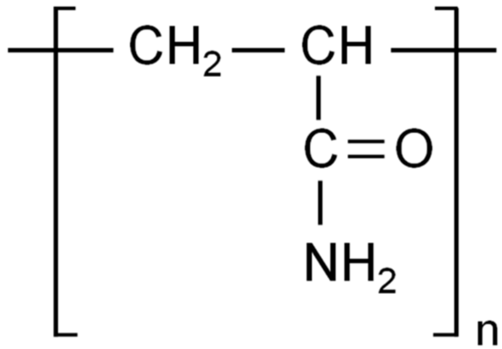
Performance Evaluation of Anionic Polymers for Treatment of Construction Runoff

and

Anionic Polyacrylamide Application Guide for Urban Construction in Ontario

The Living City Foundation
Toronto and Region Conservation for The Living City

What is Anionic Polyacrylamide?



- High molecular weight, water soluble molecule formed by polymerization of negatively charged acrylamide co-monomer.
- PAM aids solid-liquid separation by causing suspended particles to bind and form larger aggregates.
- The process is known as ***polymer bridging***.

What is Anionic Polyacrylamide?

- One of the most common polymer flocculants on the market
- Common uses of PAM as a flocculant:
  - reduction of sediment and nutrient loads to natural lakes and ponds
  - wastewater and drinking water treatment
  - clarification of effluents in industries like pulp & paper, aquaculture
- Most commonly used synthetic polymer for erosion prevention in irrigation furrows and on construction sites.
- Current popularity based largely on promising performance and low toxicity findings in studies completed to date.

Other Common Polymers

- ***Chitosan***
  - A cationic biopolymer derived from chitin, found in the exoskeleton of crustaceans and cell walls of fungi.
  - Toxic to aquatic organisms
  - Intended use as part of a system with a final clean up sand filtration step to remove chitosan and particulate matter

- ***Synthetic cationic polymers*** (including cationic PAM)
  - Significantly more toxic to aquatic organisms than anionic PAM
  - Cause greater fish mortality by accumulating in gills, interfering with gill function and ion regulation

ESC Applications of PAM

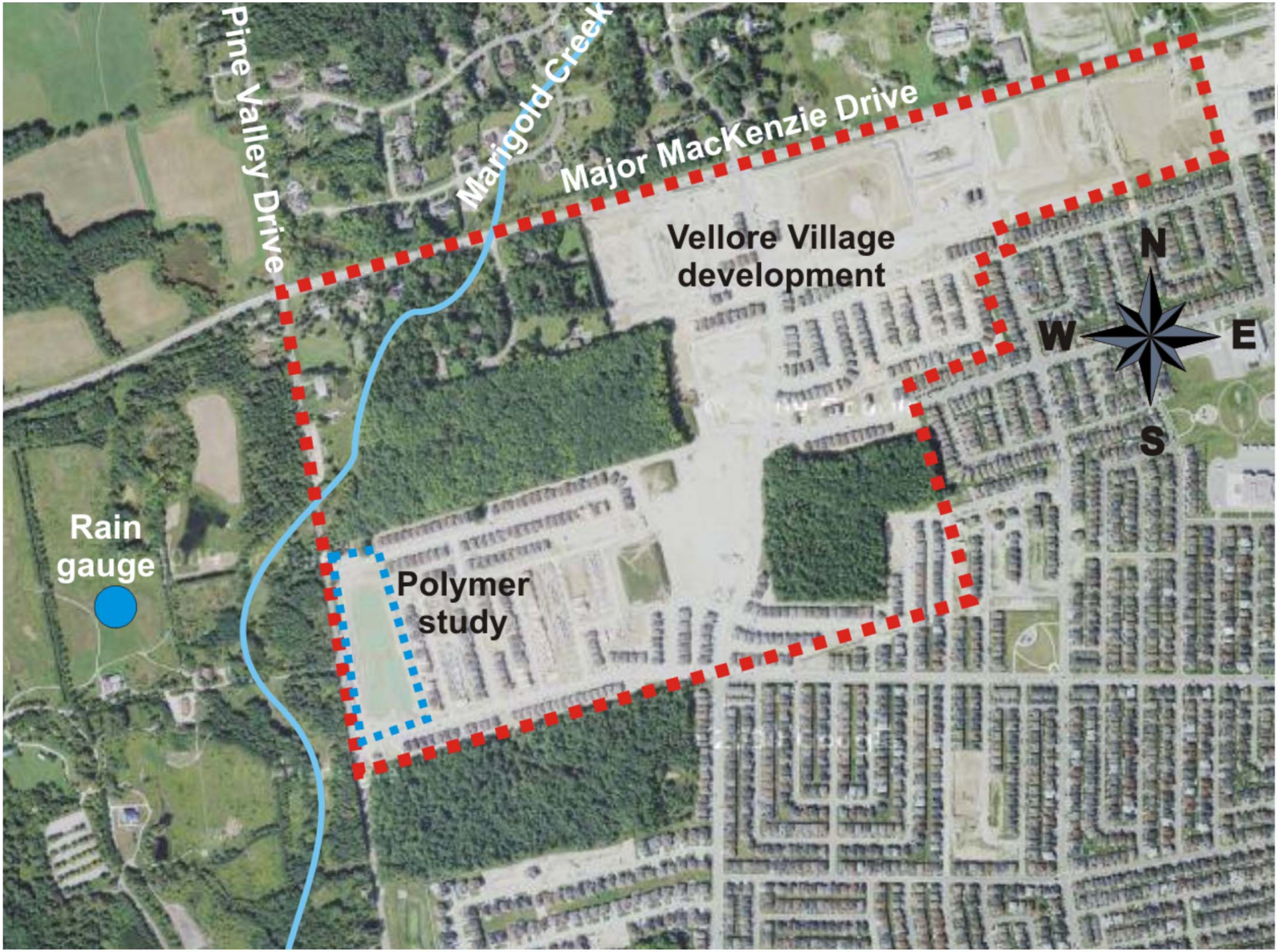
- **Clarification of construction runoff:** enhances flocculation of suspended particles, making them susceptible to settling or other removal methods.
- **Erosion control:** causes soil particles to bind to one another and form a surface resistant to erosive forces.

- **Dredging of sediment control ponds:** helps to bind soil particles together to facilitate removal and transport of wet sediment from the pond after it has been dewatered.

Evaluation of Anionic PAM

Block 39, Vaughan

- Field monitoring was carried out to assess effectiveness of PAM for clarifying water pumped from the sediment control pond.
- Two applications were tested: (i) a dewatering ditch and (ii) a PAM mixing tank used in series with a settling tank.
- These controlled treatment methods were selected because:
  - Dewatering of sediment-laden water is a common construction activity and treatment provided during this activity can be inadequate
  - The steady and controlled flow of the water being treated allows for the most accurate polymer dosing


Pine Valley Drive
Marigold Creek
Major MacKenzie Drive
Vellore Village development
N
W
E
S
Rain gauge
Polymer study

Study Objectives

- Quantify performance of anionic PAM for sediment removal from construction runoff in two pond dewatering applications.
- Determine which application tested is the most effective.
- Identify the key factors that affected performance.
- Summarize existing literature on the performance and toxicity of polymers.
- Interpret data collected to identify and assess potential ecological impacts.

Polymer Products

- Evaluated anionic PAM based products manufactured by Applied Polymer Systems (APS)
- Primary product used was the Floc Log®, a semi-solid block composed of drinking water chemicals and PAM
- In the ditch application an anionic PAM-based powder, sold by APS as Silt Stop®, was also used.

Ditch Application

- A south-draining 94 m stretch of the roadside ditch on Pine Valley Dr was retrofitted with a plastic liner, rock check dams, Floc Logs & jute netting coated with Silt Stop powder.
- Received sediment laden water pumped from the sediment control pond.
- Control for the experiment was installed on a 52-metre long north-draining stretch, including the same components with the exception of the PAM products.
- Two separate experiments were carried out during periods of elevated pond turbidity in order to assess performance.

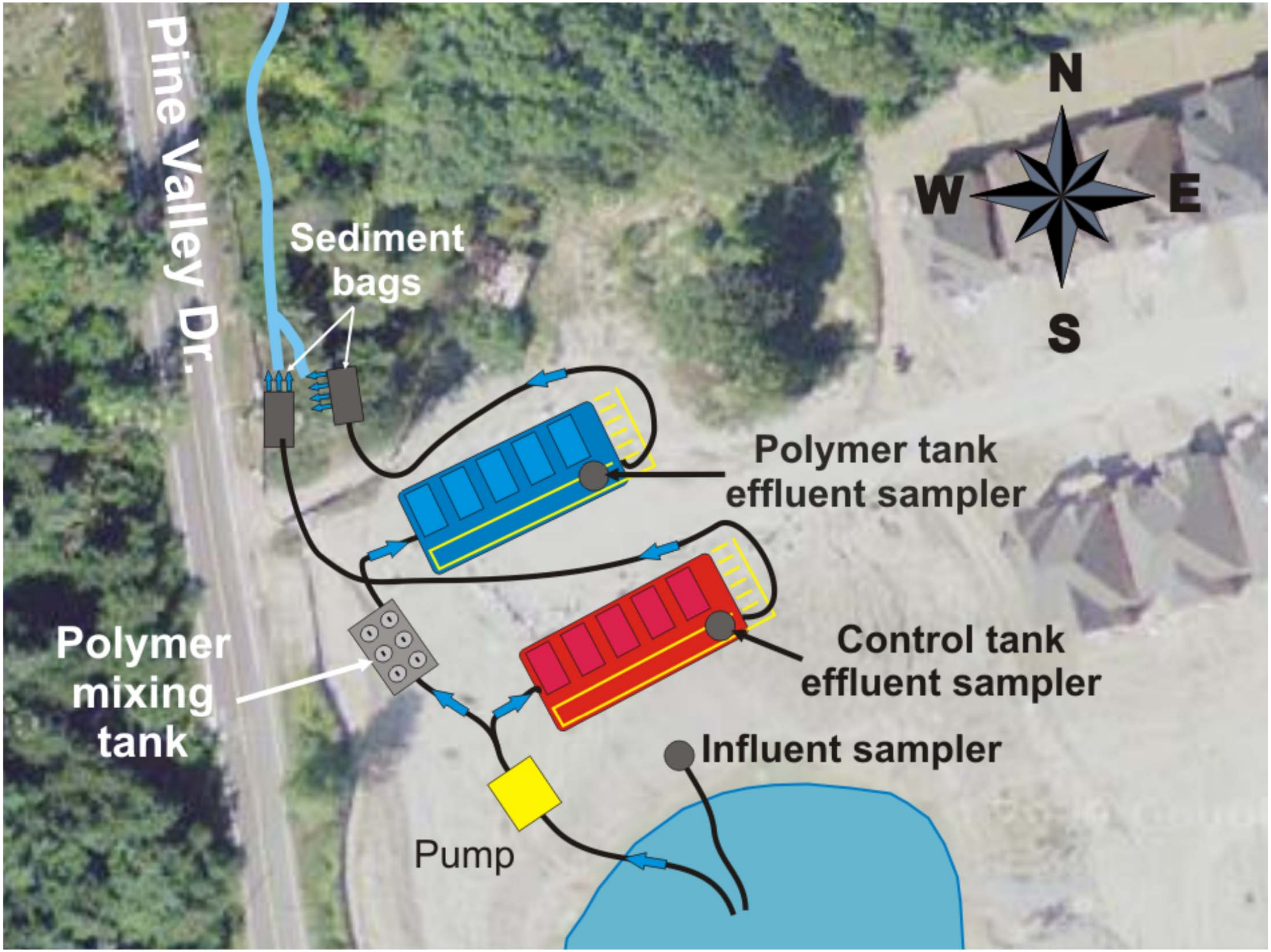
Ditch Application

- Experiment 1 – August 20, 2009
  - Water pumped into ditch at 11 L/s
  - samplers set up at beginning and end of each ditch
  - hourly samples collected for 20 hrs after a 60mm rainfall
- Experiment 2 – September 9, 2009
  - Logs re-positioned to improve contact with water
  - influent turbidity elevated through manual disturbance of pond bottom sediments near the pump intake.
  - Grab samples taken at different points in the ditches to measure the decline in turbidity along the flow path.
  - Samples were taken at two flow rates (8 L/s and 11 L/s) and at different influent turbidities


Control ditch
Polymer ditch
Before re-positioning
After
re-positioning

Tank Application

- Water pumped from the pond was dosed with anionic PAM Floc logs via a 1.8 m^3 mixing tank.
- Dosed water was pumped through to a large settling tank, followed by a sediment bag for final filtration and flow dispersion.
- Experimental control consisted of settling tank and downstream sediment bag.


Pine Valley Dr.
Sediment bags
N
W
E
S
Polymer tank effluent sampler
Polymer mixing tank
Control tank effluent sampler
Influent sampler
Pump

Tank Application

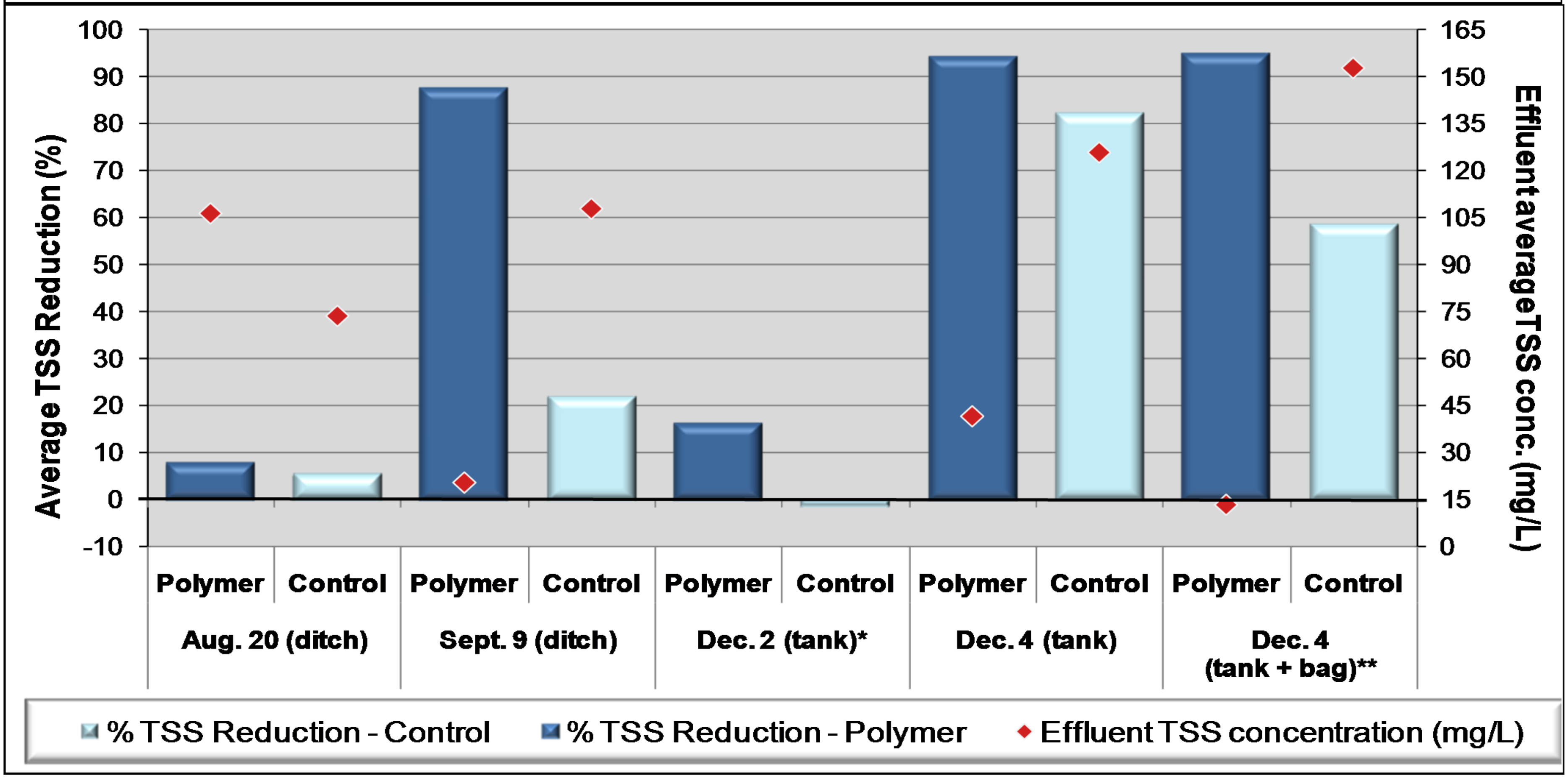
- Experiment 1: December 2, 2009
  - Sampling followed 17 mm rainfall
  - Influent and settling tank effluent samples collected
  - Handheld turbidity measurements showed samples were too clear for the test
- Experiment 2: December 4, 2009
  - Influent turbidity elevated through manual disturbance of pond bottom sediments
  - Samples collected included influent, settling tank effluent, and sediment bag (final) effluent
  - Prior to start of experiment, freezing of logs was observed, and thawing was required to maintain performance

Results

- For both applications, the polymer were consistently more effective at reducing TSS than corresponding controls.
- Largest TSS reductions observed in polymer on Sept. 9 (88%) and Dec. 4 (92%).
- Polymer systems were capable of reducing TSS concentrations to below 25 mg/L.

- Polymer tank system with the sediment bag achieved largest TSS reduction (95%) and lowest effluent TSS concentration (13 mg/L).
- For controls, effluent TSS consistently >25 mg/L (ranging from 74 to 153 mg/L), even when percent TSS reduction was high.

Experiment date	Application	Average TSS concentration (mg/L)				Average % TSS reduction		Comments
		Control influent	Control effluent	Polymer influent	Polymer effluent	Control	Polymer	
Aug. 20	ditch	78.0	73.7	115.3	106.5	5.4	7.7	Before correction of Floc Log® positions
Sept. 9	ditch	148	108	171	20.4	22.3	87.7	After correction of Floc Log® positions
Dec. 2	tank	TSS data not collected				-1.5*	16.2*	* No TSS data available; values represent turbidity reduction
Dec. 4	tank	706	126	706	41.6	82.2	94.1	Tank effluent prior to sediment bag filtration
Dec. 4	tank + bag	564 **	153 **	564 **	13.3 **	58.6 **	94.9 **	Tank effluent after sediment bag filtration **Average of only 4 samples; other results for Dec. 4 represent 16 samples.



Factors influencing performance

Three functions governing the effectiveness of PAM-based systems:

1. *Dosing*
   - Re-positioning of the Floc Logs after the first ditch test resulted in greater contact between water and logs, and a substantial performance improvement (from 7.7% to 87.7% TSS reduction).
   - Freezing of the logs during monitoring in December resulted in decreased sediment removal performance.
2. *Mixing*
   - During the Sept. 9 ditch test, TSS levels progressively decreased through the polymer ditch from the inlet to the outlet.
   - Optimization of flow rate and system length and structure are essential to proper mixing.

Factors influencing performance

3. Final filtration

- The effect of filtration in the tank experiment was substantial – sediment bag filtration decreased TSS in polymer tank effluent from 42 mg/L to 13 mg/L.

Factors influencing performance

- For controls systems, factors affecting gravitational settling of suspended particles (*e.g.* flow rate, PSD) are biggest determinants of performance.
- Lack of TSS removal in the control systems mainly due to lack of detention time.
- Re-suspension of previously deposited sediments can also hamper performance in settling tanks if they are not cleaned out regularly.

Field Study Conclusions

- Both the ditch and the tank were more effective with PAM than without.
- Dry weather pond turbidity may be too low to warrant polymer use during dewatering.
- Open ditch system is vulnerable to damage and sediment contamination.
- Final filtration was an essential component of the polymer tank system.
- Regular maintenance is essential to achieving optimal performance of the practices tested, with or without PAM.

Literature Findings

Performance

- Both anionic and cationic PAMs were effective in clarifying turbid waters.
- Several studies have shown that anionic PAM applied to soil as an erosion control can be highly effective in reducing runoff contaminant levels.
- Anionic PAM may either increase or decrease the hydraulic conductivity of a soil surface depending on soil structure and application method.

Literature Findings

Toxicity

- Little to no ill effect on mammals.
- Low toxicity to aquatic invertebrates and fish.
- PAM log from APS releases at between 2 and 30 mg/L; manufacturer toxicity studies indicate that the 48-hr LC-50 of the log >> 30 mg/L for invertebrate and fish species tested.
- Some evidence of higher toxicity to aquatic invertebrates than to fish, but this can vary widely based on the species.
- Oil-based emulsions are much more toxic than other PAM forms, likely due to additives (*e.g.* emulsifiers, surfactants).

Literature Findings

Toxicity

- Some concerns regarding potential release of acrylamide (AMD) – a carcinogen and neurotoxin – from PAM products.
- PAMs are highly stable and do not readily degrade to AMD.
- AMD is not released from anionic PAM at levels toxic to aquatic biota if it is properly selected and applied.
- Anionic PAM application rate and procedures should be carried out based on manufacturer recommendations.
- Residual levels of AMD in manufactured PAMs should be below potable water threshold set by the U.S. EPA (0.05%).

Recommendations

- PAM delivery systems must be designed for proper dosing, mixing, and final filtration.
- Site-specific water and sediment quality data should be used by supplier to determine the right polymer blend.
- Ongoing monitoring is needed to mitigate accidental polymer release.

Recommendations

- Risk of accidental polymer release can be minimized by
  - installing protection surrounding a ditch application or providing extra filtration at the end of the system;
  - ensuring dosage calculations are accurate; and
  - educating construction staff about the polymer product.
- Geotextile bags used for final filtration should be monitored closely and replaced as needed.

Knowledge gaps

- Physical impact of flocculated PAM sediment deposition aquatic habitats
- Effect of anionic PAM on other sensitive benthic invertebrates in southern Ontario

- Viability of other applications of anionic PAM for treating runoff from construction sites as well as built-out areas
- Relationship between TSS concentration of the water to be treated and the effectiveness of polymer dosing
- Performance of anionic PAM for erosion control on construction sites in southern Ontario

Anionic Polyacrylamide Application Guide for Urban Construction in Ontario

STEP

Toronto and Region Conservation for The Living City

THE CONSERVATION FOUNDATION OF GREATER TORONTO

Product selection criteria

- Anionic PAM as the active ingredient
- Site specific performance testing
- Moderate charge density
- High molecular weight
- No emulsions
- Safe according to toxicity reports and MSDS, given the expected release rates
- Residual acrylamide <0.05%
- Appropriate product labels and use instructions

Qualifications of professionals

- Components of an ESC plan that include anionic PAM should be designed by a qualified individual.
- Qualification is based on completion of previous training and field experience with anionic PAM.

- All onsite staff working with or around the polymer should be informed about proper handling and disposal.

Documentation

- All instances in which anionic PAM is used on a construction site should be documented.
- As a minimum the following information should be recorded:
  - Product details
  - Quantity used
  - Application rate
  - Site specific performance testing
  - Location of product application
  - Date of application
  - Name and qualification of installer
  - Method of application
  - Weather conditions during application
  - Description of intended function
  - Other observations relevant to the functioning of the product

Safe handling and disposal

- Always follow manufacturer guidelines for product handling.
- The following measures are typically taken to ensure the product is handled safely:
  - Use of the appropriate personal protective equipment (e.g. eye protection, gloves, dust mask as needed)
  - Skid protection employed during wet conditions if vehicle or foot traffic is expected on a PAM treated area
  - Clean up of dry product with simple sweeping, not water
  - Clean up of wet product by treating with an absorbent material first to make it easier to collect and remove

Safe handling and disposal

- Settled sediment must be tested to determine disposal options.
- Ministry of Environment's *Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act* (2011) provides contaminant thresholds and disposal options.
- Anionic PAM is not listed in the Standards and is not classified as hazardous waste.
- Disposal options for PAM treated sediments include:
  - reuse on site (with no off-site impacts); or
  - disposal at a regulated landfill site (if other contaminant levels don't exceed MOE Standards).
- Reuse of the material off-site requires site specific risk assessment.

Spill response

- Minor spills into a natural water feature should be immediately contained and removed.
- Minor spill is defined as having no adverse effect on the quality of the water, the substrate, or the aquatic organisms.
- Significant spills (i.e. those resulting in an adverse impact) should immediately be reported to the Ontario Ministry of Environment's Spills Action Centre (1-800-268-6060), the conservation authority enforcement officer, the municipality, and the landowner.
- Monitoring efforts and documentation of incident details and clean-up procedures should be initiated immediately.

Anionic PAM for erosion control

- Application methods:
  - Broadcast of granules
  - Sprayed as a water based solution
  - Incorporated into a hydroseeding mixture

- Construction site areas suitable for anionic PAM use:
  - soil stockpiles
  - low traffic sloped areas
  - stripped areas left inactive for extended periods of time
  - cut-off swales/ditches
  - other stripped areas where dust control is needed

Anionic PAM for erosion control
Guidelines

- PAM applied >15m from any watercourse, wetland, well, or other natural water feature.
- When used alone (with no other ground cover), only applied to prevent erosion in areas receiving non-concentrated flows.
- Prepare soil surface for PAM application (fill rills, gullies).
- Application of anionic PAM with seed or other ground cover is preferable to the use of the polymer alone on bare soil.
- Application rate should provide erosion control without excess product that may be washed away.

Anionic PAM for erosion control
Guidelines

- Surface wetting following application of granular PAM should be done through controlled watering (rather than awaiting rainfall).
- Re-apply according to manufacturer recommended frequency or sooner if erosion is observed (six week interval is recommended).
- The condition of the PAM-stabilized surface should be inspected weekly and before and after any rainfall event.
- Deficiencies observed during inspection of an anionic PAM treated surface should be ***rectified within 48 hours or sooner if critical environmental receptors are at risk of adverse impact.***

Construction runoff clarification

- An anionic PAM based treatment system may be a desirable means of promoting greater sediment removal, particularly:
  - for dewatering an area with highly turbid water;
  - in situations where conveyance of turbid water to a sediment control pond is not possible; and
  - when the available sediment retention measure will not allow for adequate settling time because incoming flows are too high.
- These systems are best suited to treat runoff with suspended solids concentrations >100 mg/L.
- Guidance on the maximum TSS concentration that can be effectively treated should be obtained from the manufacturer.

Construction runoff clarification

System design

- System functions: dosing, mixing, settling and final filtration.
- In open systems (ditches, swales), care should be taken to prevent unintended sediment-laden runoff from entering the system during wet weather.
- Water flowing ***out*** of the system from somewhere other than the outlet should be controlled to ensure polymer-dosed water is not released without filtration.

Construction runoff clarification

Dosing

- Success of dosing depends upon:
  - **Polymer product formulation**
    determined based on site specific soil and water testing
  - **Flow rate of water through the system**
    determined based on consultation with manufacturer, with consideration for intended use, system design/dimensions, site restrictions (e.g. space)
  - **Polymer product amount**
    calculated from standard 'quantity per unit flow rate' value provided by the manufacturer
  - **Physical structure of the system**
    designed to allow maximum contact between the PAM and the water, avoiding any short circuiting

Construction runoff clarification
Mixing

- Physical mixing increases opportunity for sediment particles to react with the PAM to form larger particles.
- Often passive, achieved by allowing water to flow through barriers to create turbulence.
- Length of mixing zone depends partly on flow rate; faster flow rate requires a longer flow path through the mixing zone than a slower flow rate.
- Mixing time determined based on manufacturer guidance.

Construction runoff clarification
Settling

- Settling area allows gravitational settling of flocculated masses.
- Should be large enough to hold a significant amount of sediment without requiring very frequent clean out.
- Clean out when sediment accumulates to 30% of the height of the sediment retention barrier, or if re-suspension occurs.
- Settling area may include a natural fibre (e.g. jute or coir) coated with a powder form of the anionic PAM product.
- PAM-coated fibre will have an electrostatic affinity for flocculated sediment particles that helps enhance settling.

Construction runoff clarification
Filtration

- All PAM-based treatment system effluents should be filtered.
- Filter rated for removing particles 150 microns or smaller (apparent opening size no larger than 0.15 mm).
- Acceptable filtration methods include:
  - non-woven geotextile filter bags
  - non-woven geotextile particle curtains
  - non-woven geotextile fabric in another configuration
  - sand filters

- Prevent erosion downstream of system outlet - stabilization of flow path and/or dispersion of effluent.

Construction runoff clarification

System siting

- Never sited in natural areas, including woodlots and water features (e.g. streams, lakes, wetlands).
- If effluent is discharged to a natural water feature, the distance between the system outlet and the feature should >10 metres, with flow dispersion applied to prevent concentrated flows.
- Always consider susceptibility to vandalism, or damage related to extreme weather or construction activities.
- Designs that are more resilient and/or protected from the elements and vandalism are preferable to exposed systems.

Construction runoff clarification

Inspection, monitoring and maintenance

- Inspection frequency will vary based on system design and how often it is used.
- Daily inspections should be conducted when the system is active.
- During inactive periods, before and after wet weather events.
- Monitoring and maintenance program should include:
  - Inspection of filters
  - Assessment of sediment accumulation and clean out as needed (i.e. at 30% accumulation or if re-suspension occurs)
  - Inspection and maintenance of anionic PAM blocks
  - General inspection and maintenance of system components
  - Periodic collection of effluent samples for suspended solids testing

Pond demucking

- Use of anionic PAM helps to consolidate or thicken saturated soils that would otherwise be difficult to remove.
- For hydraulic dredging, a water-based liquid form of the product should be used rather than an emulsion.
- As in other applications, testing with site specific sediment and water samples is essential.
- Excess water should be removed to the extent feasible prior to PAM application, as it has an adverse effect on performance .
- Powder forms applied directly to wet sediment should be mixed according to manufacturer recommendations.
- Optimal performance during warm temperatures (>10°C).

What's next?

- Polymer Training Workshop – June 19, 2013
- ESC Field Training Workshop – June 20, 2013 (to include polymer field demonstrations)
- Full scale field evaluation of a pond demucking project using anionic PAM
- Explore compilation of an approved polymer product list

Questions?

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