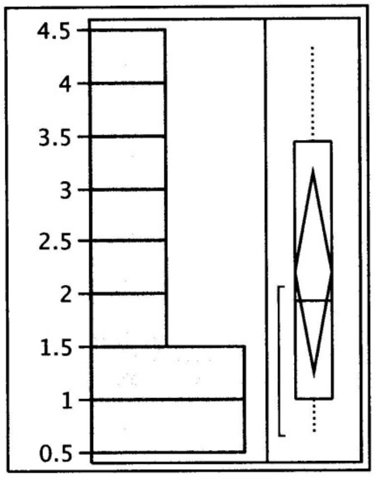
Quantiles

100.0%	maximum	40.1
99.5%		40.1
97.5%		40.1
90.0%		39.34
75.0%	quartile	33
50.0%	median	13.2
25.0%	quartile	3.2
10.0%		1.36
2.5%		1.3
0.5%		1.3
0.0%	minimum	1.3

Moments

Mean	17.336364
Std Dev	15.032649
Std Err Mean	4.5325143
Upper 95% Mean	27.435435
Lower 95% Mean	7.2372924
N	11

Turbidity (NTU)



Quantiles

100.0%	maximum	4.36
99.5%		4.36
97.5%		4.36
90.0%		4.312
75.0%	quartile	3.445
50.0%	median	1.935
25.0%	quartile	1
10.0%		0.667
2.5%		0.65
0.5%		0.65
0.0%	minimum	0.65

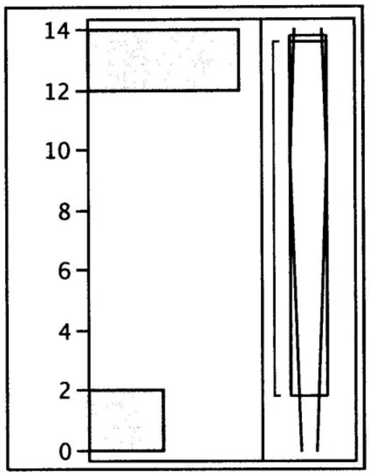
Moments

Mean	2.196
Std Dev	1.3250426
Std Err Mean	0.4190152
Upper 95% Mean	3.1438783
Lower 95% Mean	1.2481217
N	10

Distributions Hydration Time (hrs)=8

Distributions Hydration Time (hrs)=8

Sediment (mg)



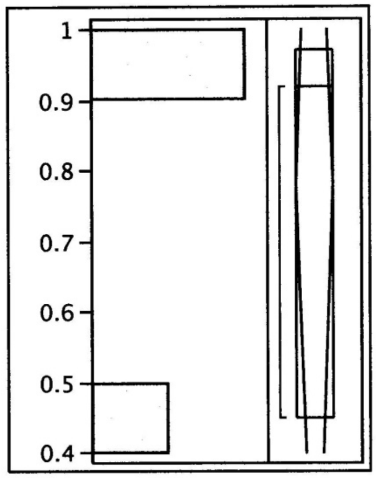
Quantiles

100.0%	maximum	13.8
99.5%		13.8
97.5%		13.8
90.0%		13.8
75.0%	quartile	13.8
50.0%	median	13.6
25.0%	quartile	1.8
10.0%		1.8
2.5%		1.8
0.5%		1.8
0.0%	minimum	1.8

Moments

Mean	9.7333333
Std Dev	6.8711959
Std Err Mean	3.9670868
Upper 95% Mean	26.80233
Lower 95% Mean	-7.335664
N	3

Turbidity (NTU)



Quantiles

100.0%	maximum	0.97
99.5%		0.97
97.5%		0.97
90.0%		0.97
75.0%	quartile	0.97
50.0%	median	0.92
25.0%	quartile	0.45
10.0%		0.45
2.5%		0.45
0.5%		0.45
0.0%	minimum	0.45

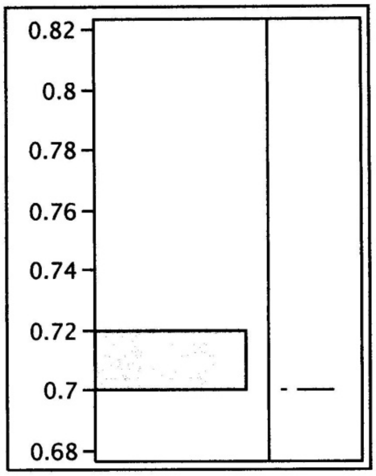
Moments

Mean	0.78
Std Dev	0.2868798
Std Err Mean	0.1656301
Upper 95% Mean	1.4926488
Lower 95% Mean	0.0673512
N	3

Distributions Hydration Time (hrs)=16

Distributions Hydration Time (hrs)=16

Sediment (mg)



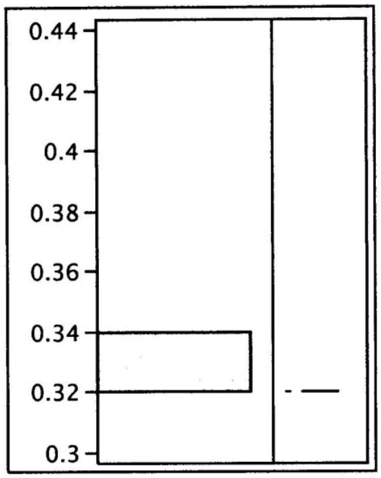
Quantiles

100.0%	maximum	0.7
99.5%		0.7
97.5%		0.7
90.0%		0.7
75.0%	quartile	0.7
50.0%	median	0.7
25.0%	quartile	0.7
10.0%		0.7
2.5%		0.7
0.5%		0.7
0.0%	minimum	0.7

Moments

Mean	0.7
Std Dev	.
Std Err Mean	.
Upper 95% Mean	.
Lower 95% Mean	.
N	1

Turbidity (NTU)



Quantiles

100.0%	maximum	0.32
99.5%		0.32
97.5%		0.32
90.0%		0.32
75.0%	quartile	0.32
50.0%	median	0.32
25.0%	quartile	0.32
10.0%		0.32
2.5%		0.32
0.5%		0.32
0.0%	minimum	0.32

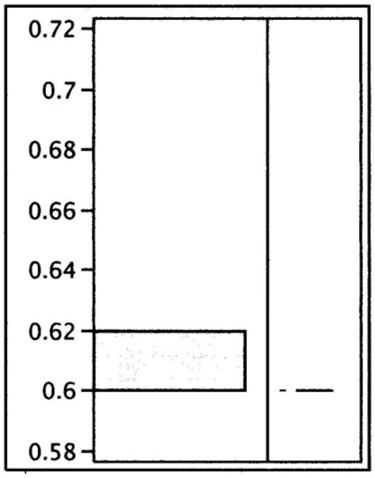
Moments

Mean	0.32
Std Dev	.
Std Err Mean	.
Upper 95% Mean	.
Lower 95% Mean	.
N	1

Distributions Hydration Time (hrs)=48

Distributions Hydration Time (hrs)=48

Sediment (mg)



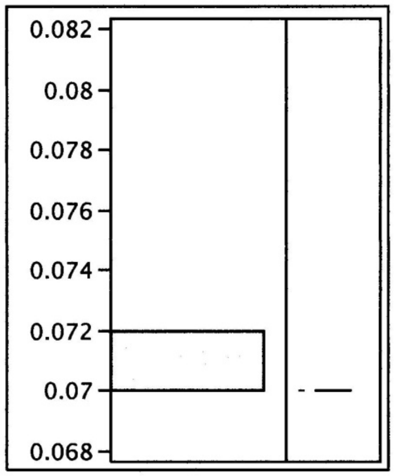
Quantiles

100.0%	maximum	0.6
99.5%		0.6
97.5%		0.6
90.0%		0.6
75.0%	quartile	0.6
50.0%	median	0.6
25.0%	quartile	0.6
10.0%		0.6
2.5%		0.6
0.5%		0.6
0.0%	minimum	0.6

Moments

Mean	0.6
Std Dev	.
Std Err Mean	.
Upper 95% Mean	.
Lower 95% Mean	.
N	1

Turbidity (NTU)



Quantiles

100.0%	maximum	0.07
99.5%		0.07
97.5%		0.07
90.0%		0.07
75.0%	quartile	0.07
50.0%	median	0.07
25.0%	quartile	0.07
10.0%		0.07
2.5%		0.07
0.5%		0.07
0.0%	minimum	0.07

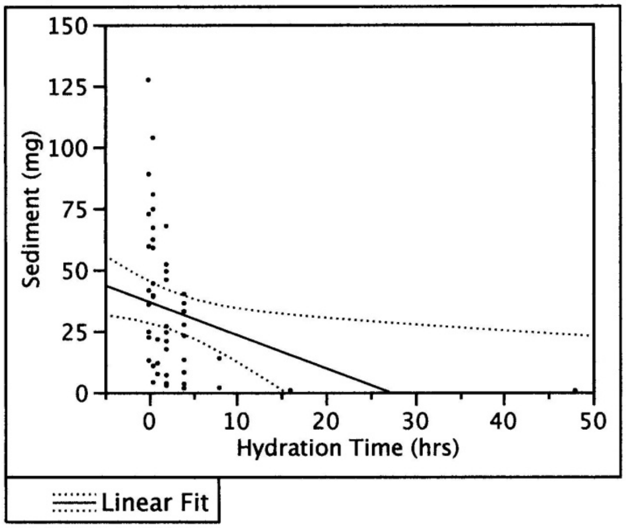
Moments

Mean	0.07
Std Dev	.
Std Err Mean	.
Upper 95% Mean	.
Lower 95% Mean	.
N	1

Drip Test Portland Cement Hydration Time 022011: Fit Y by X of Sediment (mg), Turbidity (N

Fit Y by X Group

Bivariate Fit of Sediment (mg) By Hydration Time (hrs)



Linear Fit

Sediment (mg) = 36.844675 - 1.3558919*Hydration Time (hrs)

Summary of Fit

RSquare	0.101219
RSquare Adj	0.083596
Root Mean Square Error	28.02701
Mean of Response	32.53396
Observations (or Sum Wgts)	53

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4511.625	4511.63	5.7435
Error	51	40061.174	785.51	**Prob > F**
C. Total	52	44572.799		0.0203*

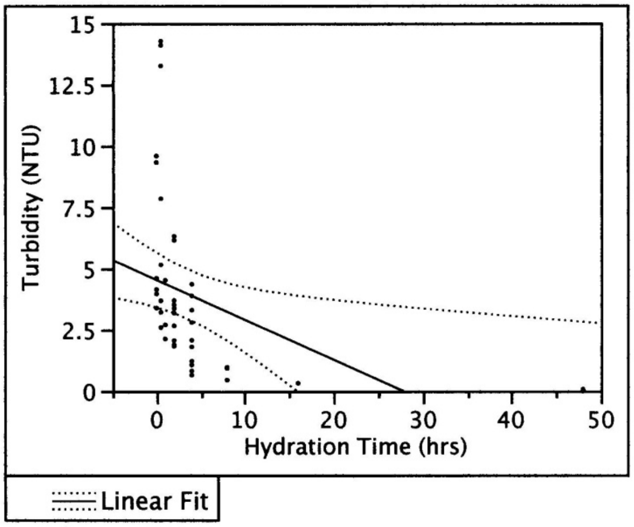
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	36.844675	4.249275	8.67	<.0001*
Hydration Time (hrs)	-1.355892	0.565764	-2.40	0.0203*

Bivariate Fit of Turbidity (NTU) By Hydration Time (hrs)

Fit Y by X Group

Bivariate Fit of Turbidity (NTU) By Hydration Time (hrs)



Linear Fit

Turbidity (NTU) = 4.5291645 - 0.1626894*Hydration Time (hrs)

Summary of Fit

RSquare	0.122784
RSquare Adj	0.101898
Root Mean Square Error	3.287715
Mean of Response	3.948659
Observations (or Sum Wgts)	44

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	63.54387	63.5439	5.8788
Error	42	453.98105	10.8091	**Prob > F**
C. Total	43	517.52492		0.0197*

Parameter Estimates

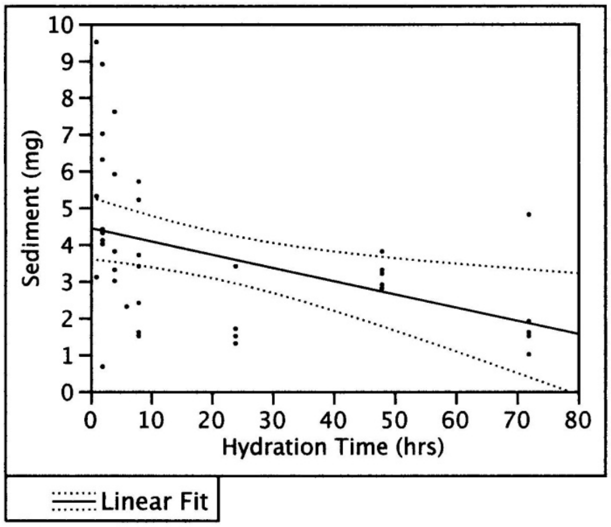
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.5291645	0.550439	8.23	<.0001*
Hydration Time (hrs)	-0.162689	0.067099	-2.42	0.0197*

Drip Test Bridge Deck Hydration 022011

	Date	Sediment	Hydration Time (hrs)	Test Type	Sediment (mg)	Turbidity (NTU)
1	07/20/2010	Bridge Deck Debris	2	Drip test	8.9	1.61
2	07/20/2010	Bridge Deck Debris	2	Drip test	6.3	2.8
3	07/20/2010	Bridge Deck Debris	2	Drip test	4.3	2.18
4	07/20/2010	Bridge Deck Debris	2	Drip test	4	1.8
5	07/20/2010	Bridge Deck Debris	2	Drip test	4.1	3.25
6	07/20/2010	Bridge Deck Debris	4	Drip test	7.6	3.55
7	07/20/2010	Bridge Deck Debris	4	Drip test	5.9	1.86
8	07/20/2010	Bridge Deck Debris	4	Drip test	3.8	1.46
9	07/20/2010	Bridge Deck Debris	4	Drip test	3	1.99
10	07/20/2010	Bridge Deck Debris	4	Drip test	3.3	1.69
11	07/20/2010	Bridge Deck Debris	6	Drip test	2.3	1.11
12	07/20/2010	Bridge Deck Debris	8	Drip test	2.4	0.98
13	07/20/2010	Bridge Deck Debris	8	Drip test	1.5	0.67
14	07/20/2010	Bridge Deck Debris	8	Drip test	1.6	1.13
15	07/20/2010	Bridge Deck Debris	8	Drip test	3.4	5.02
16	07/21/2010	Bridge Deck Debris	24	Drip test	1.3	0.28
17	07/21/2010	Bridge Deck Debris	24	Drip test	3.4	0.1
18	07/21/2010	Bridge Deck Debris	24	Drip test	1.5	0.18
19	07/21/2010	Bridge Deck Debris	24	Drip test	1.7	0.07
20	07/21/2010	Bridge Deck Debris	24	Drip test	1.7	0.19
21	07/22/2010	Bridge Deck Debris	48	Drip test	3.2	0.05
22	07/22/2010	Bridge Deck Debris	48	Drip test	3.8	0.78
23	07/22/2010	Bridge Deck Debris	48	Drip test	3.3	0.56
24	07/22/2010	Bridge Deck Debris	48	Drip test	2.9	0.57
25	07/22/2010	Bridge Deck Debris	48	Drip test	2.8	0.52
26	07/23/2010	Bridge Deck Debris	72	Drip test	1.6	0.22
27	07/23/2010	Bridge Deck Debris	72	Drip test	4.8	1.31
28	07/23/2010	Bridge Deck Debris	72	Drip test	1.5	0.05
29	07/23/2010	Bridge Deck Debris	72	Drip test	1	0.3
30	07/23/2010	Bridge Deck Debris	72	Drip test	1.9	0.22
31	08/02/2010	Bridge Deck Debris	1	Drip test	5.3	2.19
32	08/02/2010	Bridge Deck Debris	1	Drip test	9.5	2.38
33	08/02/2010	Bridge Deck Debris	1	Drip test	3.1	2.47
34	08/02/2010	Bridge Deck Debris	2	Drip test	0.67	1.06
35	08/02/2010	Bridge Deck Debris	2	Drip test	7	1.58
36	08/02/2010	Bridge Deck Debris	2	Drip test	4.4	0.92
37	08/02/2010	Bridge Deck Debris	8	Drip test	5.7	0.45
38	08/02/2010	Bridge Deck Debris	8	Drip test	5.2	0.64
39	08/02/2010	Bridge Deck Debris	8	Drip test	3.7	0.48

Fit Y by X Group

Bivariate Fit of Sediment (mg) By Hydration Time (hrs)



Linear Fit

Sediment (mg) = 4.4320317 - 0.0359065*Hydration Time (hrs)

Summary of Fit

RSquare	0.176137
RSquare Adj	0.15387
Root Mean Square Error	1.962731
Mean of Response	3.676154
Observations (or Sum Wgts)	39

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	30.47321	30.4732	7.9104
Error	37	142.53551	3.8523	**Prob > F**
C. Total	38	173.00872		0.0078*

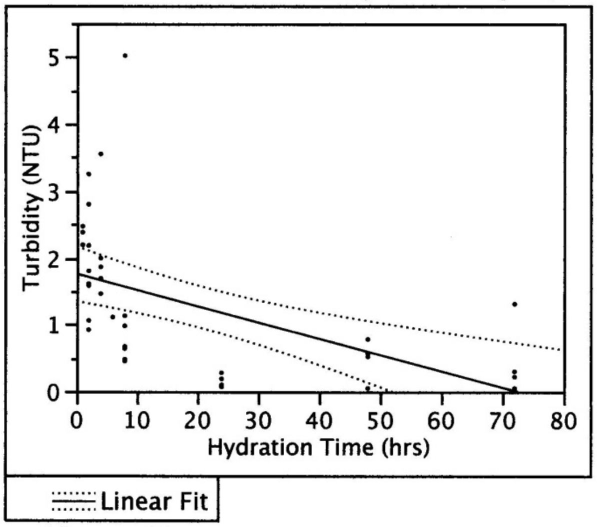
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	4.4320317	0.413528	10.72	<.0001*
Hydration Time (hrs)	-0.035906	0.012767	-2.81	0.0078*

Bivariate Fit of Turbidity (NTU) By Hydration Time (hrs)

Fit Y by X Group

Bivariate Fit of Turbidity (NTU) By Hydration Time (hrs)



Linear Fit

Turbidity (NTU) = 1.7586341 - 0.0242591*Hydration Time (hrs)

Summary of Fit

RSquare	0.290786
RSquare Adj	0.271618
Root Mean Square Error	0.95755
Mean of Response	1.247949
Observations (or Sum Wgts)	39

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	13.909833	13.9098	15.1705
Error	37	33.925403	0.9169	**Prob > F**
C. Total	38	47.835236		0.0004*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.7586341	0.201746	8.72	<.0001*
Hydration Time (hrs)	-0.024259	0.006228	-3.89	0.0004*

Appendix F
Sedimentation Analysis

Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

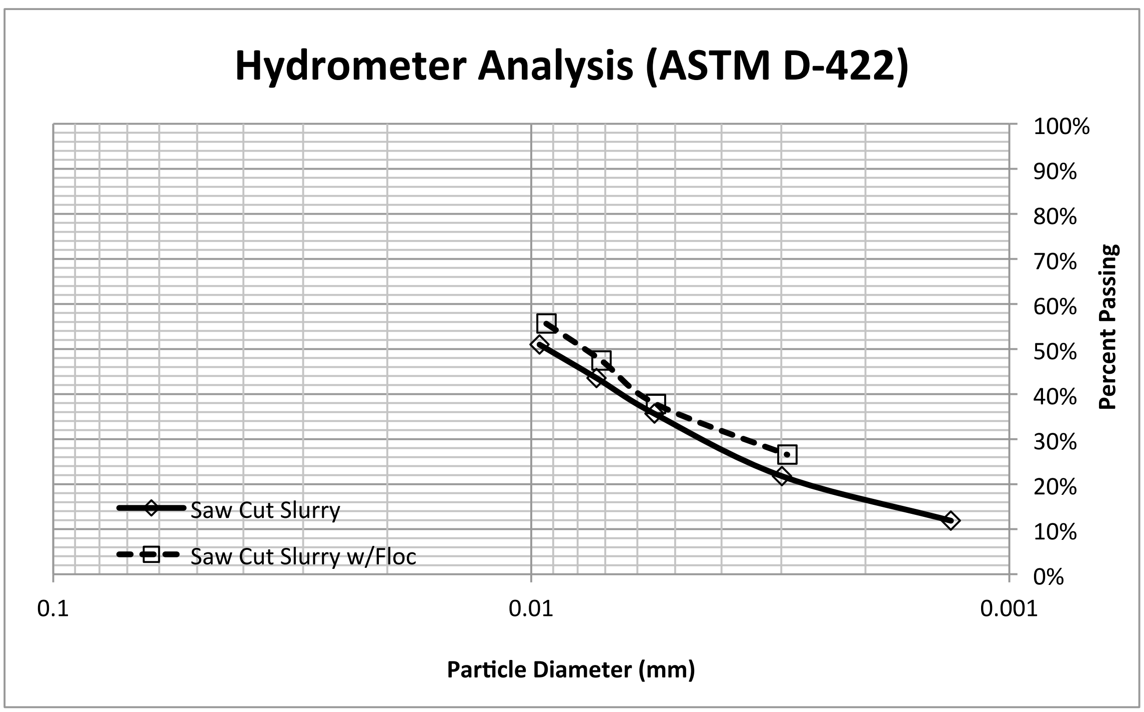
Material	Saw Cut Slurry w/Floc	Sample Mass	97.0028	g
Sample Date	July 28, 2010			
Sample Location	TH 61 Maplewood			

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L) + 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	0			
5	0			
15	54.5	7.36	0.009300403	55.6%
30	46.5	8.67	0.007138732	47.5%
60	37	10.23	0.005482717	37.8%
250	26	12.03	0.002913254	26.5%
1440	0			



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

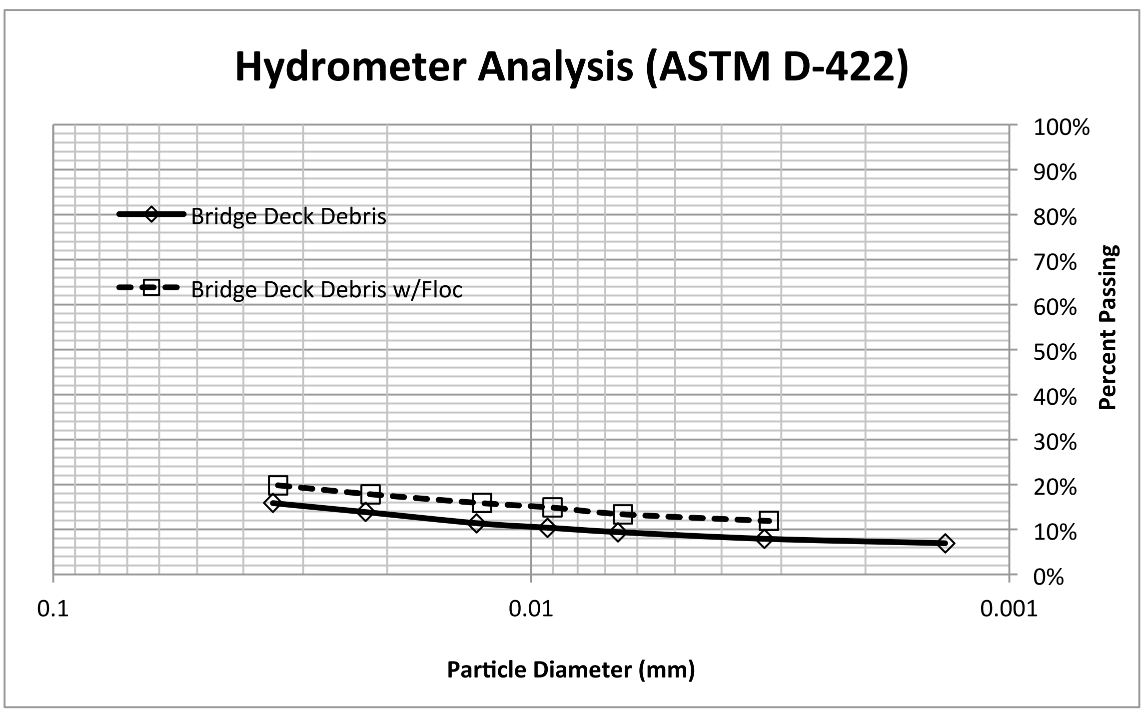
Material	Bridge Deck Debris w/Floc	Sample Mass	100	g
Sample Date	July 10, 2010			
Sample Location	LaSalle Ave over I-94			

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L) + 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	20	13.01	0.03387697	19.8%
5	18	13.34	0.02169398	17.8%
15	16	13.67	0.012678037	15.8%
30	15	13.83	0.009018337	14.9%
60	13.5	14.08	0.006433372	13.4%
250	12	14.33	0.003179107	11.9%
1440	0			



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

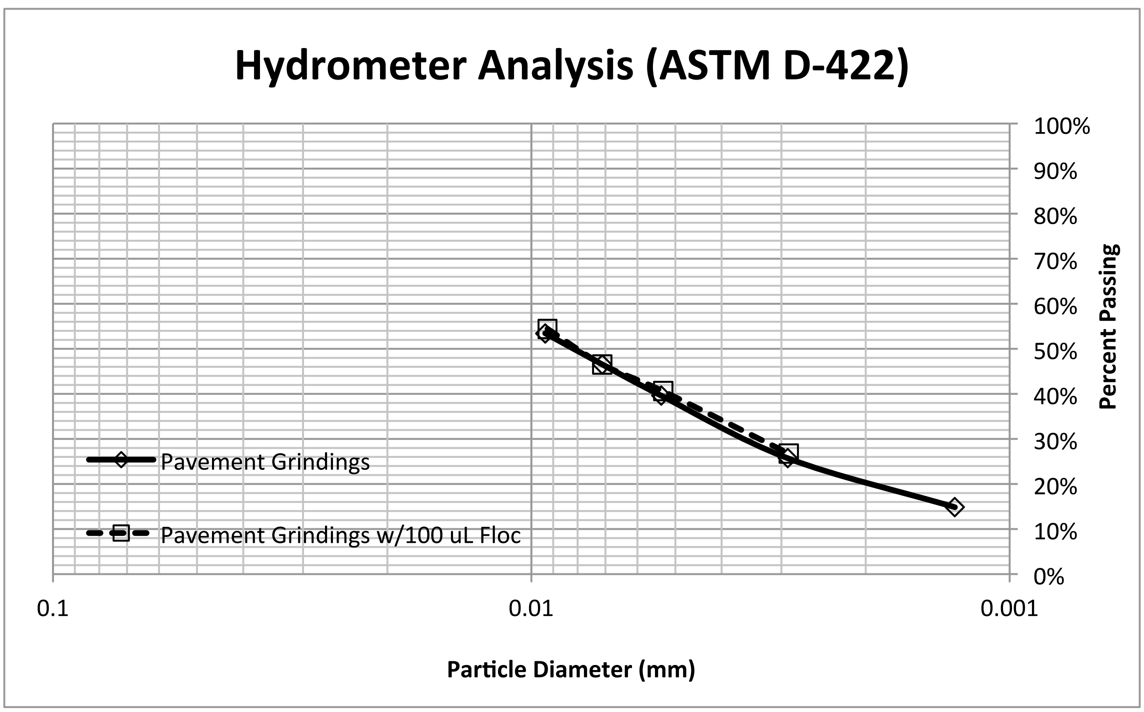
Material	Pavement Grindings w/100 u	Sample Mass	100	g
Sample Date	September 14, 2010			
Sample Location	Duluth			

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L) + 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	0			
5	0			
15	55	7.27	0.009248427	54.5%
30	47	8.59	0.007104889	46.5%
60	41	9.57	0.005303961	40.6%
250	27	11.87	0.002893329	26.7%
1440	0			



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

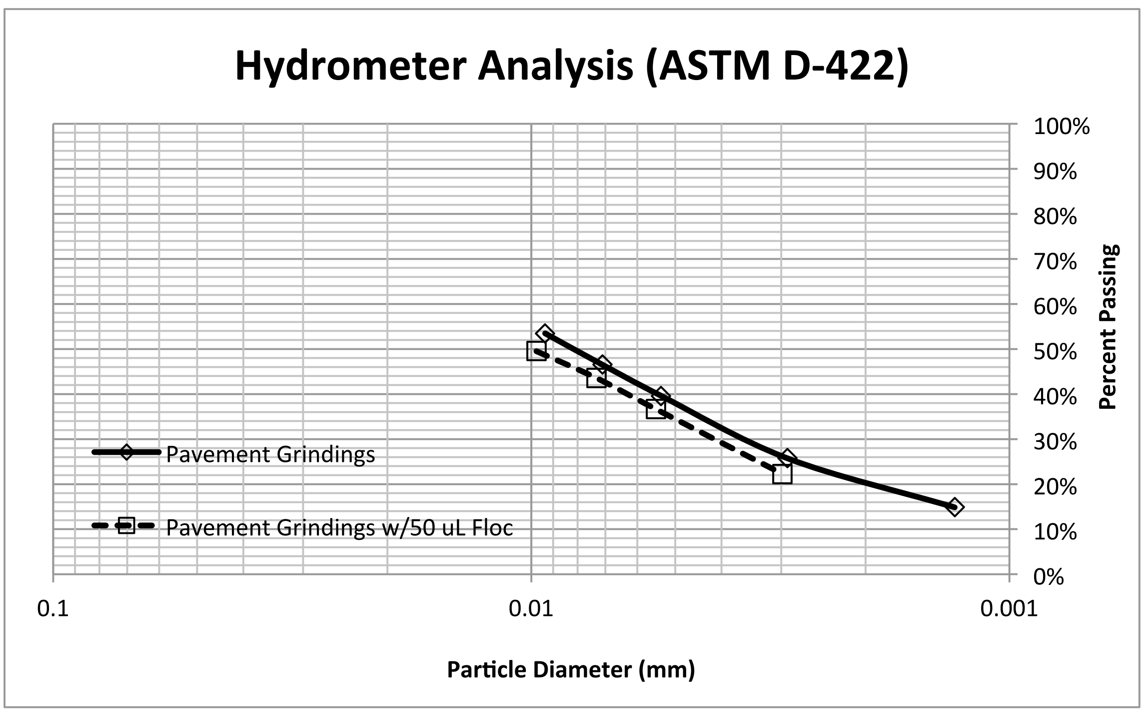
Material	Pavement Grindings w/50 ul	Sample Mass	100	g
Sample Date	September 14, 2010			
Sample Location	Duluth			

From ASTM D422

Estimated Gs =	2.70	
Gs Corr, a =	0.99	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01328	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L) + 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	0			
5	0			
15	50	8.09	0.009755733	49.5%
30	44	9.08	0.007305595	43.6%
60	37	10.23	0.005482717	36.6%
250	22.5	12.60	0.00298194	22.3%
1440	0			



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

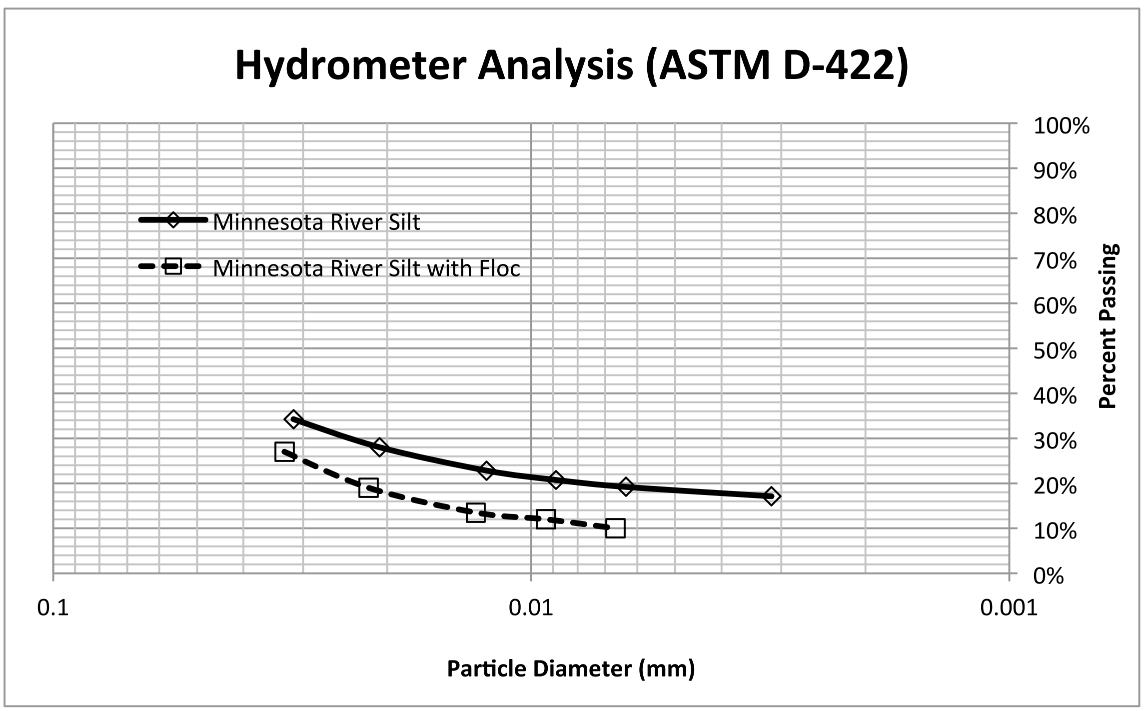
Material	Minnesota River Silt with Flo	Sample Mass	100	g
Sample Date	July 10, 2010			
Sample Location	Seven Mile Creek Park			

From ASTM D422

Estimated Gs =	2.65	
Gs Corr, a =	1.00	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01348	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L)
+ 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	27	11.87	0.032835581	27.0%
5	19	13.18	0.021884948	19.0%
15	13.5	14.08	0.01306052	13.5%
30	12	14.33	0.009315504	12.0%
60	10	14.65	0.006662031	10.0%
250	0			
1440	0			



Hydrometer Data & Evaluation	Mn/DOT Concrete
S. Druschel	January 25, 2011

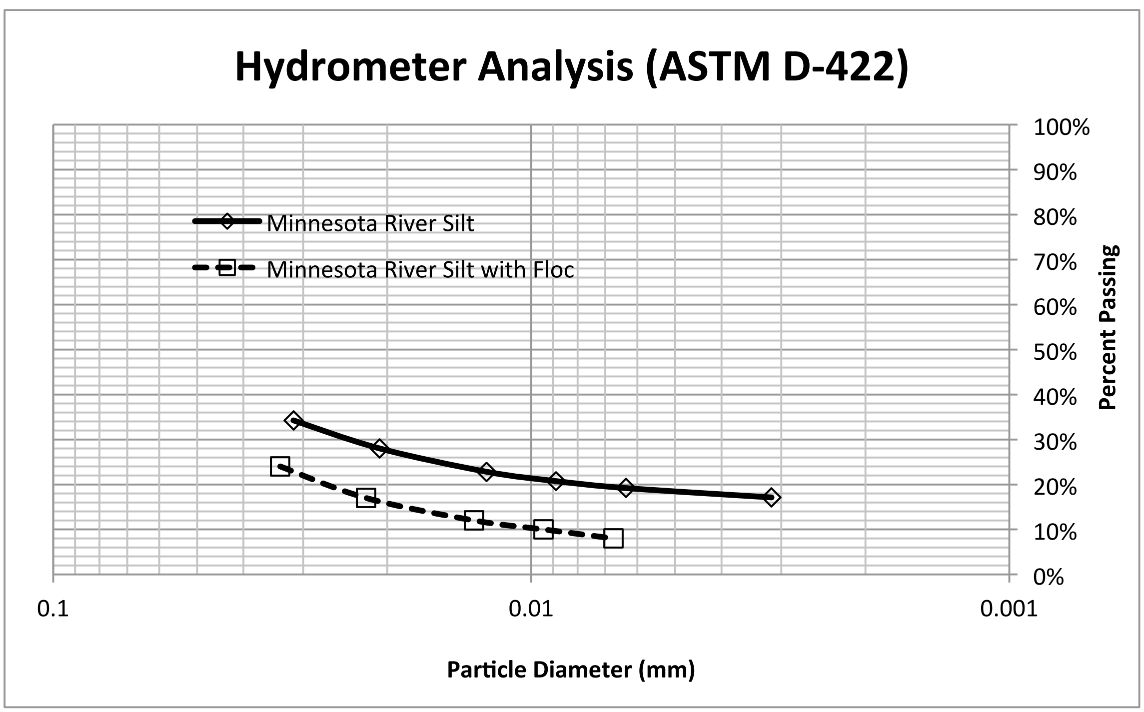
Material	Minnesota River Silt with Flo	Sample Mass	100	g
Sample Date	July 10, 2010			
Sample Location	Seven Mile Creek Park			

From ASTM D422

Estimated Gs =	2.65	
Gs Corr, a =	1.00	From ASTM D-422 Table 1
Lab Temp =	21	
K factor =	0.01348	From ASTM D-422 Table 3

Effective L (cm) = (10.5 cm - 8.2 cm * R / 50 g/L)
+ 0.5 * (14.0 cm - 67.0 cm^3/27.8 cm^2)

Time (min)	Hydrometer Reading	Effective Length (cm)	Diameter (mm)	Passing (%)
0	0			
2	24	12.36	0.033509344	24.0%
5	17	13.51	0.022155613	17.0%
15	12	14.33	0.013174112	12.0%
30	10	14.65	0.009421535	10.0%
60	8	14.98	0.006736171	8.0%
250	0			
1440	0			



Hydrometer Data & Evaluation
Mn/DOT Concrete
S. Druschel
1/25/11

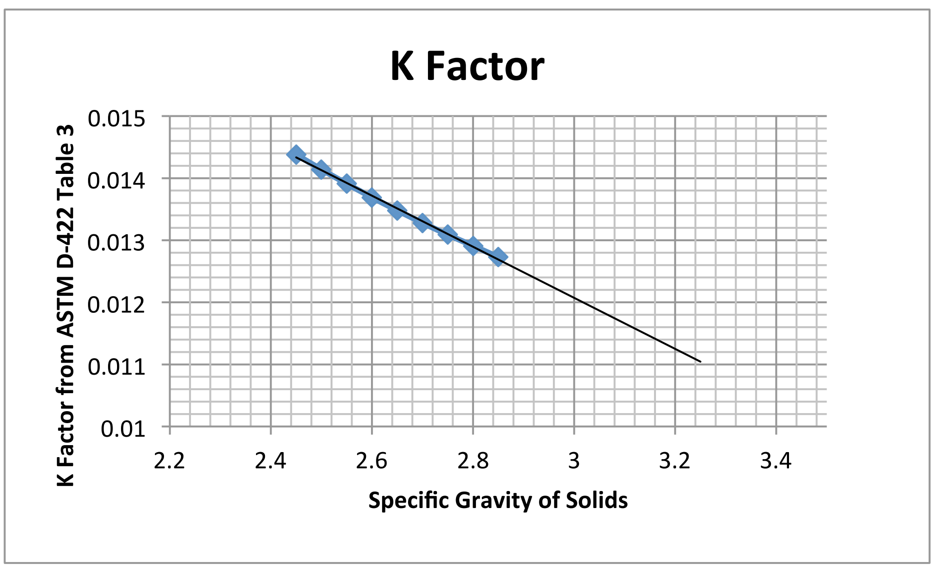
Reference: See Druschel Lab Book, Pg 81, dated January 23, 2011
ASTM D 422

Hydrometer Readings (mg/L)

Time (min)	PC	SCS	BD	Silt	SCS w/ Floc	BD w/ Floc	Silt w/ Floc		DG	DG	DG w 100 ul floc	DG w 50 ul floc
0												
2			16	33		20	27	24				
5			14	27		18	19	17				
15		51.5	11.5	22	54.5	16	13.5	12	54	53	55	50
30	50.5	44	10.5	20	46.5	15	12	10	47	46	47	44
60	38	36	9.5	18.5	37	13.5	10	8	40	41	41	37
250	16.5	22	8	16.5	26	12			26	26.5	27	22.5
1440	7	12	7						15	15		
Mass (g)	100.0	100.0	100.0	96.4	97.0	100.0 check	100.0	100.0	100.0	100.0	100.0	100.0
Date	8/19	8/19	8/19	8/19	8/19	8/19	8/19	8/19				
					check	check	100 ul Floc	100 ul Floc			100 ul Floc	50 ul Floc

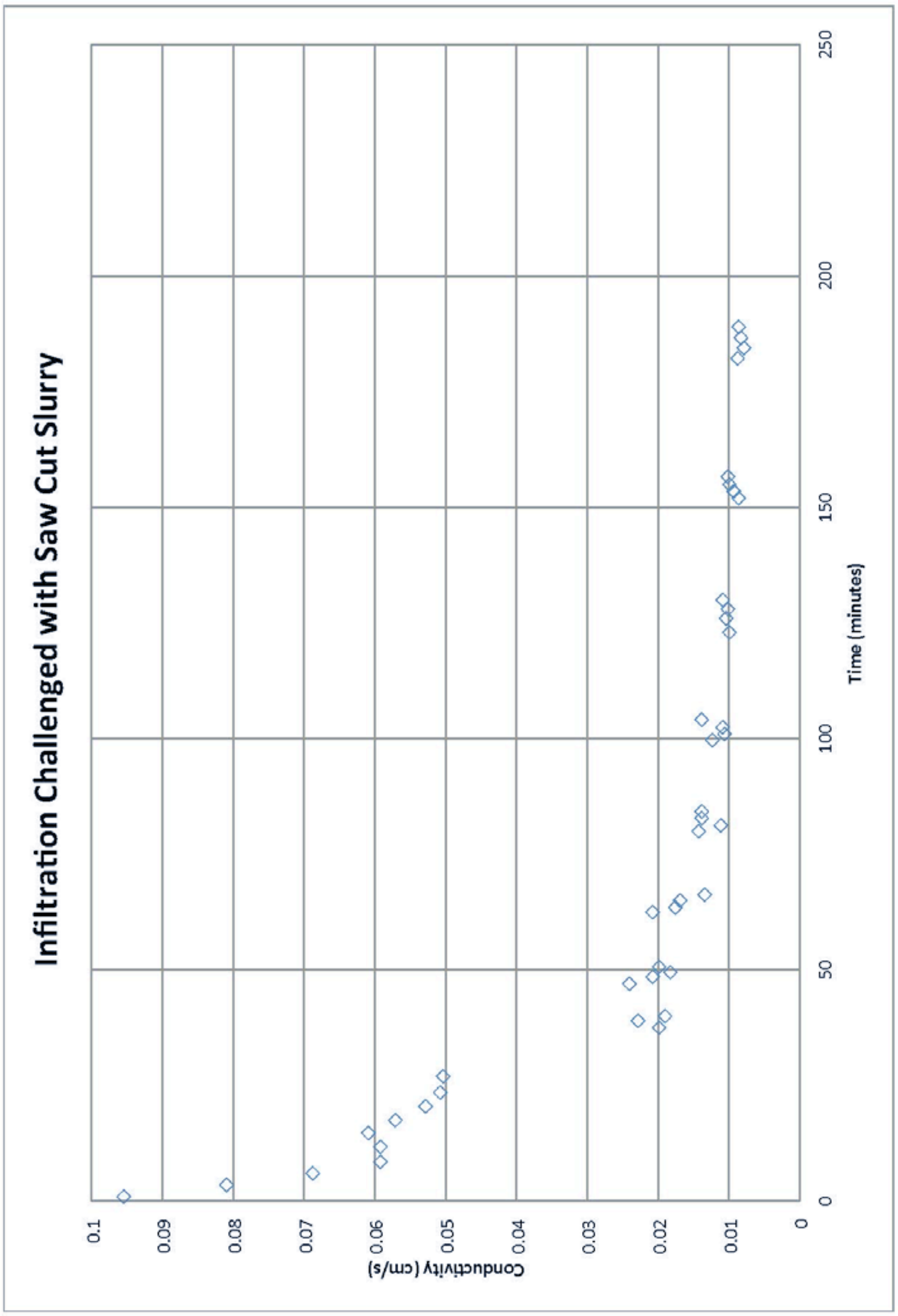
Graph values of K

	21 deg C
2.45	0.01438
2.50	0.01414
2.55	0.01391
2.60	0.01369
2.65	0.01348
2.70	0.01328
2.75	0.01309
2.80	0.01291
2.85	0.01273
2.90	
2.95	
3.00	
3.05	
3.10	
3.15	
3.20	
3.25	



Appendix G
Infiltration Analysis

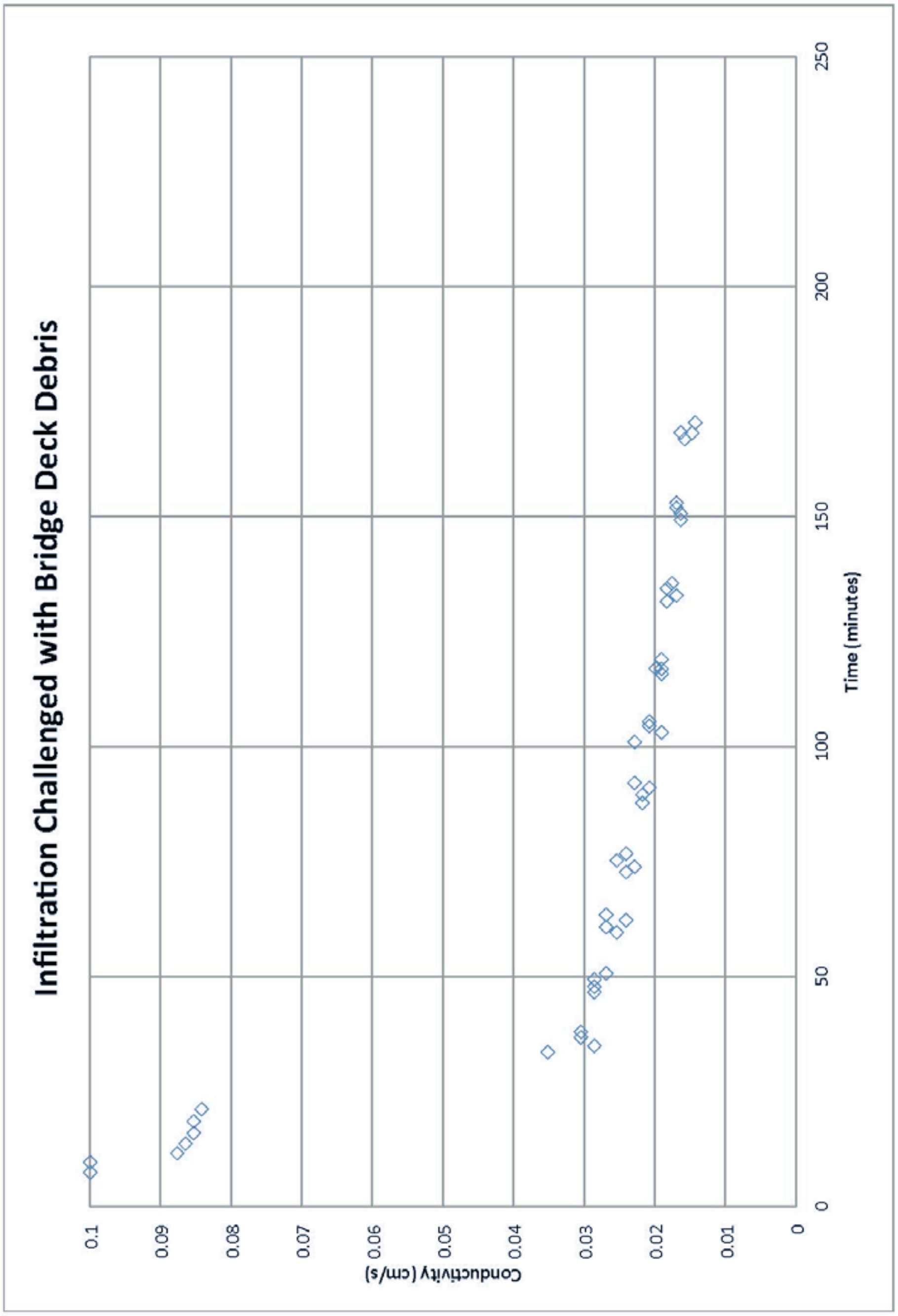
Infiltrometer with Saw Cut Slurry					
Q=kiA	k=Q/iA	i=Δh/L=12in/4in=3	A=∏r²=36∏	iA=3*36∏=108∏in²	
				1in=2.54cm	
Time (s)	14 L time (s)	Q=Vol (mL) / time (s)	k=vol/time/cm² = cm/s	108∏in²=2188.9 cm²	
60	67	208.9552239	0.095457965	2188.97631	
150	filled				
210	79	177.2151899	0.080958021		
345	filled				
360	93	150.5376344	0.068770792		
480	filled				
510	108	129.6296296	0.059219293		
690	filled				
705	108	129.6296296	0.059219293		
870	filled				
885	105	133.3333333	0.060911273		
1005	filled				
1050	112	125	0.057104318		
1125	filled				
1230	121	115.7024793	0.05285689		
1380	filled				
1410	126	111.1111111	0.050759394		
1575	filled				
1620	127	110.2362205	0.050359714	0.0513	8.3 min.
Now Challenged with Saw Cut Slurry					
Time (s)	1 L time (s)	Q vol (ml) / time (s)	k=vol/time/cm² = cm/s		
1860	200g added				
2160	filled				
2250	23	43.47826087	0.019862372		6.5 min.
2340	20	50	0.022841727		
2400	24	41.66666667	0.019034773	0.0206	
2460	100g added				
2775	filled				
2820	19	52.63157895	0.024043924		6 min.
2910	22	45.45454545	0.020765207		
2970	25	40	0.018273382		
3040	23	43.47826087	0.019862372	0.0207	
3060	200g added				
3660	filled				
3750	22	45.45454545	0.020765207		11.5 min.
3810	26	38.46153846	0.017570559		
3900	27	37.03703704	0.016919798		
3975	34	29.41176471	0.01343631	0.0172	
4020	100g added				
4680	filled				
4800	32	31.25	0.01427608		13 min.
4875	41	24.3902439	0.011142306		
4970	33	30.3030303	0.013843471		
5055	33	30.3030303	0.013843471	0.0133	
5130	100g added				
5850	filled				
5980	37	27.02702703	0.01234688		14.2 min.
6060	43	23.25581395	0.010624059		
6150	42	23.80952381	0.010877013		
6247	33	30.3030303	0.013843471	0.0119	
6300	100g added				
7200	filled				
7380	46	21.73913043	0.009931186		18.0 min.
7560	44	22.72727273	0.010382603		
7680	45	22.22222222	0.010151879		
7800	42	23.80952381	0.010877013	0.0103	
7860	100g added				
8970	filled				
9120	53	18.86792453	0.00861952		21.0 min.
9210	49	20.40816327	0.009323154		
9300	46	21.73913043	0.009931186		
9400	45	22.22222222	0.010151879	0.0095	
9480	100g added				
10800	filled				
10935	52	19.23076923	0.00878528		24.3 min.
11070	58	17.24137931	0.007876458		
11200	55	18.18181818	0.008306083		
11340	53	18.86792453	0.00861952	0.0084	


Infiltration Challenged with Saw Cut Slurry
Conductivity (cm/s)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Time (minutes)
0
50
100
150
200
250

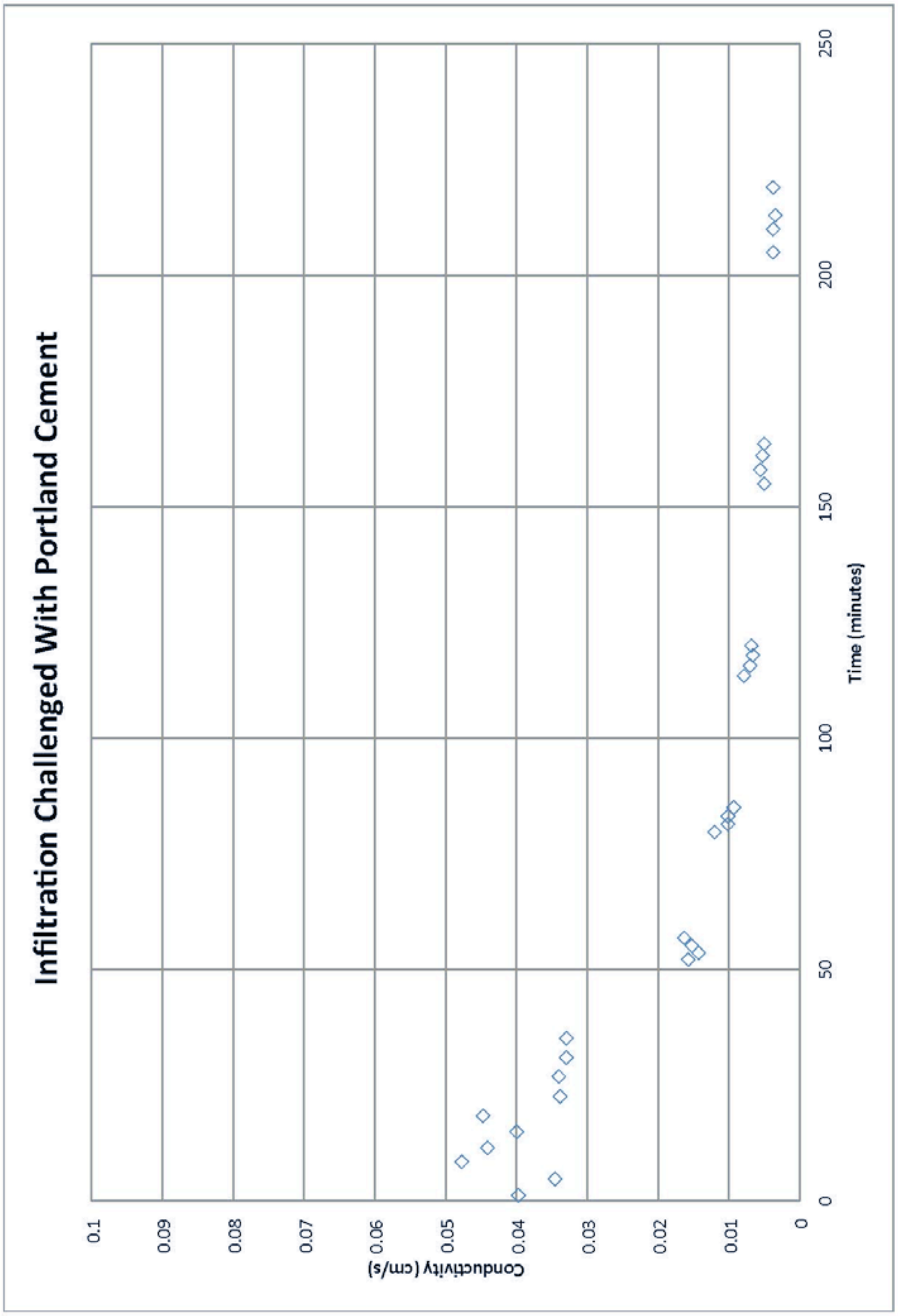
Infiltrometer with Bridge Deck Run through #4 Sieve

Q=kiA	k=Q/iA	i=δh/L=12in/4in=3	$A=\pi r^2=36\pi$	$iA=3*36\pi=108\pi in^2$	
				1in=2.54cm	
Time (s)	14 L time (s)	Q=Vol (mL) / time (s)	$k=vol/time/cm^2 = cm/s$	$108\pi in^2=2188.9\ cm^2$	
90	53	264.1509434	0.120673276	iA=.218897631	
153	filled			2188.97631	
210	58	241.3793103	0.110270408		
278	filled				
321	60	233.3333333	0.106594728		
391	filled				
442	64	218.75	0.099932557		
522	filled				
575	64	218.75	0.099932557		
649	filled				
694	73	191.7808219	0.087612105		
777	filled				
820	74	189.1891892	0.086428157		
907	filled				
957	75	186.6666667	0.085275782		
1045	filled				
1110	75	186.6666667	0.085275782		
1196	filled				
1269	76	184.2105263	0.084153732		
1595	filled			0.0847	10.6 min.
Now Challenged with Bridge Deck Run Through #4 sieve					
Time (s)	14 L time (s)				
1672	200g added		0		
2015	13	76.92307692	0.035141119		5.7 min.
2096	16	62.5	0.028552159		
2204	15	66.66666667	0.030455636		
2277	15	66.66666667	0.030455636	0.0312	
2338	200g added				
2696	filled				
2795	16	62.5	0.028552159		7.6 min.
2866	16	62.5	0.028552159		
2963	16	62.5	0.028552159		
3042	17	58.82352941	0.02687262	0.0281	
3112	200g added				
3474	filled				
3577	18	55.55555556	0.025379697		7.8 min.
3646	17	58.82352941	0.02687262		
3735	19	52.63157895	0.024043924		
3806	17	58.82352941	0.02687262	0.0258	
3873	200g added				
4200	filled				
4362	19	52.63157895	0.024043924		8.2 min.
4433	20	50	0.022841727		
4515	18	55.55555556	0.025379697		
4603	19	52.63157895	0.024043924	0.0241	
4677	200g added				
5164	filled				
5265	21	47.61904762	0.021754026		9.8 min.
5372	21	47.61904762	0.021754026		
5464	22	45.45454545	0.020765207		
5527	20	50	0.022841727	0.0218	
5586	200g added				
6030	filled				
6062	20	50	0.022841727		7.9 min.
6185	24	41.66666667	0.019034773		
6271	22	45.45454545	0.020765207		
6327	22	45.45454545	0.020765207	0.0209	
6393	200g added				
6885	filled				
6951	24	41.66666667	0.019034773		9.3 min.
7015	24	41.66666667	0.019034773		
7022	23	43.47826087	0.019862372		
7138	24	41.66666667	0.019034773	0.0192	
7200	200g added				
7792	filled				
7895	25	40	0.018273382		11.6 min.
7972	27	37.03703704	0.016919798		
8066	25	40	0.018273382		
8131	26	38.46153846	0.017570559	0.0178	
8206	200g added				
8840	filled				
8957	28	35.71428571	0.01631552		12.5 min.
9042	28	35.71428571	0.01631552		
9118	27	37.03703704	0.016919798		
9182	27	37.03703704	0.016919798	0.0166	
9243	200g added				
9954	filled				
10012	29	34.48275862	0.015752915		12.8 min.
10093	31	32.25806452	0.014736598		
10100	28	35.71428571	0.01631552		
10228	32	31.25	0.01427608	0.0153	

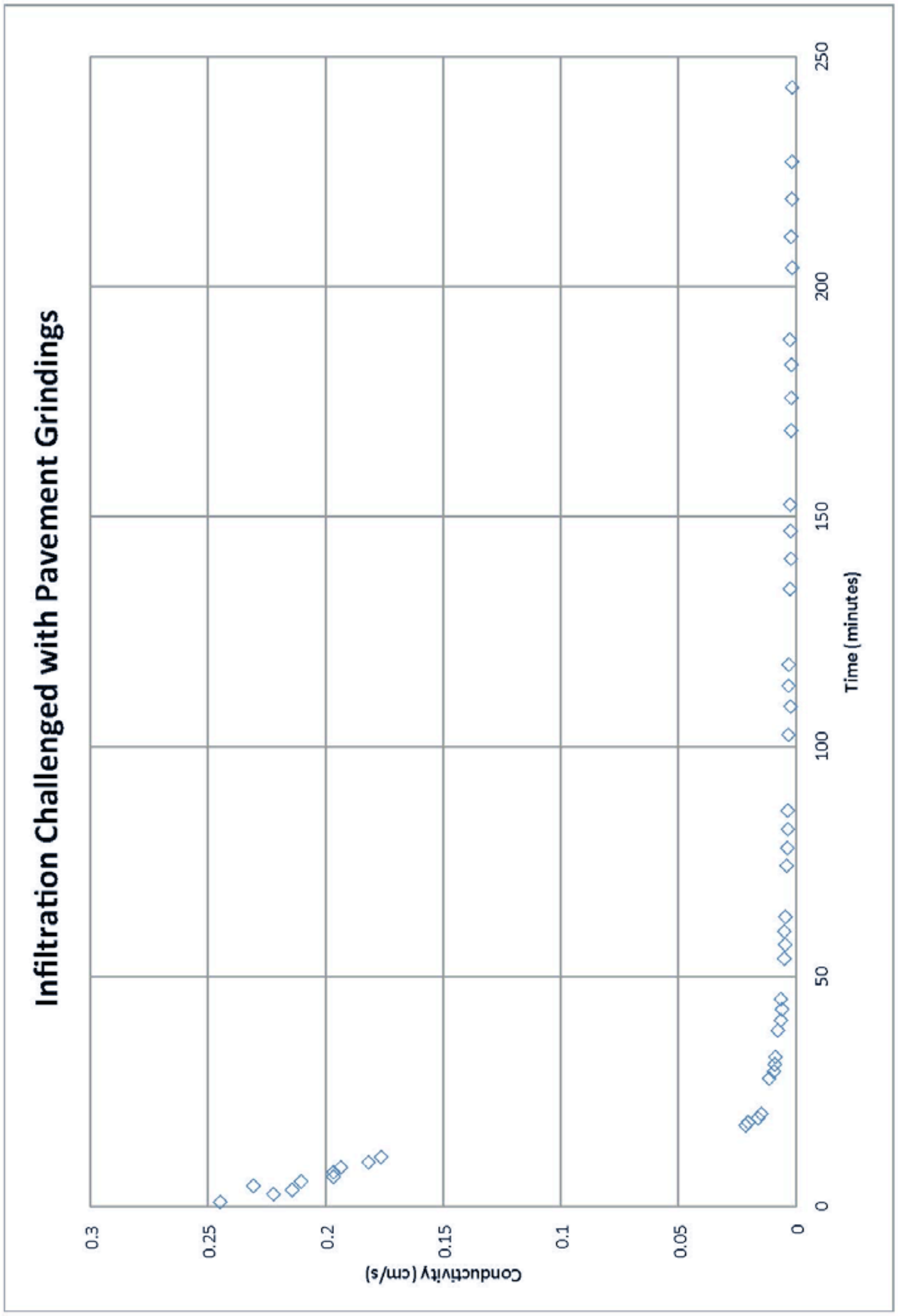
Time	K	Time (min)
90	0.1206733	1.5
153		2.6
210	0.1102704	3.5
278		4.6
321	0.1065947	5.4
391		6.5
442	0.0999326	7.4
522		8.7
575	0.0999326	9.6
649		10.8
694	0.0876121	11.6
777		13.0
820	0.0864282	13.7
907		15.1
957	0.0852758	16.0
1045		17.4
1110	0.0852758	18.5
1196		19.9
1269	0.0841537	21.2
1595		26.6
1672		27.9
2015	0.0351411	33.6
2096	0.0285522	34.9
2204	0.0304556	36.7
2277	0.0304556	38.0
2338		39.0
2696		44.9
2795	0.0285522	46.6
2866	0.0285522	47.8
2963	0.0285522	49.4
3042	0.0268726	50.7
3112		51.9
3474		57.9
3577	0.0253797	59.6
3646	0.0268726	60.8
3735	0.0240439	62.3
3806	0.0268726	63.4
3873		64.6
4200		70.0
4362	0.0240439	72.7
4433	0.0228417	73.9
4515	0.0253797	75.3
4603	0.0240439	76.7
4677		78.0
5164		86.1
5265	0.021754	87.8
5372	0.021754	89.5
5464	0.0207652	91.1
5527	0.0228417	92.1
5586		93.1
6030		100.5
6062	0.0228417	101.0
6185	0.0190348	103.1
6271	0.0207652	104.5
6327	0.0207652	105.5
6393		106.6
6885		114.8
6951	0.0190348	115.9
7015	0.0190348	116.9
7022	0.0198624	117.0
7138	0.0190348	119.0
7200		120.0
7792		129.9
7895	0.0182734	131.6
7972	0.0169198	132.9
8066	0.0182734	134.4
8131	0.0175706	135.5
8206		136.8
8840		147.3
8957	0.0163155	149.3
9042	0.0163155	150.7
9118	0.0169198	152.0
9182	0.0169198	153.0
9243		154.1
9954		165.9
10012	0.0157529	166.9
10093	0.0147366	168.2
10100	0.0163155	168.3
10228	0.0142761	170.5


Infiltration Challenged with Bridge Deck Debris
Conductivity (cm/s)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Time (minutes)
0
50
100
150
200
250

Infiltrometer with Portland Cement					
Q=kiA	k=Q/iA	i=Δh/L=12in/4	A=∏r²=36∏	iA=3*36∏=108∏in²	
				1in=2.54cm	
Time (s)	14 L time (s)	Q=Vol (mL) / t	k=vol/time/cm² = cm	108∏in²=2188.9 cm²	
45	filled		0	iA=.218897631	
75	161	86.95652174	0.039724743	2188.97631	
240	filled				
285	185	75.67567568	0.034571263		
480	filled				
510	134	104.4776119	0.047728982		
660	filled				
690	145	96.55172414	0.044108163		
870	filled				
900	160	87.5	0.039973023		
1065	filled				
1105	143	97.9020979	0.044725061		
1320	filled				
1358	189	74.07407407	0.033839596		
1560	filled				
1616	188	74.46808511	0.034019594		
18115	filled				
1860	194	72.16494845	0.032967442		
2070	filled				
32110	194	72.16494845	0.032967442	0.0333	509.2 min.
Now Challenged with Portland Cement					
Time(s)	14 L time (s)				
2400	200g added		0		
3060	filled		0		
3132	29	34.48275862	0.015752915		12.2 min.
3220	32	31.25	0.01427608		
3310	30	33.33333333	0.015227818		
3411	28	35.71428571	0.01631552	0.0154	
3480	200g added				
4680	filled				
4784	38	26.31578947	0.012021962		21.7 min.
4888	45	22.22222222	0.010151879		
4990	45	22.22222222	0.010151879		
5102	49	20.40816327	0.009323154	0.0104	
5190	100g added				
6645	filled				
6810	58	17.24137931	0.007876458		27.0 min.
6940	65	15.38461538	0.007028224		
7074	69	14.49275362	0.006620791		
7200	67	14.92537313	0.006818426	0.0071	
7380	100g added				
9180	filled				
9300	91	10.98901099	0.00502016		32.0 min.
9480	82	12.19512195	0.005571153		
9665	87	11.49425287	0.005250972		
9817	91	10.98901099	0.00502016	0.0052	
9960	100g added				
12180	filled				
12300	122	8.196721311	0.003744545		39.0 min.
12600	122	8.196721311	0.003744545		
12780	133	7.518796992	0.003434846		
13140	122	8.196721311	0.003744545	0.0037	

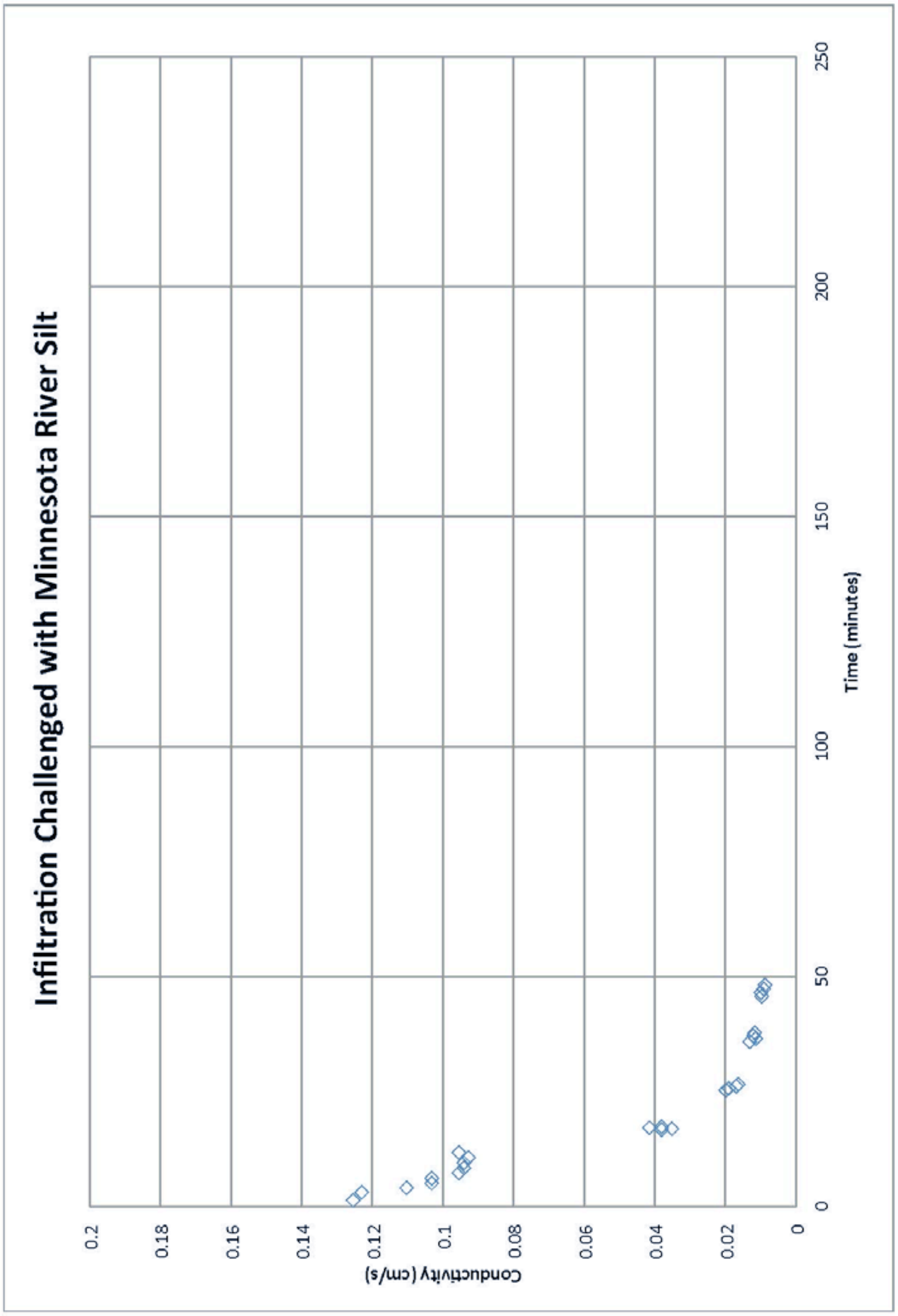

Infiltration Challenged With Portland Cement
Conductivity (cm/s)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
50
100
150
200
250
Time (minutes)

Infiltrometer with Pavement Grindings Run through #4 Sieve					
NOTE: Sand layer was 7.5 inches thick for L					
Q=kiA	k=Q/iA	i=δh/L=12in/7.5in=1.6	A=∏r^2=36∏	iA=1.6*36∏=57.6∏in^2	
				1in=2.54cm	
Time (s)	14 L time (s)	Q=Vol (mL) / time (s)	k=vol/time/cm^2 = cm/s	57.6∏in^2=1167.4 cm^2	
57	49	285.7142857	0.244741395	iA=.1167413	
106	filled			1167.413	
160	54	259.2592593	0.222080154		
160	filled				
216	56	250	0.21414872		
216	filled				
268	52	269.2307692	0.230621699		
268	filled				
325	57	245.6140351	0.210391725		
325	filled				
386	61	229.5081967	0.196595546		
386	filled				
447	61	229.5081967	0.196595546		
447	filled				
509	62	225.8064516	0.193424651		
509	filled				
575	66	212.1212121	0.181701944		
575	filled				
643	68	205.8823529	0.17635777		
643	filled			0.1790	2.2 min.
Now Challenged with Pavement Grindings Run Through #4 sieve					
Time (s)	1 L time (s)				
1015	200g added		0		
1055	40	25	0.021414872		0.7 min.
1097	42	23.80952381	0.020395116		
1150	53	18.86792453	0.016162168		
1208	58	17.24137931	0.014768877	0.0182	
1259	200g added				
1593	filled				
1668	75	13.33333333	0.011421265		6.8 min.
1759	91	10.98901099	0.009413131		
1854	95	10.52631579	0.009016788		
1952	98	10.20408163	0.008740764	0.0096	
1952	200g added				
2185	filled				
2296	111	9.009009009	0.007717071		5.7 min.
2429	133	7.518796992	0.006440563		
2572	143	6.993006993	0.005990174		
2705	133	7.518796992	0.006440563	0.0066	
2705	200g added				
3060	filled				
3234	174	5.747126437	0.004922959		8.8 min.
3418	184	5.434782609	0.004655407		
3589	171	5.847953216	0.005009327		
3780	191	5.235602094	0.00448479	0.0048	
3780	200g added				
4230	filled				
4446	216	4.62962963	0.003965717		11.1 min.
4676	230	4.347826087	0.003724326		
4923	247	4.048582996	0.003467995		
5167	244	4.098360656	0.003510635	0.0037	
5180	200g added				
5887	filled				
6154	267	3.745318352	0.003208221		16.2 min.
6523	369	2.7100271	0.002321395		
6795	272	3.676470588	0.003149246		
7070	275	3.636363636	0.00311489	0.0029	
7070	200g added				
7722	filled				
8057	335	2.985074627	0.002557		16.5 min.
8451	394	2.538071066	0.002174099		
8815	364	2.747252747	0.002353283		
9158	343	2.915451895	0.002497361	0.0024	
9158	200g added				
9715	filled				
10124	409	2.444987775	0.002094364		16.1 min.
10551	427	2.341920375	0.002006077		
10983	432	2.314814815	0.001982859		
11310	327	3.058103976	0.002619556	0.0022	
11310	200g added				
11718	filled				
12248	530	1.886792453	0.001616217		15.6 min.
12653	405	2.469135802	0.002115049		
13147	494	2.024291498	0.001733998		
13633	486	2.057613169	0.001762541	0.0018	
13633	200g added				
14073	filled				
14602	529	1.890359168	0.001619272		16.2 min.
15112	510	1.960784314	0.001679598		
15675	563	1.776198934	0.001521483		
16202	527	1.897533207	0.001625417	0.0016	


Infiltration Challenged with Pavement Grindings
Conductivity (cm/s)
Time (minutes)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
50
100
150
200
250

Infiltrometer with Minnesota River Silt Run through #4 Sieve

$Q=kiA$	$k=Q/iA$	$i=\Delta h/L=12in/4in=3$	$A=\Pi r^2=36\Pi$	$iA=3*36\Pi=108\Pi in^2$	
				1in=2.54cm	
Time (s)	14 L time (s)	Q=Vol (mL) / time (s)	k=vol/time/cm^2 = cm/s	108∏in^2=2188.9 cm^2	
82	51	274.5098039	0.125405562	iA=.218897631	
133	filled			2188.97631	
185	52	269.2307692	0.122993916		
185	filled				
243	58	241.3793103	0.110270408		
243	filled				
305	62	225.8064516	0.103156188		
305	filled				
367	62	225.8064516	0.103156188		
367	filled				
434	67	208.9552239	0.095457965		
434	filled				
502	68	205.8823529	0.094054171		
502	filled				
570	68	205.8823529	0.094054171		
570	filled				
639	69	202.8985507	0.092691067		
639	filled				
706	67	208.9552239	0.095457965		
706	filled			0.0941	2.3 min.
Now Challenged with MN River Silt Run Through #4 sieve					
Time (s)	1 L time (s)				
990	200g added		0		
1002	12	83.33333333	0.038069546		0.2 min.
1015	13	76.92307692	0.035141119		
1026	11	90.90909091	0.041530413		
1038	12	83.33333333	0.038069546	0.0382	
1051	200g added				
1493	filled				
1516	23	43.47826087	0.019862372		7.8 min.
1540	24	41.66666667	0.019034773		
1567	27	37.03703704	0.016919798		
1595	28	35.71428571	0.01631552	0.0180	
1595	200g added				
2115	filled				
2150	35	28.57142857	0.013052416		9.3 min.
2190	40	25	0.011420864		
2228	38	26.31578947	0.012021962		
2267	39	25.64102564	0.011713706	0.0121	
2267	200g added				
2695	filled				
2742	47	21.27659574	0.009719884		7.9 min.
2788	46	21.73913043	0.009931186		
2838	50	20	0.009136691		
2890	52	19.23076923	0.00878528	0.0094	


Infiltration Challenged with Minnesota River Silt
Conductivity (cm/s)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
250
Time (minutes)

Appendix H
Geotextile Filtration Results

Geotextile Filteration of Concrete Sediments
Mn/DOT Concrete Sediments
S. Druschel
21-Jan-12

Sediment	Geotextile	Original Sed	Geotextile sed Caught	Proportion Caught on Geotextile	0.45um sed caught	Proportion Caught on 0.45 um Filter	Sed lost	Proportion Sediment Lost
Bridge Deck Debris	Non-Woven 4 oz/sy	1.0024	0.8991	0.90	0.0507	0.05	0.0526	0.05
Bridge Deck Debris	Non-Woven 4 oz/sy	1.0133	0.803	0.79	0.048	0.05	0.1623	0.16
Bridge Deck Debris	Non-Woven 4 oz/sy	1.0121	0.9517	0.94	0.0319	0.03	0.0285	0.03
Bridge Deck Debris	Silt Fence	1.0192	0.9772	0.96	0.0397	0.04	0.0023	0.00
Bridge Deck Debris	Silt Fence	1.017	0.997	0.98	0.0072	0.01	0.0128	0.01
Bridge Deck Debris	Silt Fence	1.0152	0.9796	0.96	0.0188	0.02	0.0168	0.02
Bridge Deck Debris	Rock Bag Woven	1.0157	0.8195	0.81	0.173	0.17	0.0232	0.02
Bridge Deck Debris	Rock Bag Woven	1.0167	0.8452	0.83	0.1407	0.14	0.0308	0.03
Bridge Deck Debris	Rock Bag Woven	1.0159	0.8523	0.84	0.1365	0.13	0.0271	0.03
Bridge Deck Debris	Dandy Bag Woven	1.036	0.8265	0.80	0.1445	0.14	0.065	0.06
Bridge Deck Debris	Dandy Bag Woven	1.0356	0.8555	0.83	0.1346	0.13	0.0455	0.04
Bridge Deck Debris	Dandy Bag Woven	1.0441	0.8504	0.81	0.1397	0.13	0.054	0.05
Mn River Silt	Non-Woven 4 oz/sy	1.0096	0.9568	0.95	0.0332	0.03	0.0196	0.02
Mn River Silt	Non-Woven 4 oz/sy	1.0495	0.9778	0.93	0.0487	0.05	0.023	0.02
Mn River Silt	Non-Woven 4 oz/sy	1.0168	0.9341	0.92	0.0603	0.06	0.0224	0.02
Mn River Silt	Silt Fence	1.0323	0.9928	0.96	0.021	0.02	0.0185	0.02
Mn River Silt	Silt Fence	1.0151	0.9642	0.95	0.0396	0.04	0.0113	0.01
Mn River Silt	Silt Fence	1.027	0.9885	0.96	0.0292	0.03	0.0093	0.01
Mn River Silt	Rock Bag Woven	1.0437	0.6887	0.66	0.2932	0.28	0.0618	0.06
Mn River Silt	Rock Bag Woven	1.0482	0.7219	0.69	0.2921	0.28	0.0342	0.03
Mn River Silt	Rock Bag Woven	1.0195	0.6628	0.65	0.3149	0.31	0.0418	0.04
Mn River Silt	Dandy Bag Woven	1.0217	0.5124	0.50	0.233	0.23	0.2763	0.27
Mn River Silt	Dandy Bag Woven	1.0125	0.5698	0.56	0.2327	0.23	0.21	0.21
Mn River Silt	Dandy Bag Woven	1.0225	0.5854	0.57	0.2356	0.23	0.2015	0.2(
Pavement Grindings	Non-Woven 4 oz/sy	1.0456	0.8233	0.79	0.1628	0.16	0.0595	0.0(
Pavement Grindings	Non-Woven 4 oz/sy	1.0049	0.7925	0.79	0.1569	0.16	0.0555	0.0(
Pavement Grindings	Non-Woven 4 oz/sy	1.0099	0.7927	0.78	0.1547	0.15	0.0625	0.0(
Pavement Grindings	Silt Fence	1.0332	0.9947	0.96	0.0164	0.02	0.0221	0.0:
Pavement Grindings	Silt Fence	1.0168	0.9832	0.97	0.012	0.01	0.0216	0.0:
Pavement Grindings	Silt Fence	1.0106	1.2423	1.23	0.0097	0.01	-0.2414	(0.2
Pavement Grindings	Rock Bag Woven	1.0109	0.5982	0.59	0.3522	0.35	0.0605	0.0(
Pavement Grindings	Rock Bag Woven	1.0197	0.6313	0.62	0.342	0.34	0.0464	0.0
Pavement Grindings	Rock Bag Woven	1.0699	0.678	0.63	0.3234	0.30	0.0685	0.06
Pavement Grindings	Dandy Bag Woven	1.0156	1.1703	1.15	-0.2298	(0.23)	0.0751	0.07
Pavement Grindings	Dandy Bag Woven	1.0491	0.6819	0.65	0.2801	0.27	0.0871	0.08
Pavement Grindings	Dandy Bag Woven	1.0138	0.5765	0.57	0.3463	0.34	0.091	0.09
Saw Cut Slurry	Non-Woven 4 oz/sy	1.0018	0.943	0.94	0.0332	0.03	0.0256	0.03
Saw Cut Slurry	Non-Woven 4 oz/sy	1.006	0.9409	0.94	0.0429	0.04	0.0222	0.02
Saw Cut Slurry	Non-Woven 4 oz/sy	1.0063	0.9418	0.94	0.039	0.04	0.0255	0.03
Saw Cut Slurry	Silt Fence	1.0147	0.9779	0.96	0.0222	0.02	0.0146	0.01
Saw Cut Slurry	Silt Fence	1.0048	0.9725	0.97	0.00325	0.00	0.02905	0.03
Saw Cut Slurry	Silt Fence	1.0545	1.0088	0.96	0.0254	0.02	0.0203	0.02
Saw Cut Slurry	Rock Bag Woven	1.0794	0.9548	0.88	0.1052	0.10	0.0194	0.02
Saw Cut Slurry	Rock Bag Woven	1.0174	0.8976	0.88	0.0885	0.09	0.0313	0.03
Saw Cut Slurry	Rock Bag Woven	1.0151	0.8798	0.87	0.1118	0.11	0.0235	0.02
Saw Cut Slurry	Dandy Bag Woven	1.0101	0.8869	0.88	0.0921	0.09	0.0311	0.03
Saw Cut Slurry	Dandy Bag Woven	1.018	0.9106	0.89	0.0669	0.07	0.0405	0.04
Saw Cut Slurry	Dandy Bag Woven	1.0011	0.8744	0.87	0.0827	0.08	0.044	0.04

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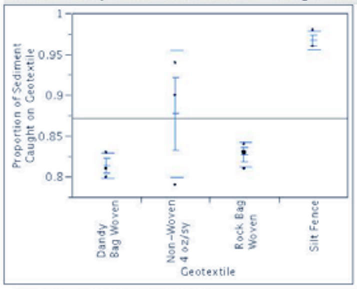
Fit Y by X Group

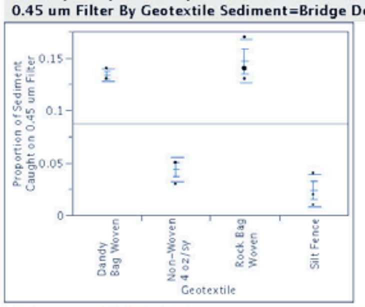
Oneway Analysis of Proportion of Sediment Caught on Geotextile By Geotextile Sediment=Bridge Deck Debris



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.813333	0.015275	0.00882	0.77539	0.8513
Non-Woven 4 oz/sy	3	0.876667	0.077675	0.04485	0.68371	1.0696
Rock Bag Woven	3	0.826667	0.015275	0.00882	0.78872	0.8646
Silt Fence	3	0.966667	0.011547	0.00667	0.93798	0.9954

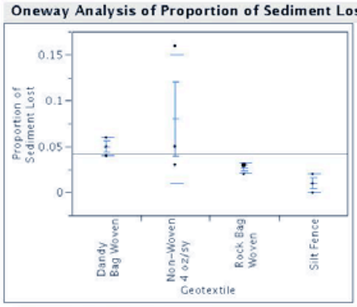
Oneway Analysis of Proportion of Sediment Caught on 0.45 um Filter By Geotextile Sediment=Bridge Deck Debris



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.133333	0.005774	0.00333	0.1190	0.14768
Non-Woven 4 oz/sy	3	0.043333	0.011547	0.00667	0.0146	0.07202
Rock Bag Woven	3	0.146667	0.020817	0.01202	0.0950	0.19838
Silt Fence	3	0.023333	0.015275	0.00882	-0.0146	0.06128

Oneway Analysis of Proportion of Sediment Lost By Geotextile Sediment=Bridge Deck Debris



Means and Std Deviations

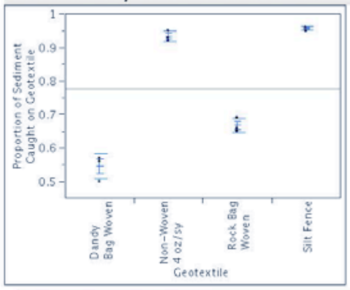
Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.050000	0.010000	0.00577	0.0252	0.07484
Non-Woven 4 oz/sy	3	0.080000	0.070000	0.04041	-0.0939	0.25389
Rock Bag Woven	3	0.026667	0.005774	0.00333	0.0123	0.04101
Silt Fence	3	0.010000	0.010000	0.00577	-0.0148	0.03484

Fit Y by X Group

Oneway Analysis of Proportion of Sediment Caught on Geotextile By Geotextile Sediment=Mn River Silt

Fit Y by X Group

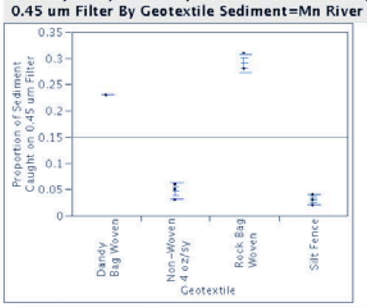
Oneway Analysis of Proportion of Sediment Caught on Geotextile By Geotextile Sediment=Mn River Silt



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.543333	0.037859	0.02186	0.44929	0.63738
Non-Woven 4 oz/sy	3	0.933333	0.015275	0.00882	0.89539	0.97128
Rock Bag Woven	3	0.666667	0.020817	0.01202	0.61496	0.71838
Silt Fence	3	0.956667	0.005774	0.00333	0.94232	0.97101

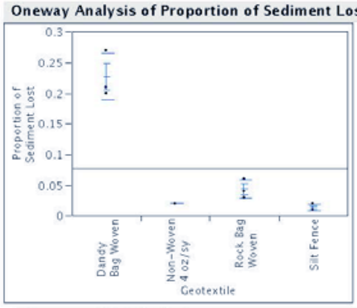
Oneway Analysis of Proportion of Sediment Caught on 0.45 um Filter By Geotextile Sediment=Mn River Silt



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.230000	0.000000	0.00000	0.23000	0.23000
Non-Woven 4 oz/sy	3	0.046667	0.015275	0.00882	0.00872	0.08461
Rock Bag Woven	3	0.290000	0.017321	0.01000	0.24697	0.33303
Silt Fence	3	0.030000	0.010000	0.00577	0.00516	0.05484

Oneway Analysis of Proportion of Sediment Lost By Geotextile Sediment=Mn River Silt



Means and Std Deviations

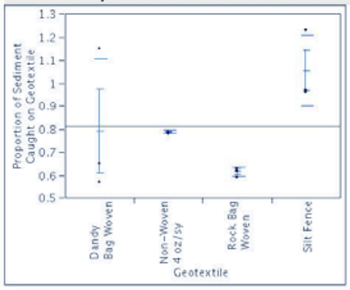
Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.226667	0.037859	0.02186	0.1326	0.32071
Non-Woven 4 oz/sy	3	0.020000	0.000000	0.00000	0.0200	0.02000
Rock Bag Woven	3	0.043333	0.015275	0.00882	0.0054	0.08128
Silt Fence	3	0.013333	0.005774	0.00333	-0.0010	0.02768

Fit Y by X Group

Oneway Analysis of Proportion of Sediment Caught on Geotextile By Geotextile Sediment=Pavement Grindings

Fit Y by X Group

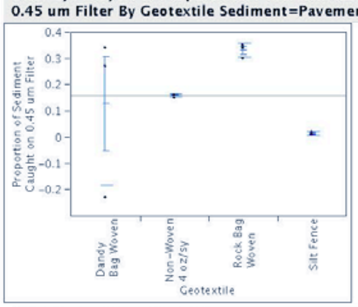
Oneway Analysis of Proportion of Sediment Caught on Geotextile By Geotextile Sediment=Pavement Grindings



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.79000	0.314325	0.18148	0.00917	1.5708
Non-Woven 4 oz/sy	3	0.78667	0.005774	0.00333	0.77232	0.8010
Rock Bag Woven	3	0.61333	0.020817	0.01202	0.56162	0.6650
Silt Fence	3	1.05333	0.153080	0.08838	0.67306	1.4336

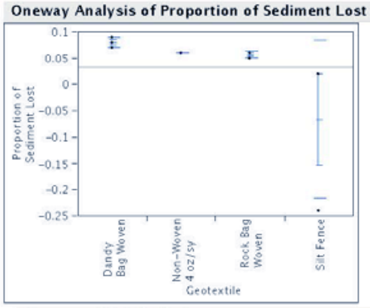
Oneway Analysis of Proportion of Sediment Caught on 0.45 um Filter By Geotextile Sediment=Pavement Grindings



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.126667	0.310859	0.17947	-0.6455	0.89888
Non-Woven 4 oz/sy	3	0.156667	0.005774	0.00333	0.1423	0.17101
Rock Bag Woven	3	0.330000	0.026458	0.01528	0.2643	0.39572
Silt Fence	3	0.013333	0.005774	0.00333	-0.0010	0.02768

Oneway Analysis of Proportion of Sediment Lost By Geotextile Sediment=Pavement Grindings



Means and Std Deviations

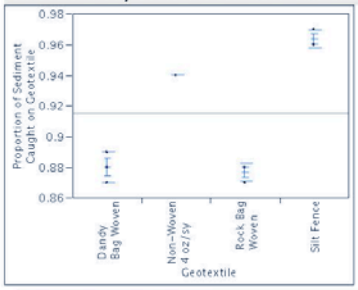
Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.08000	0.010000	0.00577	0.0552	0.10484
Non-Woven 4 oz/sy	3	0.06000	0.000000	0.00000	0.0600	0.06000
Rock Bag Woven	3	0.05667	0.005774	0.00333	0.0423	0.07101
Silt Fence	3	-0.06667	0.150111	0.08667	-0.4396	0.30623

Fit Y by X Group

Oneway Analysis of Proportion of Sediment Caught on Geotextile By Geotextile Sediment=Saw Cut Slurry

Fit Y by X Group

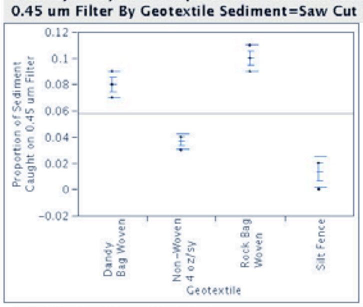
Oneway Analysis of Proportion of Sediment Caught on Geotextile By Geotextile Sediment=Saw Cut Slurry



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.880000	0.010000	0.00577	0.85516	0.90484
Non-Woven 4 oz/sy	3	0.940000	0.000000	0.00000	0.94000	0.94000
Rock Bag Woven	3	0.876667	0.005774	0.00333	0.86232	0.89101
Silt Fence	3	0.963333	0.005774	0.00333	0.94899	0.97768

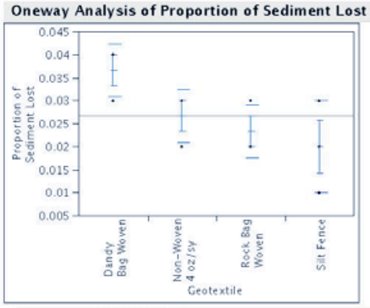
Oneway Analysis of Proportion of Sediment Caught on 0.45 um Filter By Geotextile Sediment=Saw Cut Slurry



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.080000	0.010000	0.00577	0.0552	0.10484
Non-Woven 4 oz/sy	3	0.036667	0.005774	0.00333	0.0223	0.05101
Rock Bag Woven	3	0.100000	0.010000	0.00577	0.0752	0.12484
Silt Fence	3	0.013333	0.011547	0.00667	-0.0154	0.04202

Oneway Analysis of Proportion of Sediment Lost By Geotextile Sediment=Saw Cut Slurry



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Dandy Bag Woven	3	0.036667	0.005774	0.00333	0.0223	0.05101
Non-Woven 4 oz/sy	3	0.026667	0.005774	0.00333	0.0123	0.04101
Rock Bag Woven	3	0.023333	0.005774	0.00333	0.0090	0.03768
Silt Fence	3	0.020000	0.010000	0.00577	-0.0048	0.04484

Appendix I
Acidity Treatment

pH Measurements
Mn/DOT Concrete Sediments
S. Druschel
June 10, 2011

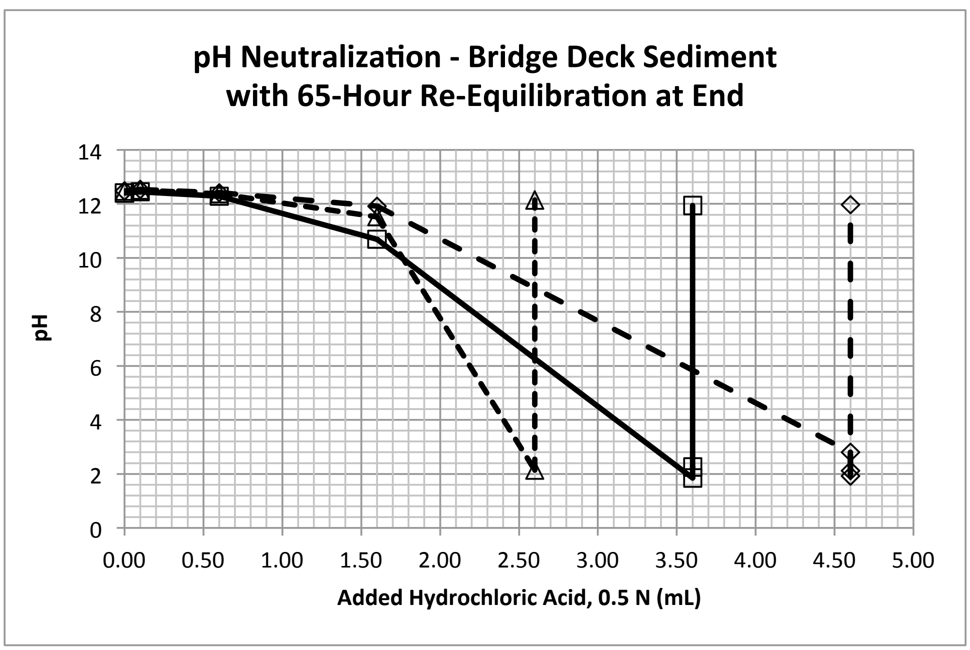
10.00 g sediment + 50.00 mL DI water
Minimum 7 days of time to equilibrate

	pH	Molarity $[H^+]$ (moles per liter)	Molarity $[OH^-]$ (moles per liter)		
Bridge Deck	12.48	3.3113E-13	0.03019952		
Bridge Deck	12.4	3.9811E-13	0.02511886		
Bridge Deck	12.47	3.3884E-13	0.02951209		
Bridge Deck	12.54	2.8840E-13	0.03467369	n =	7
Bridge Deck	12.56	2.7542E-13	0.03630781	Mean =	0.0350
Bridge Deck	12.65	2.2387E-13	0.04466836	Std Dev =	0.0075
Bridge Deck	12.65	2.2387E-13	0.04466836	RSD =	21%
Saw Cut Slurry	11.11	7.7625E-12	0.00128825		
Saw Cut Slurry	10.91	1.2303E-11	0.00081283		
Saw Cut Slurry	11.15	7.0795E-12	0.00141254		
Saw Cut Slurry	11.16	6.9183E-12	0.00144544	n =	7
Saw Cut Slurry	10.38	4.1687E-11	0.00023988	Mean =	0.000828
Saw Cut Slurry	10.63	2.3442E-11	0.00042658	Std Dev =	0.000558
Saw Cut Slurry	10.24	5.7544E-11	0.00017378	RSD =	67%
Pavement Grindings	8.62	2.3988E-09	0.00000417		
Pavement Grindings	9.83	1.4791E-10	0.00006761		
Pavement Grindings	9.93	1.1749E-10	0.00008511		
Pavement Grindings	9.52	3.0200E-10	0.00003311	n =	7
Pavement Grindings	8.91	1.2303E-09	0.00000813	Mean =	0.0000373
Pavement Grindings	9.66	2.1878E-10	0.00004571	Std Dev =	0.0000307
Pavement Grindings	9.24	5.7544E-10	0.00001738	RSD =	82%
Portland Cement	12.88	1.3183E-13	0.07585776		
Portland Cement	12.86	1.3804E-13	0.07244360		
Portland Cement	12.85	1.4125E-13	0.07079458		
Portland Cement	12.83	1.4791E-13	0.06760830	n =	7
Portland Cement	12.85	1.4125E-13	0.07079458	Mean =	0.0729
Portland Cement	12.93	1.1749E-13	0.08511380	Std Dev =	0.0061
Portland Cement	12.83	1.4791E-13	0.06760830	RSD =	8%

Sediment Contact Water Neutralization
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 10, 2011

Begin: 10 g sediment in 50 mL water. Allow to equilibrate for 7 days.
Add HCl 0.50 Normal, mix and read pH.

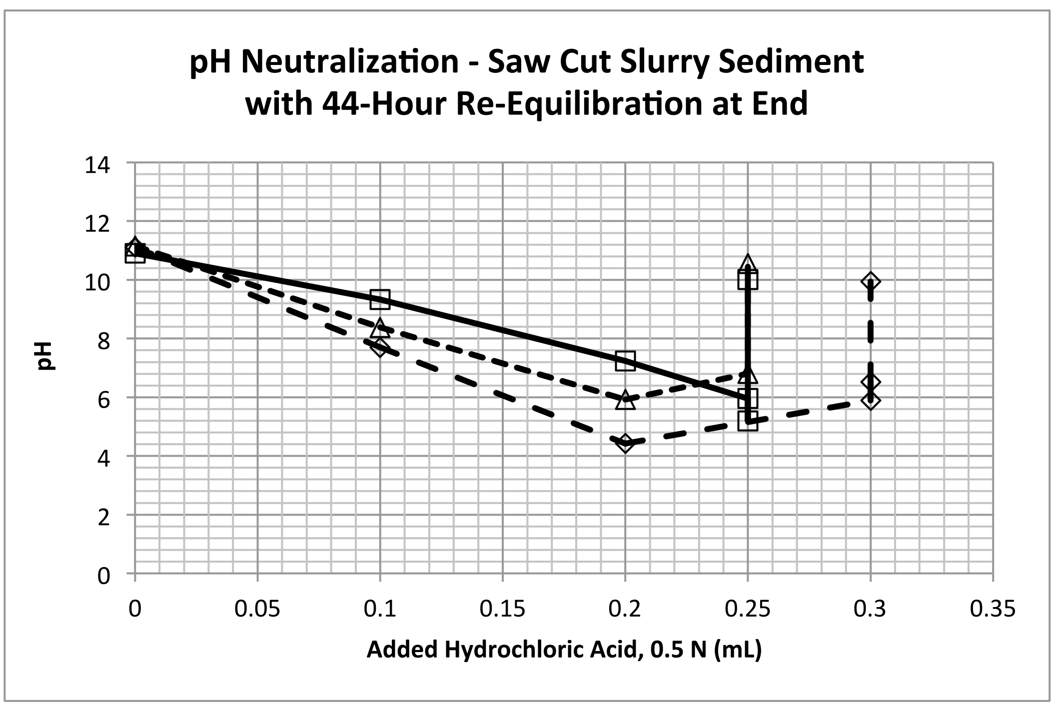
Date	material	Total HCl N/2 added µL	pH Reading	
Jan 10th 2011	Bridge Deck	0	12.48	
Jan 10th 2011	Bridge Deck	100	12.53	
Jan 10th 2011	Bridge Deck	600	12.42	
Jan 10th 2011	Bridge Deck	1600	11.92	
Jan 10th 2011	Bridge Deck	4600	2.8	
Jan 10th 2011	Bridge Deck	4600	1.92	30 min after 2.80 reading
Jan 10th 2011	Bridge Deck	4600	2.11	1 hr 30 min after 2.80 reading
Jan 10th 2011	Bridge Deck	4600	11.97	66 hours after start
Jan 10th 2011	Bridge Deck	0	12.4	
Jan 10th 2011	Bridge Deck	100	12.45	
Jan 10th 2011	Bridge Deck	600	12.28	
Jan 10th 2011	Bridge Deck	1600	10.69	
Jan 10th 2011	Bridge Deck	3600	1.85	
Jan 10th 2011	Bridge Deck	3600	2.25	30 min after 1.85 reading
Jan 10th 2011	Bridge Deck	3600	11.94	65 hours after start
Jan 10th 2011	Bridge Deck	0	12.47	
Jan 10th 2011	Bridge Deck	100	12.51	
Jan 10th 2011	Bridge Deck	600	12.37	
Jan 10th 2011	Bridge Deck	1600	11.52	
Jan 10th 2011	Bridge Deck	2600	2.14	
Jan 10th 2011	Bridge Deck	2600	12.14	66 hours after start



Sediment Contact Water Neutralization
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 10, 2011

Begin: 10 g sediment in 50 mL water. Allow to equilibrate for 7 days.
Add HCl 0.50 Normal, mix and read pH.

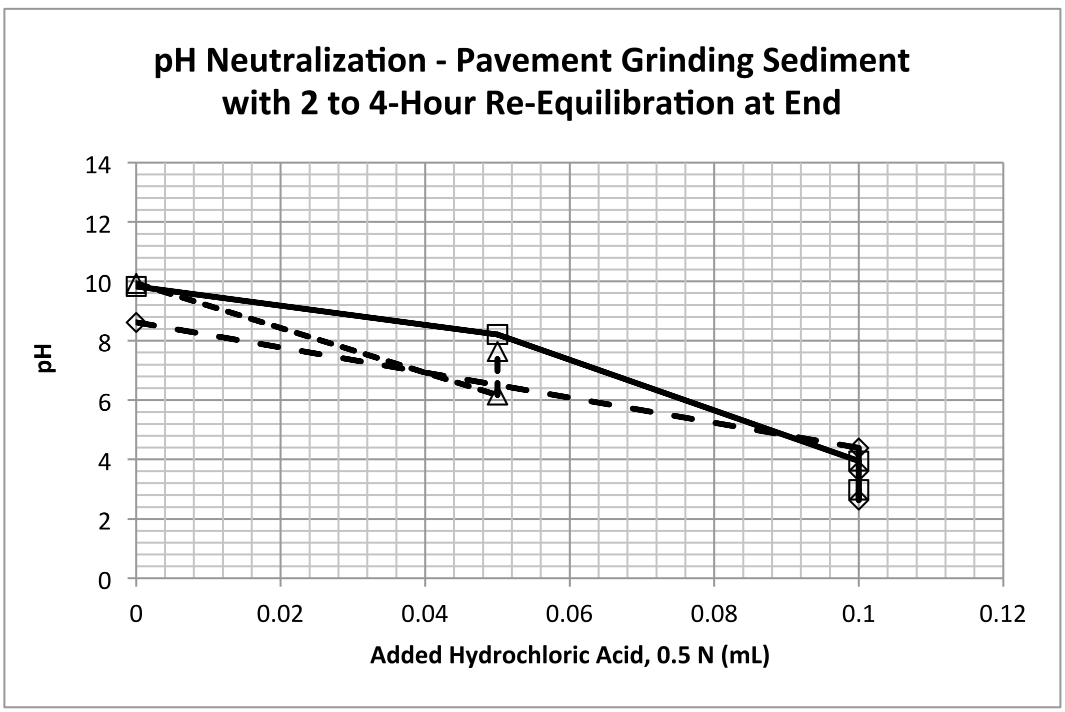
Date	material	Total HCl N/2 added μL	pH Reading	
Jan 10th 2011	Saw Cut Slurry	0	11.11	
Jan 10th 2011	Saw Cut Slurry	100	7.7	
Jan 10th 2011	Saw Cut Slurry	200	4.42	
Jan 10th 2011	Saw Cut Slurry	300	5.89	
Jan 10th 2011	Saw Cut Slurry	300	6.52	2.5 hours after 5.89 reading
Jan 10th 2011	Saw Cut Slurry	300	9.95	45.75 hours after start
Jan 10th 2011	Saw Cut Slurry	0	10.91	
Jan 10th 2011	Saw Cut Slurry	100	9.33	
Jan 10th 2011	Saw Cut Slurry	200	7.24	
Jan 10th 2011	Saw Cut Slurry	250	5.95	
Jan 10th 2011	Saw Cut Slurry	250	5.2	4 hours 10 min after 5.95 read
Jan 10th 2011	Saw Cut Slurry	250	10.01	44 hours after start
Jan 10th 2011	Saw Cut Slurry	0	11.15	
Jan 10th 2011	Saw Cut Slurry	100	8.38	
Jan 10th 2011	Saw Cut Slurry	200	5.92	
Jan 10th 2011	Saw Cut Slurry	250	6.81	
Jan 10th 2012	Saw Cut Slurry	250	10.55	45 hours after start



Sediment Contact Water Neutralization
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 10, 2011

Begin: 10 g sediment in 50 mL water. Allow to equilibrate for 7 days.
Add HCl 0.50 Normal, mix and read pH.

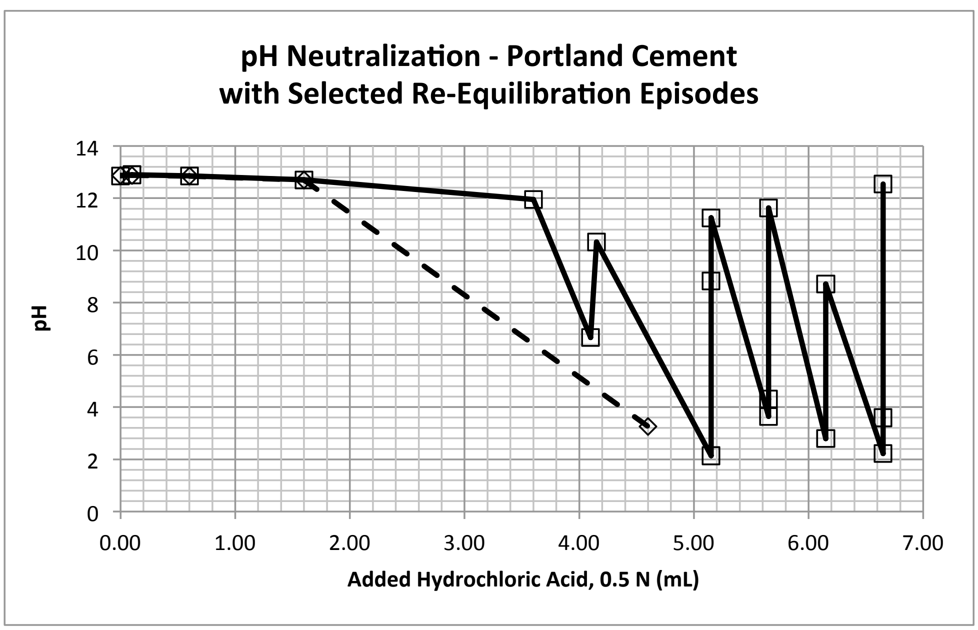
Date	material	Total HCl N/2 added µL	pH Reading	
Jan 12th 2011	Duluth Grinder	0	8.62	
Jan 12th 2011	Duluth Grinder	100	4.39	
Jan 12th 2011	Duluth Grinder	100	2.63	1.5 hours after 4.39 reading
Jan 12th 2011	Duluth Grinder	100	3.6	4 hours after 4.39 reading
Jan 12th 2011	Duluth Grinder	0	9.83	
Jan 12th 2011	Duluth Grinder	50	8.21	
Jan 12th 2011	Duluth Grinder	100	3.95	
Jan 12th 2011	Duluth Grinder	100	2.98	2.5 hours after 3.95 reading
Jan 12th 2011	Duluth Grinder	0	9.93	
Jan 12th 2011	Duluth Grinder	50	6.17	
Jan 12th 2011	Duluth Grinder	50	7.64	2 hours fter 6.17 reading



Sediment Contact Water Neutralization
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 10, 2011

Begin: 10 g sediment in 50 mL water. Allow to equilibrate for 7 days.
Add HCl 0.50 Normal, mix and read pH.

Date	material	Total HCl N/2 added µL	pH Reading	
Jan7th 2011	Portland Cement	0	12.88	
Jan7th 2011	Portland Cement	100	12.88	
Jan7th 2011	Portland Cement	600	12.85	
Jan7th 2011	Portland Cement	1600	12.69	
Jan7th 2011	Portland Cement	4600	3.26	
Jan7th 2011	Portland Cement	0	12.86	
Jan7th 2011	Portland Cement	100	12.9	
Jan7th 2011	Portland Cement	600	12.86	
Jan7th 2011	Portland Cement	1600	12.71	
Jan7th 2011	Portland Cement	3600	11.95	
Jan7th 2011	Portland Cement	4100	6.67	
Jan7th 2011	Portland Cement	4150	10.32	rebounded from below to 6 to
Jan7th 2011	Portland Cement	5150	2.14	
Jan7th 2011	Portland Cement	5150	8.82	1.25 hrs after 2.14 measureme
Jan7th 2011	Portland Cement	5150	11.25	1.75 hrs after 2.14 reading
Jan7th 2011	Portland Cement	5650	3.65	
Jan7th 2011	Portland Cement	5650	4.3	15 min after 3.65 reading
Jan7th 2011	Portland Cement	5650	11.63	45 min after 3.65 reading
Jan7th 2011	Portland Cement	6150	2.79	
Jan7th 2011	Portland Cement	6150	8.72	1 hr 20min after 2.79 reading
Jan7th 2011	Portland Cement	6650	2.22	
Jan7th 2011	Portland Cement	6650	3.59	20 min after 2.22 reading
Jan7th 2011	Portland Cement	6650	12.54	64.67 hrs after 3.59 reading



Appendix J
Conductivity Reduction Analysis

Clogging Evaluation - Sedimentation Basin Conductivity Reduction
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 11, 2011

Begin: Develop 4 inch thick sand filter layer maintain constant 12 inch head.
Area = 0.785 ft^2
Measure constant head conductivity (initial) using average of 3 @ 14 L measured flows.
Add measured sediment amount and allow minimum 6 minutes of settlement time.
Measure constant head conductivity (step) using average of 4 @ 1 L measured flows.
Compare conductivities and calculate remaining conductivity available.

Sediment	Amount Added (g)	Total Amount of Sediment (g)	Sediment Load (lb/ft^2)	Average Conductivity (cm/s)	Conductivity Remaining	Conductivity Reduction
none	0	0	0.00	0.0333	100%	0%
Portland Cement	200	200	0.56	0.0154	46%	54%
Portland Cement	200	400	1.12	0.0104	31%	69%
Portland Cement	100	500	1.40	0.0071	21%	79%
Portland Cement	100	600	1.68	0.0052	16%	84%
Portland Cement	100	700	1.96	0.0037	11%	89%
none	0	0	0.00	0.0847	100%	0%
Bridge Deck Debris	200	200	0.56	0.0312	37%	63%
Bridge Deck Debris	200	400	1.12	0.0281	33%	67%
Bridge Deck Debris	200	600	1.68	0.0258	30%	70%
Bridge Deck Debris	200	800	2.24	0.0241	28%	72%
Bridge Deck Debris	200	1000	2.81	0.0218	26%	74%
Bridge Deck Debris	200	1200	3.37	0.0209	25%	75%
Bridge Deck Debris	200	1400	3.93	0.0192	23%	77%
Bridge Deck Debris	200	1600	4.49	0.0178	21%	79%
Bridge Deck Debris	200	1800	5.05	0.0166	20%	80%
Bridge Deck Debris	200	2000	5.61	0.0153	18%	82%
none	0	0	0.00	0.0941	100%	0%
MN River Silt	200	200	0.56	0.0382	41%	59%
MN River Silt	200	400	1.12	0.018	19%	81%
MN River Silt	200	600	1.68	0.0121	13%	87%
MN River Silt	200	800	2.24	0.0094	10%	90%
none	0	0	0.00	0.0513	100%	0%
Saw Cut Slurry	200	200	0.56	0.0206	40%	60%
Saw Cut Slurry	100	300	0.84	0.0207	40%	60%
Saw Cut Slurry	200	500	1.40	0.0172	34%	66%
Saw Cut Slurry	100	600	1.68	0.0133	26%	74%
Saw Cut Slurry	100	700	1.96	0.0119	23%	77%
Saw Cut Slurry	100	800	2.24	0.0103	20%	80%
Saw Cut Slurry	100	900	2.53	0.0095	19%	81%
Saw Cut Slurry	100	1000	2.81	0.0084	16%	84%
none	0	0	0.00	0.179	100%	0%
Pavement Grindings	200	200	0.56	0.0182	10%	90%
Pavement Grindings	200	400	1.12	0.0096	5%	95%
Pavement Grindings	200	600	1.68	0.0066	4%	96%
Pavement Grindings	200	800	2.24	0.0048	3%	97%
Pavement Grindings	200	1000	2.81	0.0037	2%	98%
Pavement Grindings	200	1200	3.37	0.0029	2%	98%
Pavement Grindings	200	1400	3.93	0.0024	1%	99%
Pavement Grindings	200	1600	4.49	0.0022	1%	99%
Pavement Grindings	200	1800	5.05	0.0018	1%	99%
Pavement Grindings	200	2000	5.61	0.0016	1%	99%

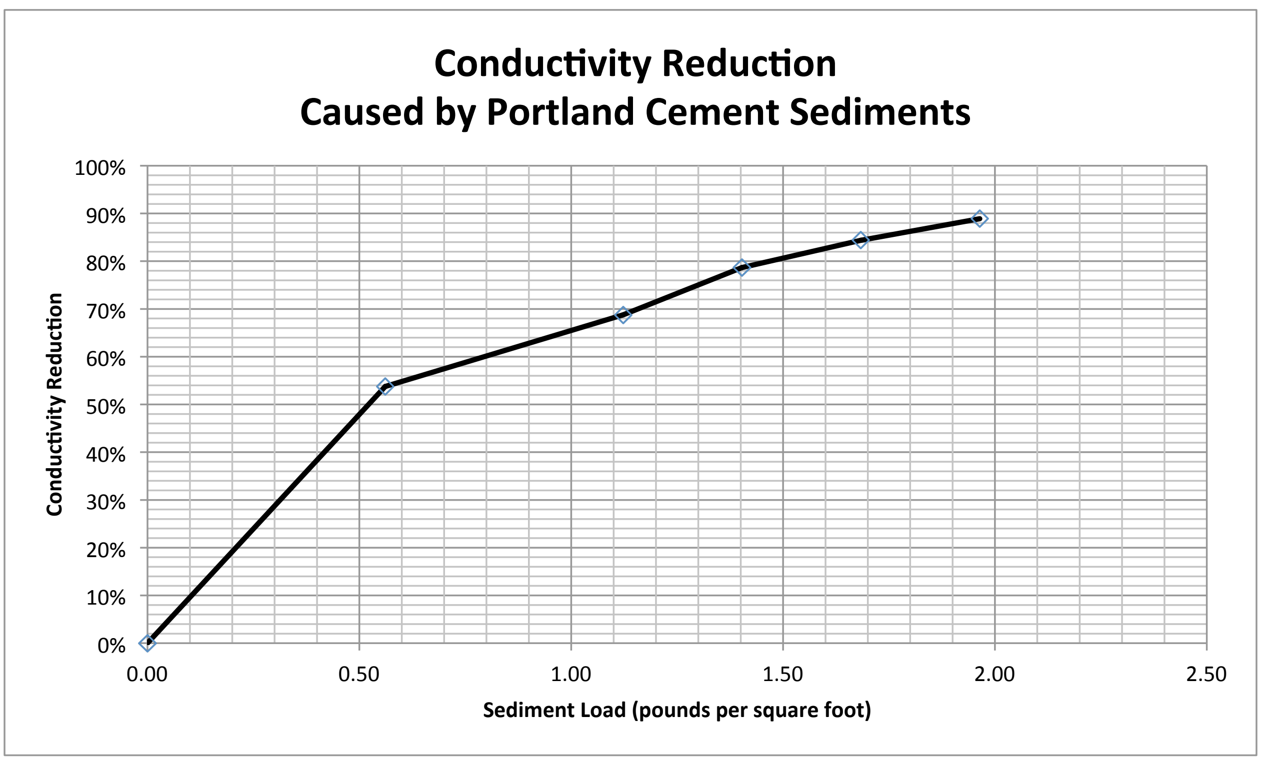
Clogging Evaluation - Sedimentation Basin Conductivity Reduction
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 11, 2011

Begin: Develop 4 inch thick sand filter layer maintain constant 12 inch head.

Area = 0.785 ft^2

Measure constant head conductivity (initial) using average of 3 @ 14 L measured flows.
Add measured sediment amount and allow minimum 6 minutes of settlement time.
Measure constant head conductivity (step) using average of 4 @ 1 L measured flows.
Compare conductivities and calculate remaining conductivity available.

Sediment	Amount Added (g)	Total Amount of Sediment (g)	Sediment Load (lb/ft^2)	Average Conductivity (cm/s)	Conductivity Remaining	Conductivity Reduction
none	0	0	0.00	0.0333	100%	0%
Portland Cement	200	200	0.56	0.0154	46%	54%
Portland Cement	200	400	1.12	0.0104	31%	69%
Portland Cement	100	500	1.40	0.0071	21%	79%
Portland Cement	100	600	1.68	0.0052	16%	84%
Portland Cement	100	700	1.96	0.0037	11%	89%



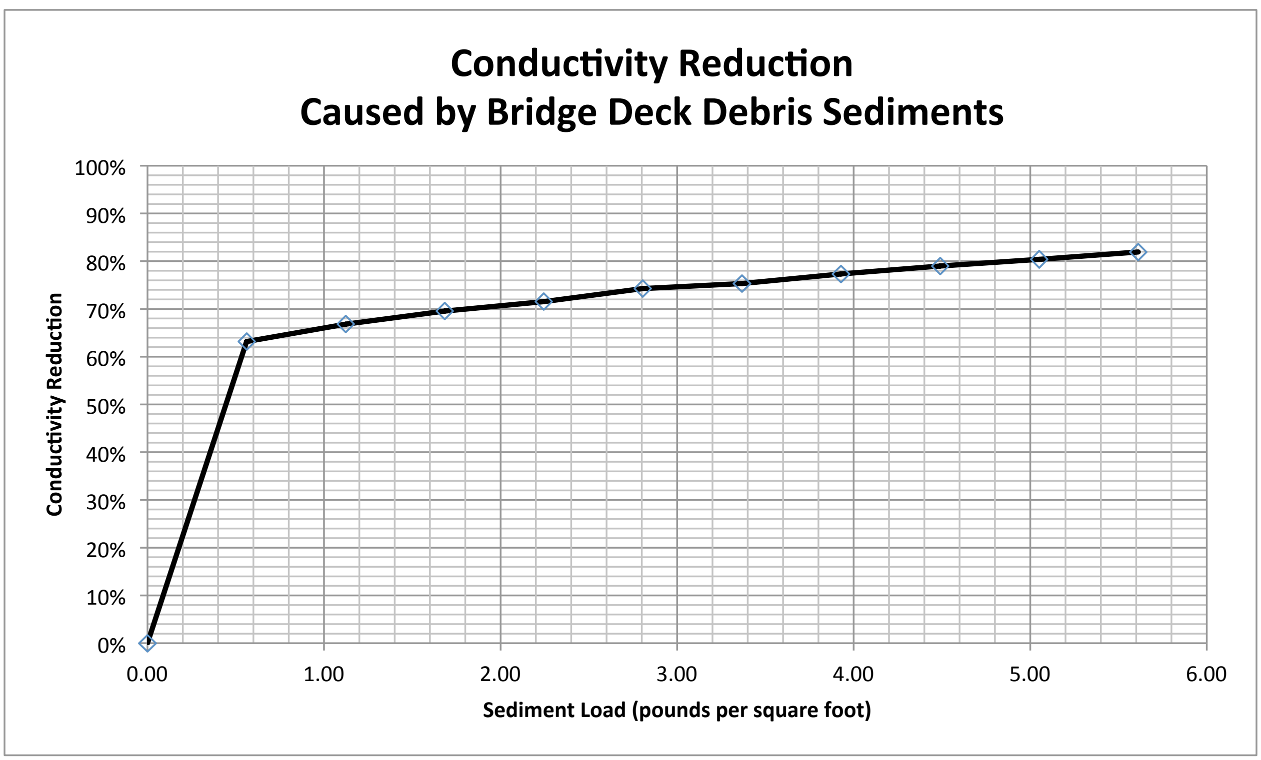
Clogging Evaluation - Sedimentation Basin Conductivity Reduction
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 11, 2011

Begin: Develop 4 inch thick sand filter layer maintain constant 12 inch head.

Area = 0.785 ft^2

Measure constant head conductivity (initial) using average of 3 @ 14 L measured flows.
Add measured sediment amount and allow minimum 6 minutes of settlement time.
Measure constant head conductivity (step) using average of 4 @ 1 L measured flows.
Compare conductivities and calculate remaining conductivity available.

Sediment	Amount Added (g)	Total Amount of Sediment (g)	Sediment Load (lb/ft^2)	Average Conductivity (cm/s)	Conductivity Remaining	Conductivity Reduction
Bridge Deck Debris	0	0	0.00	0.0847	100%	0%
Bridge Deck Debris	200	200	0.56	0.0312	37%	63%
Bridge Deck Debris	200	400	1.12	0.0281	33%	67%
Bridge Deck Debris	200	600	1.68	0.0258	30%	70%
Bridge Deck Debris	200	800	2.24	0.0241	28%	72%
Bridge Deck Debris	200	1000	2.81	0.0218	26%	74%
Bridge Deck Debris	200	1200	3.37	0.0209	25%	75%
Bridge Deck Debris	200	1400	3.93	0.0192	23%	77%
Bridge Deck Debris	200	1600	4.49	0.0178	21%	79%
Bridge Deck Debris	200	1800	5.05	0.0166	20%	80%
Bridge Deck Debris	200	2000	5.61	0.0153	18%	82%



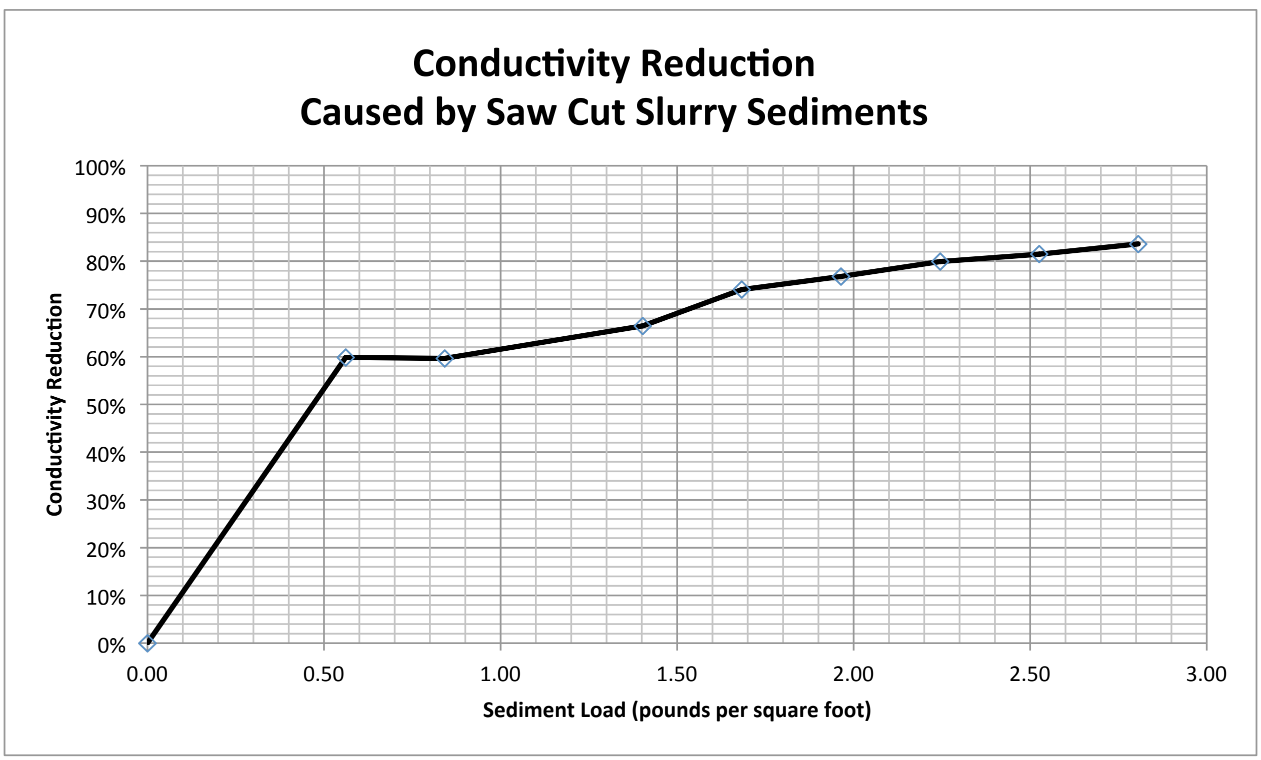
Clogging Evaluation - Sedimentation Basin Conductivity Reduction
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 11, 2011

Begin: Develop 4 inch thick sand filter layer maintain constant 12 inch head.

Area = 0.785 ft^2

Measure constant head conductivity (initial) using average of 3 @ 14 L measured flows.
Add measured sediment amount and allow minimum 6 minutes of settlement time.
Measure constant head conductivity (step) using average of 4 @ 1 L measured flows.
Compare conductivities and calculate remaining conductivity available.

Sediment	Amount Added (g)	Total Amount of Sediment (g)	Sediment Load (lb/ft^2)	Average Conductivity (cm/s)	Conductivity Remaining	Conductivity Reduction
Saw Cut Slurry	0	0	0.00	0.0513	100%	0%
Saw Cut Slurry	200	200	0.56	0.0206	40%	60%
Saw Cut Slurry	100	300	0.84	0.0207	40%	60%
Saw Cut Slurry	200	500	1.40	0.0172	34%	66%
Saw Cut Slurry	100	600	1.68	0.0133	26%	74%
Saw Cut Slurry	100	700	1.96	0.0119	23%	77%
Saw Cut Slurry	100	800	2.24	0.0103	20%	80%
Saw Cut Slurry	100	900	2.53	0.0095	19%	81%
Saw Cut Slurry	100	1000	2.81	0.0084	16%	84%



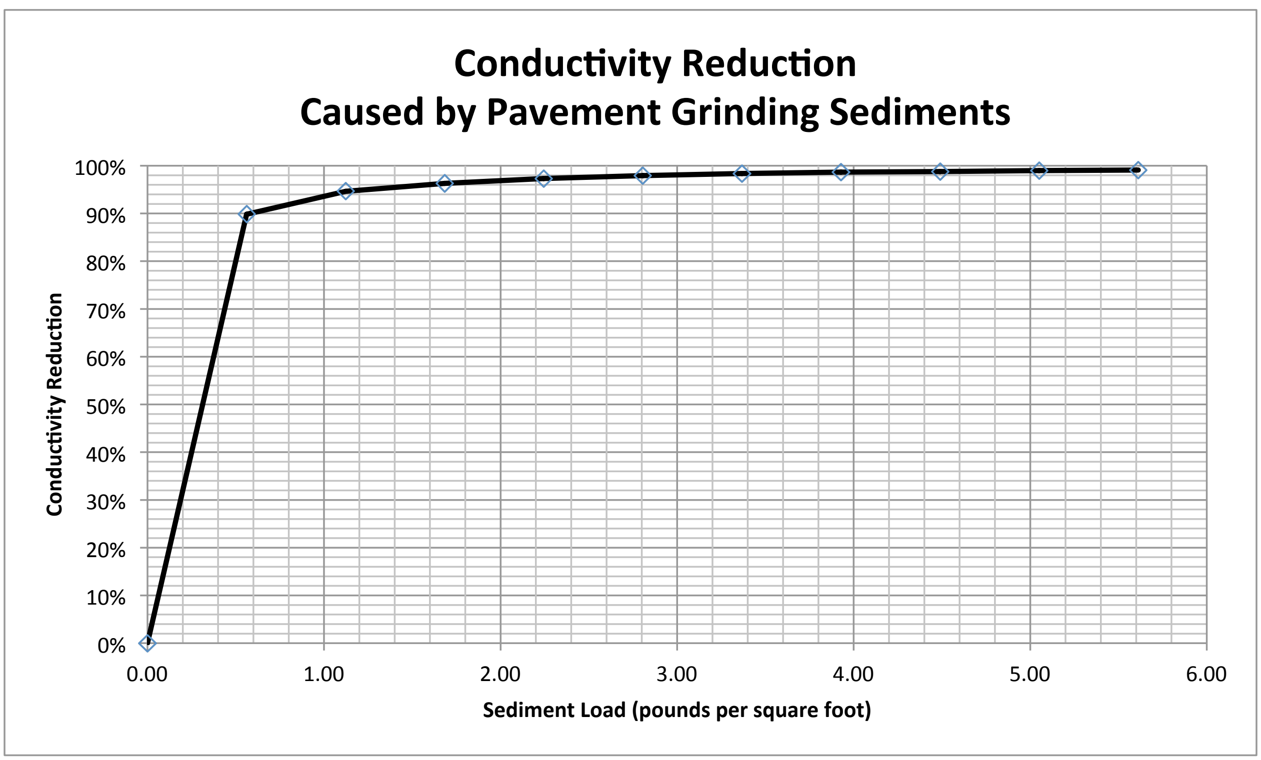
Clogging Evaluation - Sedimentation Basin Conductivity Reduction
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 11, 2011

Begin: Develop 4 inch thick sand filter layer maintain constant 12 inch head.

Area = 0.785 ft^2

Measure constant head conductivity (initial) using average of 3 @ 14 L measured flows.
Add measured sediment amount and allow minimum 6 minutes of settlement time.
Measure constant head conductivity (step) using average of 4 @ 1 L measured flows.
Compare conductivities and calculate remaining conductivity available.

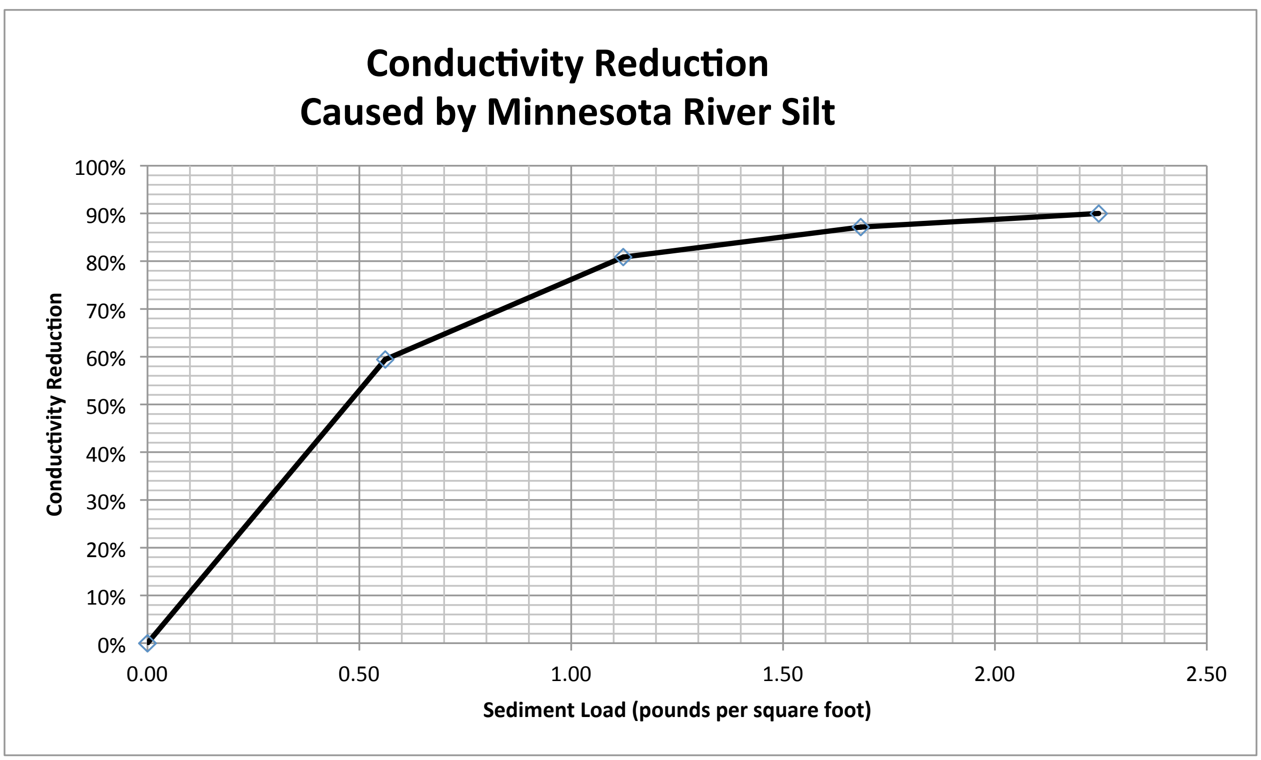
Sediment	Amount Added (g)	Total Amount of Sediment (g)	Sediment Load (lb/ft^2)	Average Conductivity (cm/s)	Conductivity Remaining	Conductivity Reduction
none	0	2000	5.61	0.1790	100%	0%
Pavement Grindings	200	2000	5.61	0.0182	10%	90%
Pavement Grindings	200	1800	5.05	0.0096	5%	95%
Pavement Grindings	200	1600	4.49	0.0066	4%	96%
Pavement Grindings	200	1400	3.93	0.0048	3%	97%
Pavement Grindings	200	1200	3.37	0.0037	2%	98%
Pavement Grindings	200	1000	2.81	0.0029	2%	98%
Pavement Grindings	200	800	2.24	0.0024	1%	99%
Pavement Grindings	200	600	1.68	0.0022	1%	99%
Pavement Grindings	200	400	1.12	0.0018	1%	99%
Pavement Grindings	200	200	0.56	0.0016	1%	99%



Clogging Evaluation - Sedimentation Basin Conductivity Reduction
Mn/DOT Concrete Sediments
S. Druschel/ MSU Mankato Civil Engineering
June 11, 2011

Begin: Develop 4 inch thick sand filter layer maintain constant 12 inch head.
Area = 0.785 ft^2
Measure constant head conductivity (initial) using average of 3 @ 14 L measured flows.
Add measured sediment amount and allow minimum 6 minutes of settlement time.
Measure constant head conductivity (step) using average of 4 @ 1 L measured flows.
Compare conductivities and calculate remaining conductivity available.

Sediment	Amount Added (g)	Total Amount of Sediment (g)	Sediment Load (lb/ft^2)	Average Conductivity (cm/s)	Conductivity Remaining	Conductivity Reduction
none	0	800	2.24	0.0941	100%	0%
MN River Silt	200	800	2.24	0.0382	41%	59%
MN River Silt	200	600	1.68	0.018	19%	81%
MN River Silt	200	400	1.12	0.0121	13%	87%
MN River Silt	200	200	0.56	0.0094	10%	90%



Appendix K
Best Management Practices Flow Charts

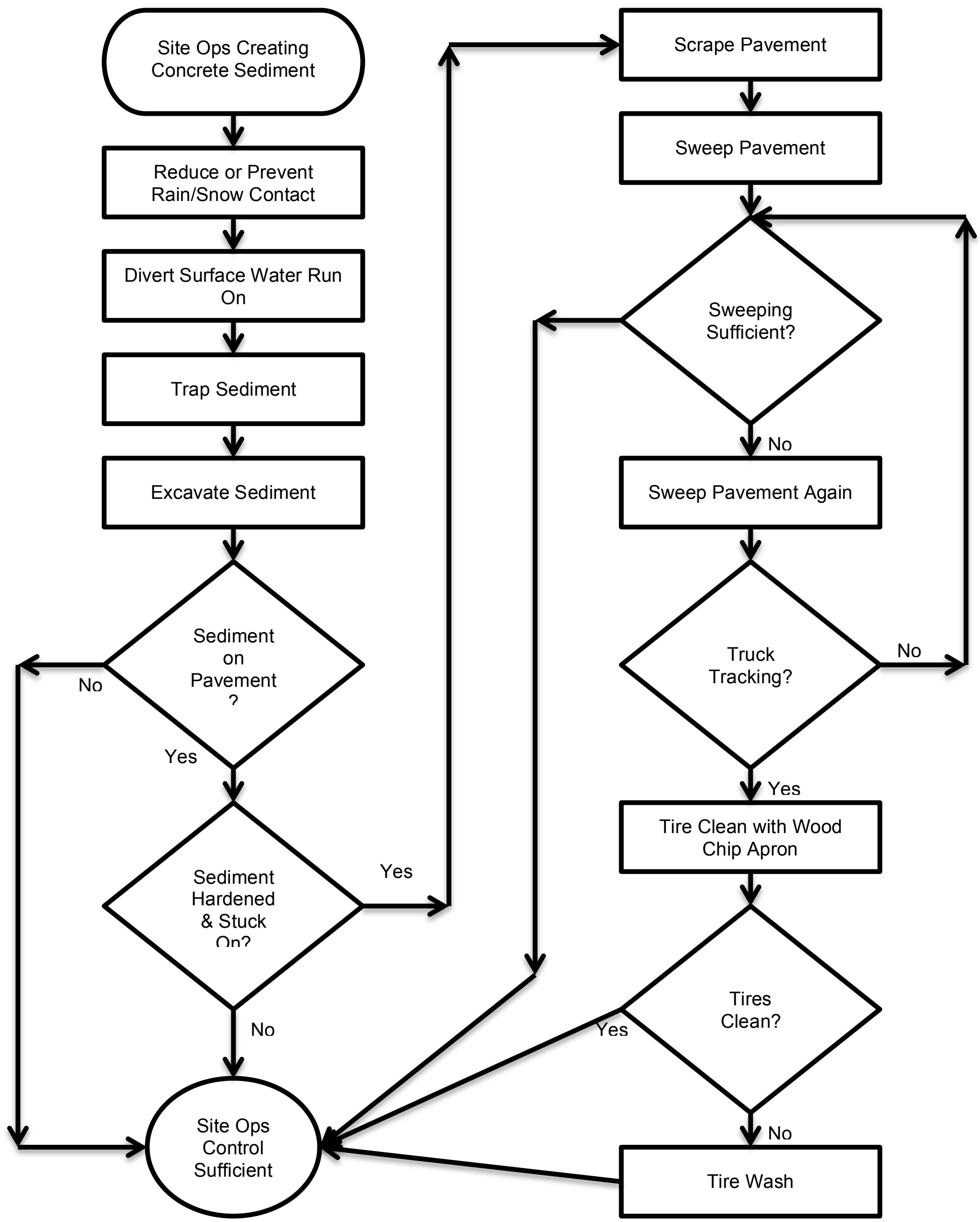


Figure A. Site Operations Flow Chart.

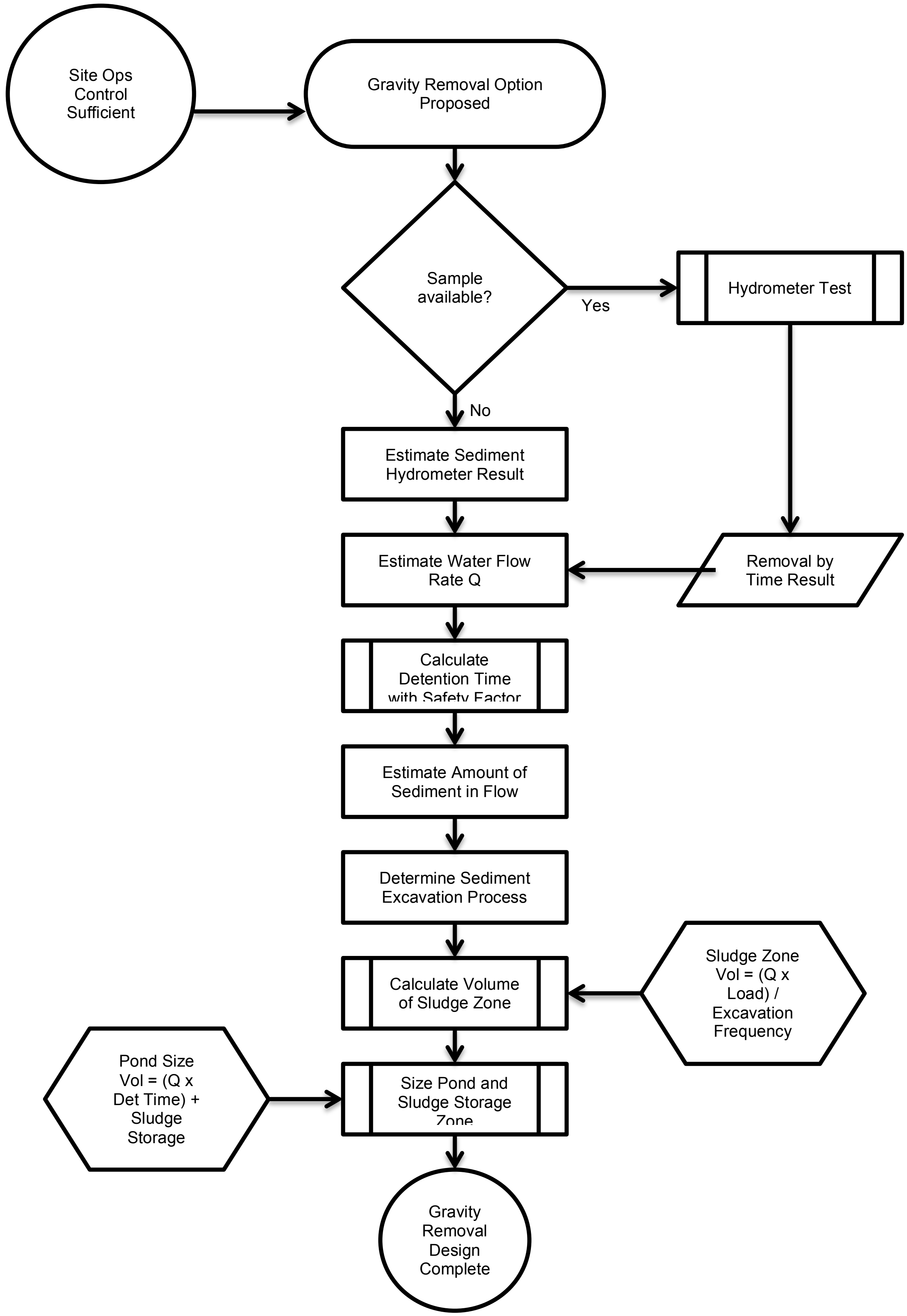


Figure B. Gravity Removal Design Flow Chart.

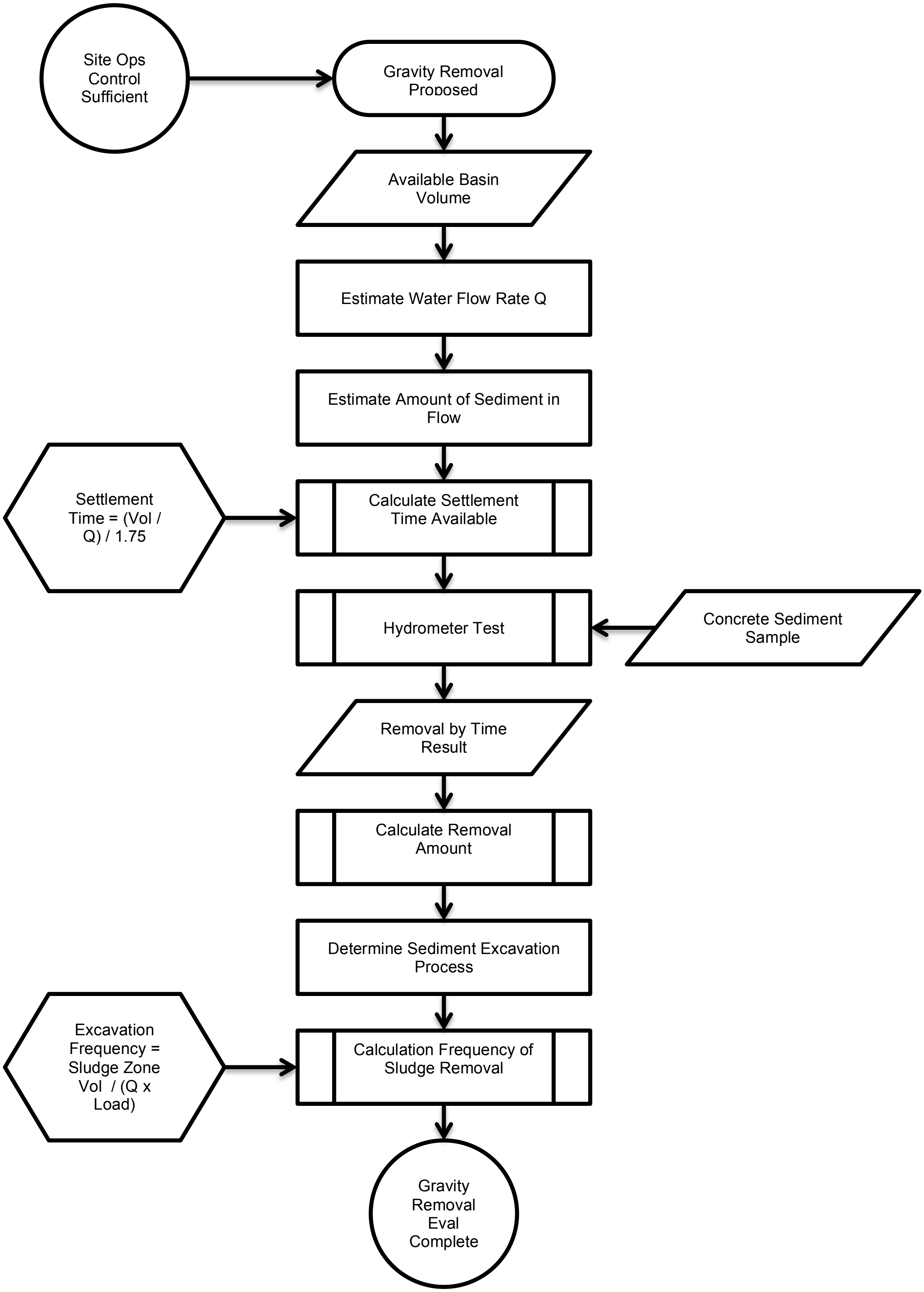


Figure C. Flow Chart of Gravity Removal by Volume Available.

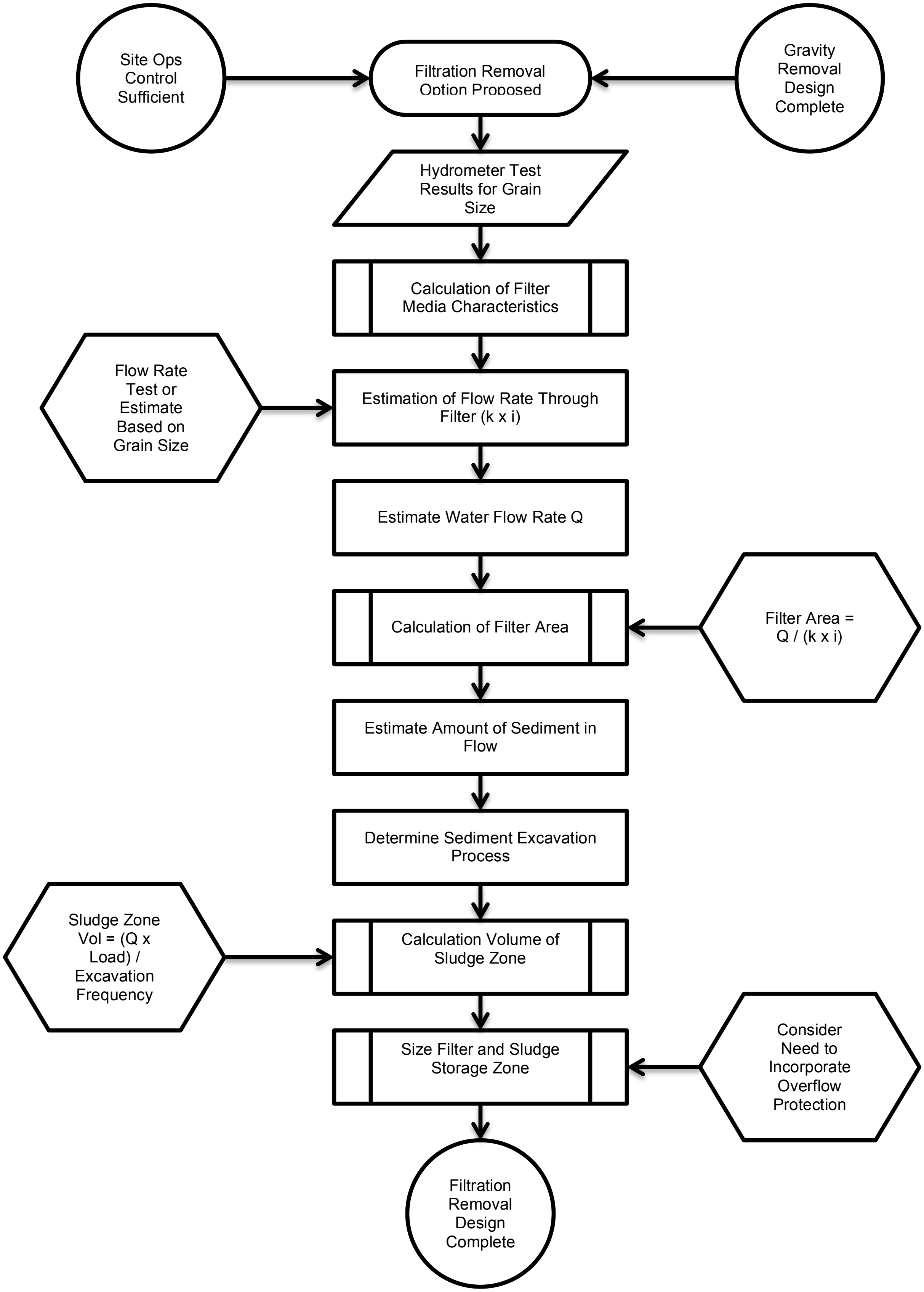


Figure D. Filtration Flow Chart.

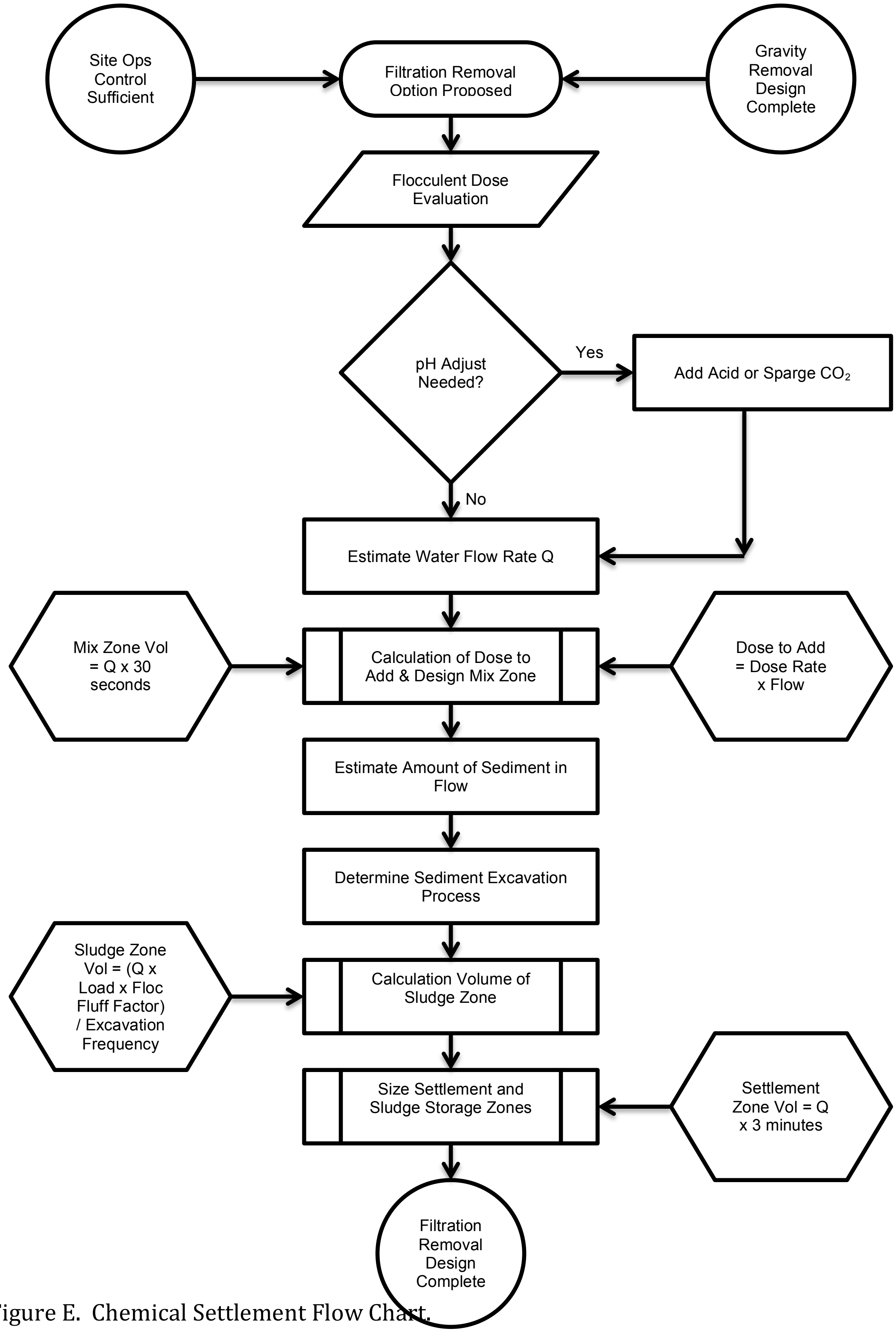


Figure E. Chemical Settlement Flow Chart.

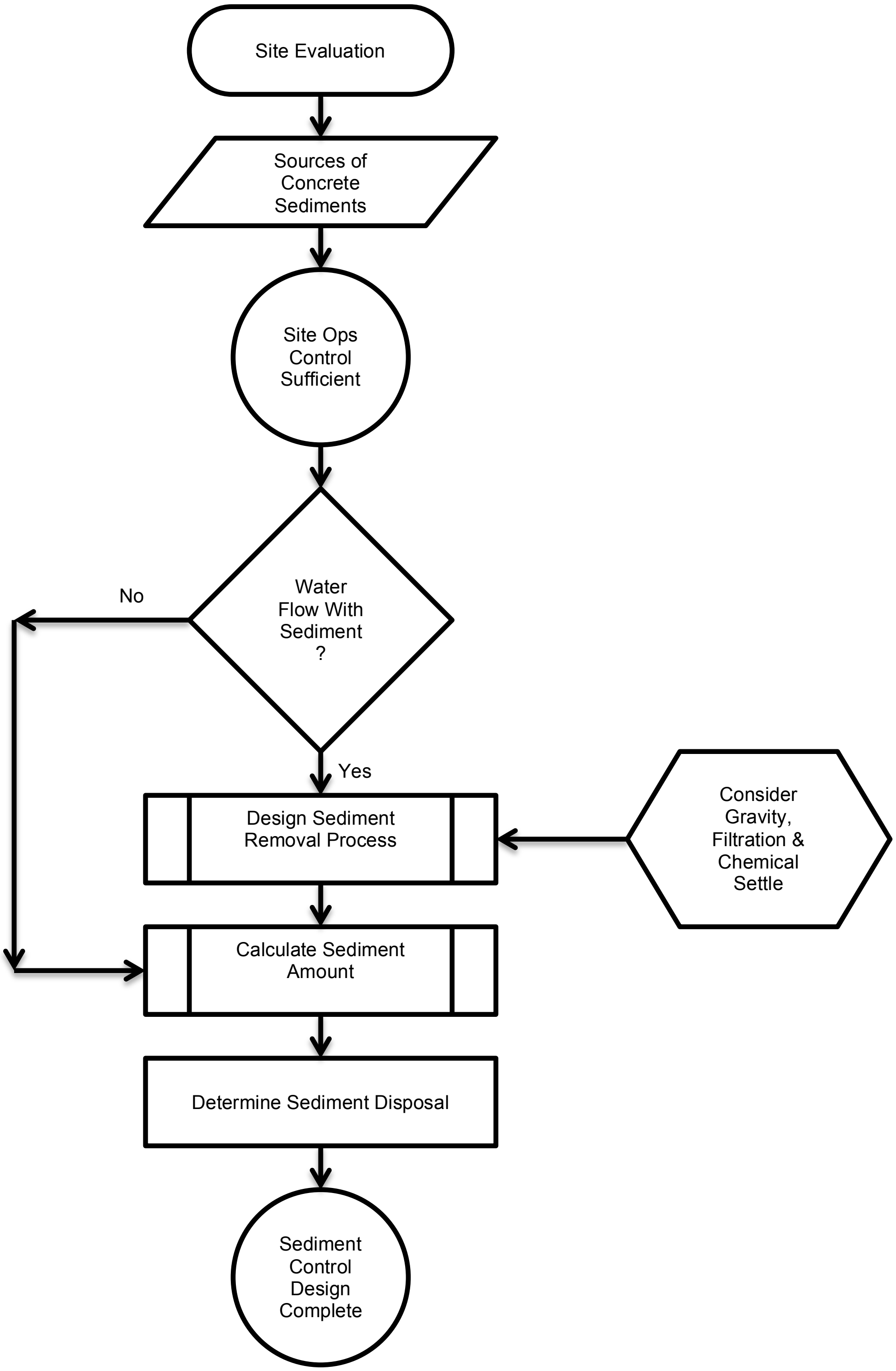


Figure F. Overview Flow Chart For All Concrete Sediment Sites.

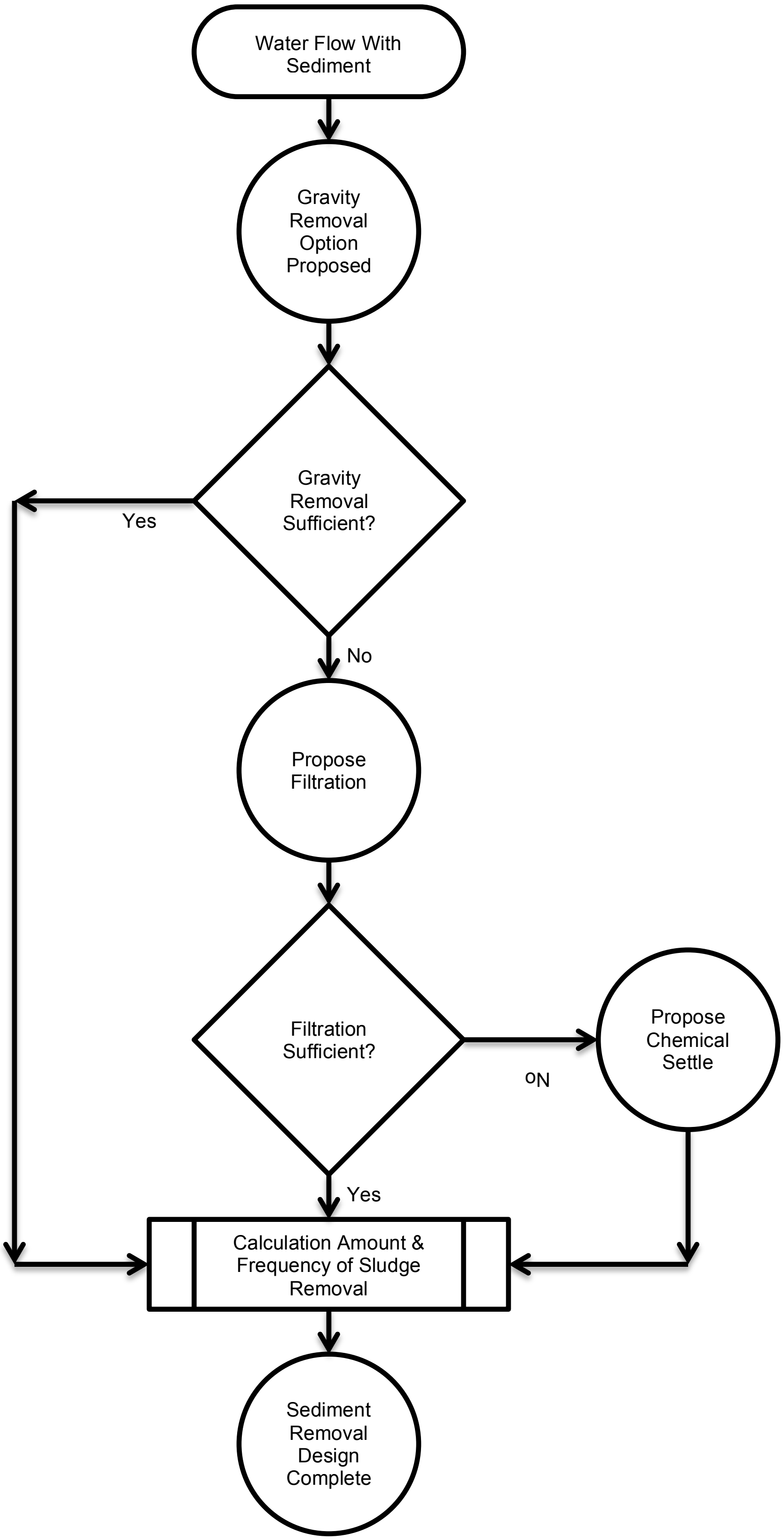


Figure G. Overview Flow Chart For Sediment With Water.