Pilot Testing Project Report:

Sampling and analysis of potential surface water sources using conventional jar testing methods for Wahta Mohawk First Nation

Walkerton Clean Water Centre

Research & Technology

May 28th, 2019

Disclaimer

The pilot testing project report is presented solely for information purposes and is not intended to provide specific advice or recommendations in any circumstances. This pilot testing project report may include information from different sources and such information has not been independently confirmed for correctness or completeness. The information provided does not imply on the part of the Government of Ontario, the Walkerton Clean Water Centre (Centre) or its employees, any endorsement or guarantee of any of the information. The Government of Ontario, the Centre and its employees, do not assume and are not responsible for any liability whatsoever for any information, interpretation, comments or opinions expressed in the pilot testing project report.

Acknowledgments

This report was prepared by:

Jeff Avedesian, M.Sc., Scientist

Laura Zettler, C.E.T., Drinking Water Resource Coordinator

Elliot Jones, B.A.Sc., Acting Scientist

Souleymane Ndiongue, Ph.D., P.Eng., Manager

Table of Contents

List of Figures

List of Tables

Executive Summary

Background

The Wahta Mohawk First Nation (WMFN) community is investigating the potential implementation of a drinking water treatment system for residents in its core area (UMA, 2001; SBA, 2018) following the direction of a capital planning report that outlined projected growth and development (RJBA, 1994). Laforce Lake (also known as Lafarce Lake), Webster Lake, and Gibson Lake are nearby inland lakes that may be deemed appropriate for the feasibility study (UMA, 2001). Preliminary data analysis of the lakes was conducted in the fall of 2018, and again in the spring of 2019 to encompass seasonal variation and expedite the pilot phase of the feasibility study with a consultant.

Objective

The objective of this project was to evaluate the treatability of the source waters, Laforce Lake, Gibson Lake and Webster Lake, by analysis of selected general water quality parameters and jar testing performance.

Approach

The Centre sampled the three source waters during two seasons and analyzed for general water quality parameters. Jar tests were completed using selected coagulants and targeted the removal of common parameters such as turbidity and dissolved organic carbon (DOC).

Key Findings

- The three lakes had similar turbidity, pH, fluoride, and aluminum; however, natural organic matter (NOM) measured as DOC, ultraviolet absorbance (UVa) and true colour in the lakes varied.
- Parameters such as hardness, alkalinity, orthophosphate, free and total ammonia, and nitrite measured near or below the measuring range for all lakes.
- The final pH and alkalinity of the treated water should be adjusted to meet the operational guidelines to prevent corrosion in the distribution system.

1. Introduction

The Wahta Mohawk First Nation (WMFN) community investigated the potential implementation of a drinking water treatment system for residents in its core area (UMA, 2001; SBA, 2018) following the direction of a capital planning report that outlined projected growth and development (RJBA, 1994). The community expressed interest to conduct experiments with the aim of identifying potential source water options and their unique treatment implications. WMFN and Ontario First Nation Technical Services Corporation (OFNTSC) collaboratively tendered Neegan Burnside to consult and conduct a feasibility study of potential groundwater and surface water options in the area. The focus of this study was to sample and analyze the potential surface waters through conventional jar testing to better understand the water characteristics. Laforce Lake (also known as Lafarce Lake), Webster Lake, and Gibson Lake were nearby inland lakes that may be deemed appropriate for the feasibility study (UMA, 2001).

2. Rationale

Bench-scale testing was needed to compare the effect of coagulation on the surface water quality for conventional treatment of the lakes. The three lakes were sampled, and three jar tests were performed using three types of common coagulants. An aluminum sulfate (ALS) was used as a baseline because it is cost-effective and commonly used as a coagulant in conventional water treatment clarification. A polyaluminum chloride (PAX-XL6) was chosen because it is a commonly used alternative to ALS. Compared to ALS, PAX-XL6 contains highly positive charged aluminum, which typically requires less chemical demand (Kemira, 2018c). PAX-XL6 should generate less sludge, require less pH adjustment, improve filter run times, and perform well in cold waters (Kemira, 2018c), but is more expensive than ALS. Polyaluminum silicate sulfate (PASS-10) was chosen because it also has highly charged aluminum for a reduced dosage and sludge production (Kemira, 2018b). Like PAX-XL6, it should require less pH adjustment, provide longer filter runs, and have improved cold water performance compared to ALS (Kemira, 2018b).

3. Objective

The objective of this project was to evaluate the treatability of Laforce Lake, Gibson Lake and Webster Lake. Selected water quality parameters were targeted in jar tests using the selected coagulants and doses on the three water sources.

4. Methods

An untreated sample of each source was analyzed by WCWC staff at the beginning of the experiment to determine the raw water quality using the parameters, instruments and methods listed in Table 4.1.

A standard jar testing procedure, adopted from AWWA Manual 37 (2011) was used to simulate the coagulation (rapid mixing), flocculation (gentle agitation), and sedimentation (settling) stages of conventional treatment. A 'Phipps & Bird' six jar tester was filled with 2L volumes and mechanical paddle stirrers simulated the rapid mixing and flocculation stages. Sample water was mixed rapidly at 100 rpm for 1 minute, followed by 20 rpm for 30 minutes to simulate flocculation, and 0 rpm for 30 minutes to simulate the settling stage of the clarifier. Afterwards, approximately 500 mL of clarified water was sampled and analyzed for the parameters in Table 1 to assess the efficacy of each coagulant and optimum dose. Table 4.1 is a summary of the selected water quality parameters, the chosen methods and instrumentation as well as any additional sample treatment preparation if necessary.

Table 4.1. Sampling and Analysis

Parameters	Method	Instruments	MDL*	Sample Treatment
Turbidity	Nephelometric	Hach 2100P	0.01 NTU	
Alkalinity ($CaCO_3$)	Method 10280 (LR)	Hach SL1000	20 mg/L	
Hardness ($CaCO_3$)	Method 10284 (LR)	Hach SL1000	3 mg/L	
Ultraviolet absorbance (UVa)	Method 10054	Real UV254	0 abs/cm	0.45 µm Filter
Dissolved organic carbon (DOC)	Persulphate- UV oxidation	Sievers 5310C Laboratory TOC analyzer	0.03 µg/L	0.45 µm Filter
Free ammonia	Method 10268	Hach SL1000	0.05 mg/L	
Total ammonia	Method 10268	Hach SL1000	0.05 mg/L	
Nitrite	Method 10271	Hach SL1000	0.005 mg/L	
(Ortho)Phosphate (PO_4)	Method 10279 (LR)	Hach SL1000	0.20 mg/L	
Total dissolved solids (TDS)	Method 8160	Hach HQ40D/ CDC401	0 g/L	
Sodium	Method 8322	Hach HQ40D/ sodium ISE	0.023 mg/L Na^+	
Fluoride	Direct method	Hach HQ40D/ ISEF121	0.1 mg/L F^-	
pH	Method 8156	Hach HQ40D/ PHC301	0 pH	
Chloride	Direct method	Hach HQ40D/ ISECL181	0.1 mg/L Cl^-	
Colour (true)	Method 8025	Hach 3900	5 Pt-Co	0.45 µm Filter
Colour (apparent)	Method 8025	Hach 3900	5 Pt-Co	
Aluminum	Method 8012/ 8326	Hach 3900	0.02 mg/L	
Total iron	Method 8008	Hach 3900	0.05 mg/L	
Total manganese	Method 8149	Hach 3900	0.01 µg/L	

*MDL = Minimum Detection Limit

Additionally, specific ultraviolet absorbance (SUVA) was calculated to estimate the expected DOC removal and to compare to the actual organic removal (Edzwald and Tobiason, 1999; EPA, 1999) (see Results and Discussion). Selected coagulants and their details were adapted from the chemical safety data sheets (SDS), which can be found in Table 4.2, and were used to determine the concentration of dry dosages.

Table 4.2. Selected Coagulants

Coagulant	Chemical Formula	% Concentration	Properties	Name
ALS	$Al_2(SO_4)_3 \cdot 14\ H_2O$	20 – 30%	Colourless, clear liquid pH: ~ 2 S.G. 1.29 - 1.35	Aluminum sulfate
PAX-XL6	(Not Available)	30 – 35%	Clear, amber, or colorless liquid pH: 2.1 - 3.1 S.G 1.18 - 1.26	Polyaluminum chloride
Pass-10	$Al_4(OH)_6(SO_4)_3$	35 – 40%	Clear Liquid pH: 3.0 – 3.8 S.G. 1.30 – 1.34	Polyaluminum silicate sulfate

* Information adapted from chemical SDS (Kemira, 2018a, Kemira, 2018b, Kemira, 2018c); S.G. = specific gravity.

5. Results and Discussion

5.1 Fall Samples

5.1.1 Raw Water Characteristics

The results of the sampling and analysis of raw water from the fall sample can be found in Table 5.1.

Table 5.1. Fall Raw Water Characteristics

Parameter	Laforce Lake	Gibson Lake	Webster Lake
Turbidity (NTU)	1.90	2.38	1.26
Aluminum (mg/L)	0.029	0.032	0.075
UVa (cm^{-1})	0.399	0.267	0.515
DOC (mg/L)	10.1	7.9	12.2
SUVA (L/mg-m)	4.0	3.4	4.2
Alkalinity (mg/L as $CaCO_3$)	11	20	18
Hardness (mg/L as $CaCO_3$)	11	17	6
Free Ammonia (mg/L)	0.14	0.13	<0.05
Total Ammonia (mg/L)	<0.05	<0.05	<0.05
Nitrite (mg/L)	<0.005	<0.005	<0.005
(Ortho)phosphate (mg/L)	<0.2	<0.2	<0.2
Total iron (mg/L)	0.32	0.42	0.19
Total manganese (mg/L)	0.056	0.034	0.028
Apparent Colour (Pt-Co)	95	72	117
True Colour (Pt-Co)	80	51	106
pH	6.88	6.72	6.53
TDS	42.6	41.5	138.8
Sodium (mg/L)	38	40	174
Chloride (mg/L)	16.6	17.7	55.5
Fluoride (mg/L)	0.0549	0.0557	0.0645

UVa can be applied to the SUVA equation to better understand the composition of DOC. SUVA is a relationship between the measurement of DOC and UVa, acts as an operational indicator of the organic composition and provides the expected DOC removal using ALS as the coagulant (Edzwald and Tobiason, 1999). The SUVA value obtained from the raw water DOC and UVa will estimate the composition and the expected percentage of DOC removal (Table 4). The formula for SUVA is described below.

$$SUVA = \frac{UVa\ (cm^{-1})}{DOC\ (\frac{mg}{L})}\ X\ \frac{100\ cm}{1\ m}$$

Table 5.2. Guidelines for Expected Composition and Expected DOC Removals

SUVA	Composition	Coagulation Removal	DOC Removal
≥ 4	Mostly humic, hydrophobic, high molecular weight organics	Good	≥ 50%
2 – 4	Mixture of humic and non- humic	Fair – Good	25 – 50%
< 2	Mostly non-humic, hydrophilic, low molecular weight organics	Poor	< 25%

*Adapted from Edzwald and Tobiason, 1999; EPA, 1999.

The following calculations were used to determine the SUVA values of the three source waters.

$$Laforce\ Lake\ SUVA = \frac{0.399\ cm^{-1}}{10.10\ \frac{mg}{L}}\ X\ 100 \qquad = \qquad 4.0$$

$$Gibson\ Lake\ SUVA = \frac{0.267\ cm^{-1}}{7.90\ \frac{mg}{L}}\ X\ 100 \qquad = \qquad 3.4$$

$$Webster\ Lake\ SUVA = \frac{0.515\ cm^{-1}}{12.20\ \frac{mg}{L}}\ X\ 100 \qquad = \qquad 4.2$$

Turbidity

Turbidity represents the clarity of water by measuring the suspended and colloidal matter of a water sample, expressed as nephelometric turbidity units (NTU). Turbidity readings that are low have a low amount of scattered light, meaning they have fewer suspended particles and are clearer. Not only is turbidity an aesthetic parameter, but it's also an important health-based parameter because pathogens that can cause adverse health effects could be shielded from disinfection by suspended particles (MECP, 2006a). Turbidity also effects down-stream processes such as filtration, ultraviolet (UV) disinfection and chlorine disinfection. Therefore, raw and clarified waters with a lower turbidity are desired. Gibson Lake had the highest turbidity at 2.38 NTU, followed by Laforce Lake at 1.90 NTU and Webster Lake as the lowest at 1.26 NTU (Table 5.1).

UVa, DOC, and Colour

The UVa surrogate measurement of organics is proportional to the organic concentration in water (AWWA, 2017). The UVa of the three lakes can be seen in Table 5.1, where Webster Lake was the highest at 0.515 cm^{-1}, Laforce was next at 0.399 cm^{-1}, and Gibson Lake as the lowest at 0.267 cm^{-1}. The SUVA results suggest that enhanced coagulation with ALS would yield a ≥ 50% DOC reduction of Laforce Lake and Webster Lake and 25-50% DOC reduction of Gibson Lake. The organic composition and expected DOC reduction were only assessed using one grab sample and may change seasonally.

The suspended portion of organic carbon in water can be easily removed during the coagulation process; however, DOC can be more difficult to remove due to the nature of the organic composition (EPA, 1999). If left untreated, organics can negatively impact the quality of water, causing an unpleasant taste and odour, colour, increased requirement for coagulant doses, reduced UV disinfection effectiveness, increased chlorine demand and they are precursors for disinfection by-products (AWWA, 2017; MECP, 2006b). Webster Lake measured the highest at 12.2 mg/L of DOC, Laforce Lake measured at 10.1 mg/L of DOC, followed by Gibson Lake at the lowest of 7.9 mg/L of DOC.

Apparent colour is a measure of both suspended and dissolved organics such as decaying vegetation and inorganics such as iron or manganese. True colour is a measure of dissolved organic and inorganic materials and has an aesthetic objective (AO) of 5

True Colour Units (TCU) or Platinum Cobalt Units (Pt-Co) in Ontario (MECP, 2006b) and ≤15 TCU in Canada (Health Canada, 2017). Table 5.1 results show Webster Lake with the highest readings of true and apparent colour, and Gibson Lake had the lowest.

Iron and Manganese

Iron and manganese are aesthetic parameters often associated with groundwater but can exist in surface water and can be responsible for unwanted colour, taste and odour issues. The Ontario AO for iron is 0.3 mg/L and manganese is 0.05 mg/L because concentrations above those values leave brown iron stains on plumbing fixtures or black manganese stains on laundry (MECP, 2006b). Iron and manganese reducing bacteria can also lead to offensive taste and odour issues and they are often treated to improve the quality of water, although the parameters cause no known adverse health effects. Out of the three lakes, Webster Lake had the lowest total iron and manganese levels, whereas Gibson Lake had the highest total iron and Laforce Lake had the highest total manganese level (Table 5.1).

pH and Alkalinity

The pH of the three lakes fell within Ontario's operational guideline (OG) between 6.5 and 8.5, but outside Health Canada's OG of 7.0 – 10.5 (MECP, 2006b; Health Canada, 2017) (Table 5.1). It is important for the pH to fall within the OG by the end of treatment to improve the efficacy of certain processes such as disinfection; and reduce the effects of corrosion or scaling of equipment in the distribution system (MECP, 2006b). The optimum pH range for ALS coagulation is 5.8 - 6.5 (Gebbie, 2006), whereas polyaluminum coagulants have a wider range of 5.0 - 8.0 (Gebbie, 2001).

Alkalinity is the ability of water to resist a change in pH (acid resisting) and is expressed as calcium carbonate (MECP, 2006b). All three lakes measured below the OG of 30 - 500 mg/L, between 10 mg/L and 20 mg/L (Table 5.1). Although alkalinity is important to act as a buffer in the distribution system, in the case where the removal of organic carbon is the primary target of coagulation, a lower alkalinity is desired to improve the removal of organic carbon efficiency (EPA, 1999). As the coagulation process typically consumes alkalinity during the formation of floc, it is common for utilities to add alkalinity before coagulation to improve floc formation or later in treatment to improve the water's buffering capacity in the distribution system (MECP, 2006b).

Other Parameters

TDS mainly refers to inorganic substances dissolved in water which are mainly comprised of chloride, calcium, magnesium, bicarbonates, sulfates and/or sodium (MECP, 2006b). Table 5.1 indicates Webster Lake had the highest TDS at ~140 mg/L, where Laforce Lake and Gibson Lake were just above 40 mg/L. All the lakes were below Ontario's and Health Canada's AO of 500 mg/L (MECP, 2006b, Health Canada 2017).

Sodium is a common, non-toxic parameter and as a result, a maximum acceptable concentration for sodium in drinking water has yet to be specified for Ontario or Canada (Health Canada, 2017; MECP, 2006b). Sodium in the environment exists naturally but can also be caused from road salt or brine waste discharge from water softeners. Although the consumption of 10 grams of sodium per day by healthy adults does not result in noticeable adverse health effects, the AO in water is 200 mg/L due to the detection of a salty taste (Health Canada, 2017; MECP, 2006). Additionally, the local Medical Officer of Health must be notified when the sodium level exceeds 20 mg/L to notify local physicians to inform patients on sodium restricted diets (MECP, 2006b). Gibson Lake, Laforce Lake and Webster Lake had sodium levels at 39.9 mg/L, 38.0 mg/L and 174.0 mg/L, respectively (Table 5.1).

Chloride is commonly found in nature as it is associated with sodium, potassium and calcium salts. It is non-toxic and has an AO of 250 mg/L in Ontario and Canada (MECP, 2006b; Health Canada, 2017). Table 5.1 indicates the chloride levels are below 60 mg/L in all lakes, and Gibson Lake had the lowest value.

There is no OG or AO set for ammonia as it is produced in the body, does not cause adverse health effects, and can be efficiently metabolized in healthy people (Health Canada, 2017). It can occur naturally in the environment or be released from agricultural sources or industrial wastes. Ammonia is a unique parameter that when present, reacts with chlorine to form chloramines which could be used as part of a disinfection strategy. Utilities that operate a chloramination system sometimes use existing ammonia or may introduce ammonia followed by chlorine as their method for secondary disinfection. The free ammonia was measured at 0.14 mg/L, 0.13 mg/L and below the detection limit (<0.05 mg/L) for Laforce Lake, Gibson Lake and Webster Lake, respectively (Table 5.1).

Nitrite has a maximum acceptable/allowable concentration (MAC) of 1 mg/L as nitrogen because of its relationship with methaemoglobinaemia (blue baby syndrome) in bottle fed infants less than 6 months old (Health Canada, 2017; MECP, 2006b). The common sources of nitrite are naturally occurring, from leaching waste, or agriculture run-off from inorganic fertilizers, manure and domestic sewage. Nitrite was recorded below the detection limit in all three lakes (Table 5.1).

Phosphorus is a natural element found in soil and water that is vital for plant life and healthy ecosystems; however, when phosphorus concentrations in rivers and lakes become elevated, aquatic plant growth can become excessive and harmful. The decay of excess plant material can result in a decrease of dissolved oxygen that fish and other aquatic animals rely on for survival (ECCC, 2017). The common sources of concentrated phosphorus are agricultural fertilizers, manure, and municipal and industrial wastewater effluent (USGS, 2018). The chosen method to measure phosphorus was based on simplicity of on-site analysis, but all lakes were below the method detection limit (MDL) of 0.2 mg/L as orthophosphate; therefore, a lower range method should be used for future analysis. It is suggested that total phosphorus, Method 8190 PhosVer® 3 with acid persulfate digestion and a range of 0.02 - 1.10 mg/L P be used in future sampling.

The OG for hardness in Ontario is 80 – 100 mg/L as $CaCO_3$ which is set to aid a community during source water selection when a choice exists (MECP, 2006b). Water with elevated hardness can leave scale and water deposits on fixtures as well as leave excessive scum when regular soaps are used. Soft water, or water with a low level of hardness, may be corrosive and damage pipes and fixtures (MECP, 2006b). All three lakes measured below the operational guideline for hardness and near the method’s MDL (Table 5.1).

5.1.2 Laforce Lake Jar Test

Water treated with PAX-XL6 had the lowest turbidity for all coagulant doses compared to ALS and Pass-10. Figure 5.1 suggests that the optimum dose for ALS was 20 mg/L, PAX-XL6 was 20 mg/L and Pass-10 was 50 mg/L.

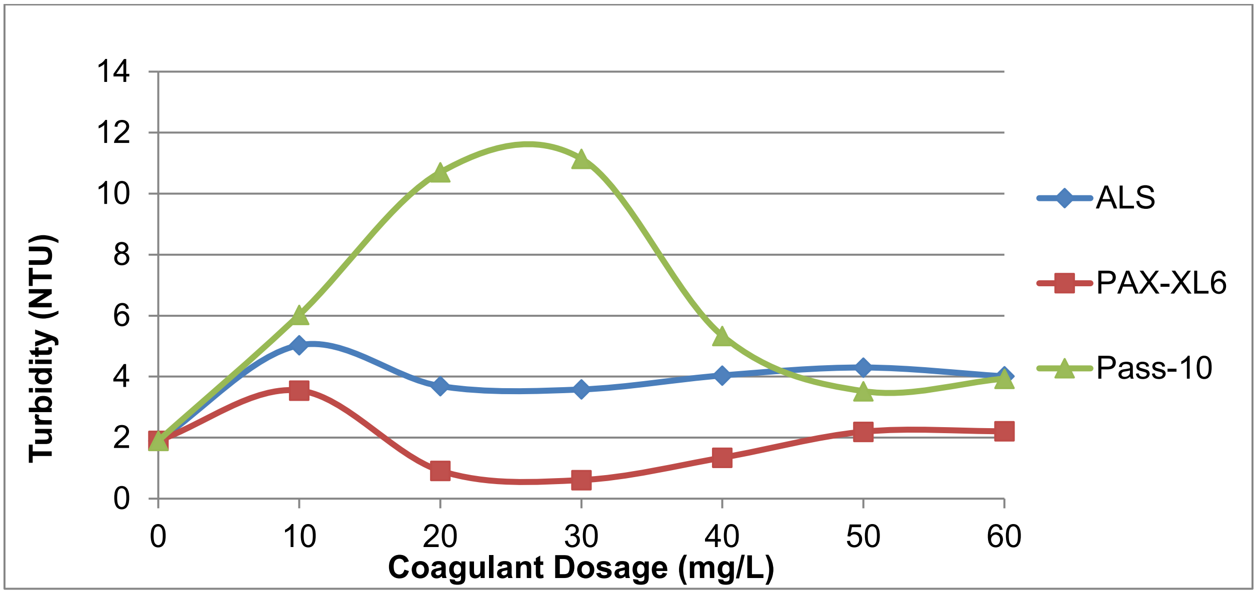

Figure 5.1. Laforce Lake Turbidity vs Coagulant Dose

The coagulant performance for the reduction of UVa and DOC was evaluated in Figure 5.2 and Figure 5.3, respectively. The ALS optimum dose was 10 mg/L, PAX-XL6 was approximately 30 mg/L, and Pass-10 performed best between 50 mg/L and 60 mg/L. The SUVA value for Laforce Lake was 4, with the expected DOC reduction ≥ 50% with ALS. The raw water began with a DOC of 10.10 mg/L and 20 mg/L of ALS brought the DOC to 4.98 mg/L, indicating a 51% reduction from raw water. Pass-10 reduced the DOC to 4.93 mg/L at a dose of 60 mg/L, which was only slightly better than ALS but used three times the chemical. PAX-XL6 provided a DOC removal of 66% to 3.38 mg/L at a dose of 30 mg/L. The jar test results are in agreeance with the SUVA expected DOC removal estimates and suggest that the enhanced coagulation process has been optimized for organic removal.

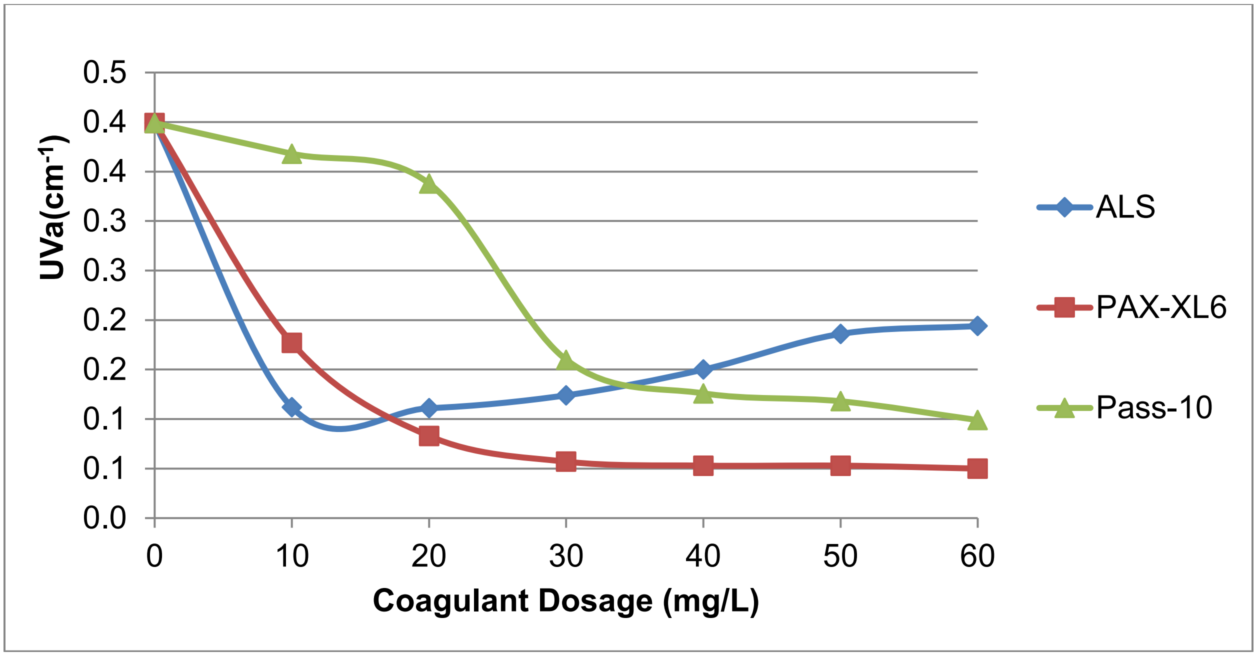

Figure 5.2. Laforce Lake UVa vs Coagulant Dose

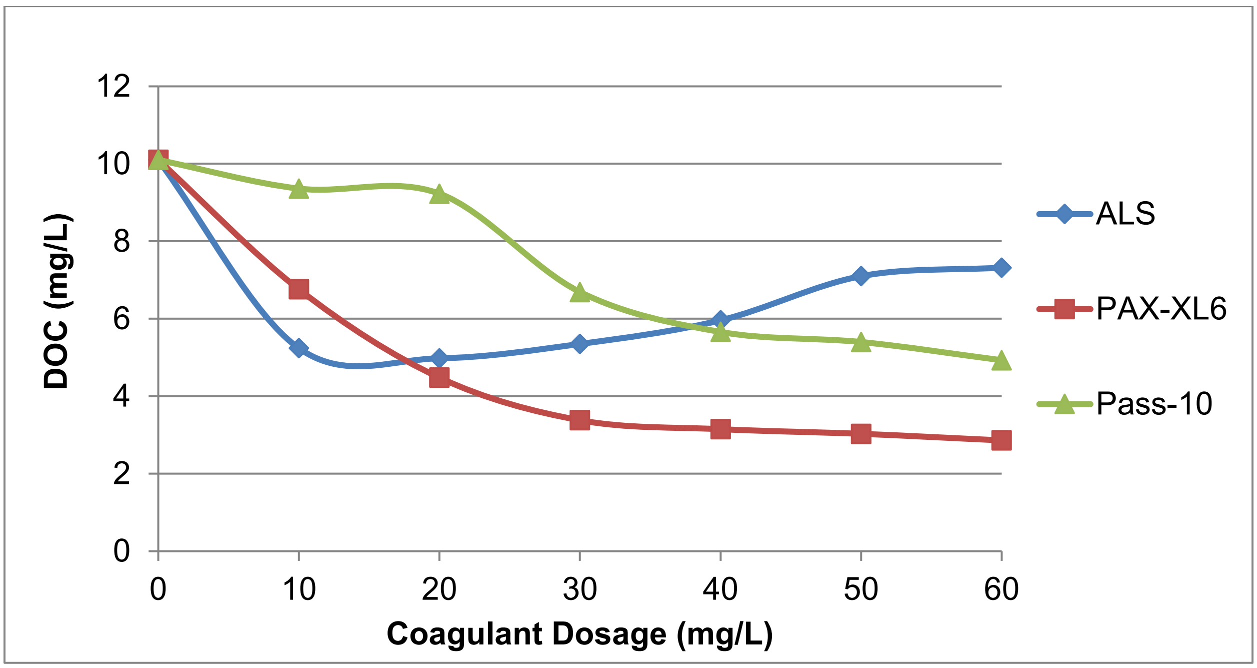

Figure 5.3. Laforce Lake DOC vs Coagulant Dose

Figure 5.4 shows the change in apparent colour with the coagulant doses and the results indicate PAX-XL6 removed the most colour. ALS and PAX-XL6 performed best at 30 mg/L, where Pass-10 performed best at 60 mg/L.

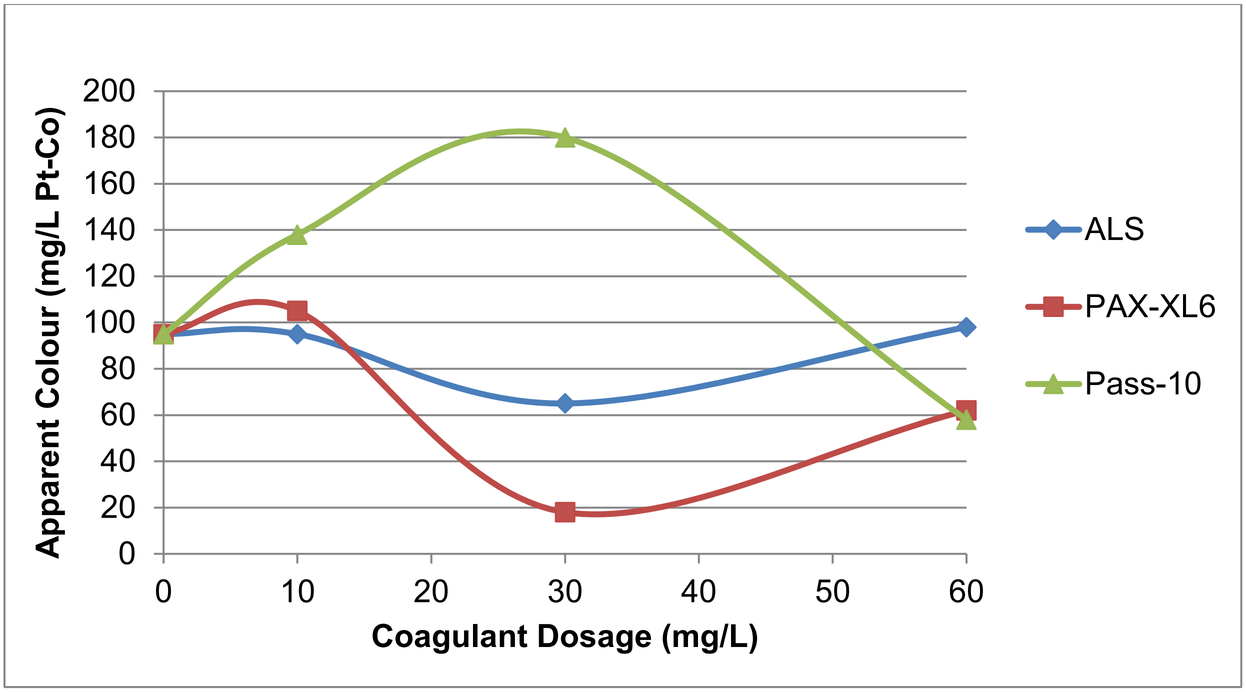

Figure 5.4. Laforce Lake Apparent Colour vs Coagulant Dose

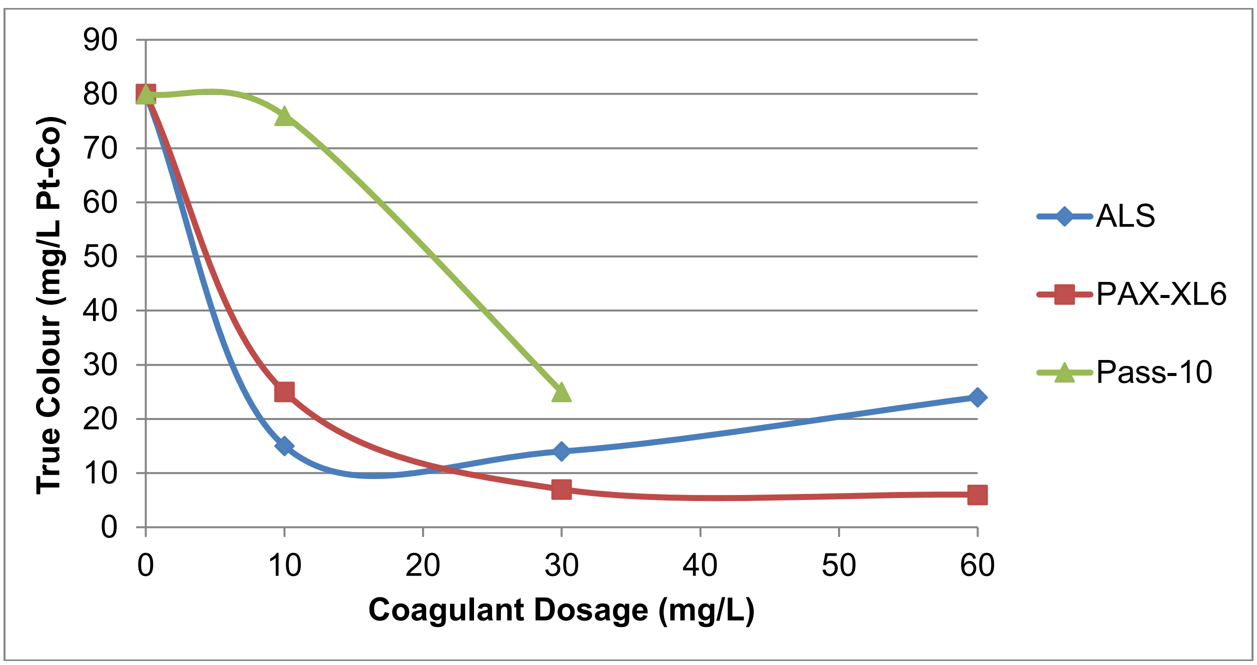

Figure 5.5. Laforce Lake True Colour vs Coagulant Dose

The true colour results in Figure 5.5 were consistent with the other results. 30 mg/L of PAX-XL6 reduced the true colour to 7 Pt-Co. Dosing with ALS reduced the true colour to about 15 Pt-Co, where Pass-10 reduced true colour to about 25 Pt-Co at the same coagulant dose of 30 mg/L.

Iron was successfully reduced to below the AO in almost all jar tests, and PAX-XL6 at 30 mg/L yielded the lowest iron concentration (Figure 5.6). Manganese was reduced below the AO in almost all the jars and saw the best reduction with ALS at 60 mg/L, although 30 mg/L would be the point of diminishing return (Figure 5.7). PAX-XL6 yielded similar results at the 60 mg/L dose, but when considering the optimum dose of other water quality parameters, it would likely not be worth the cost of additional coagulant.

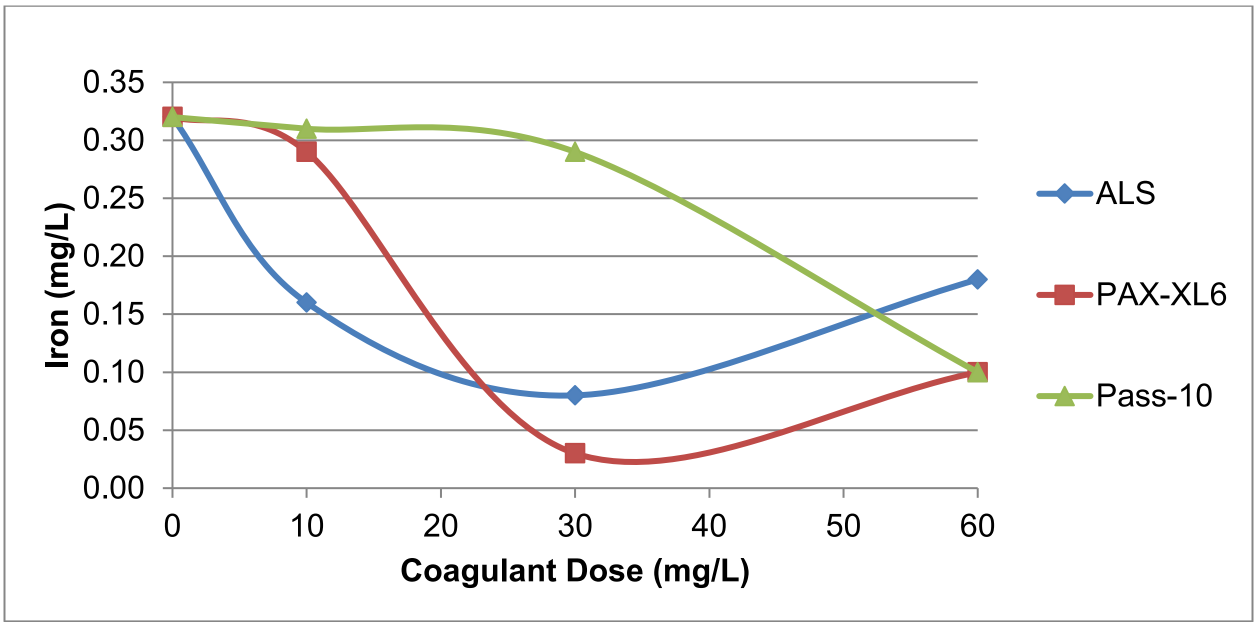

Figure 5.6. Laforce Lake Iron vs Coagulant Dose

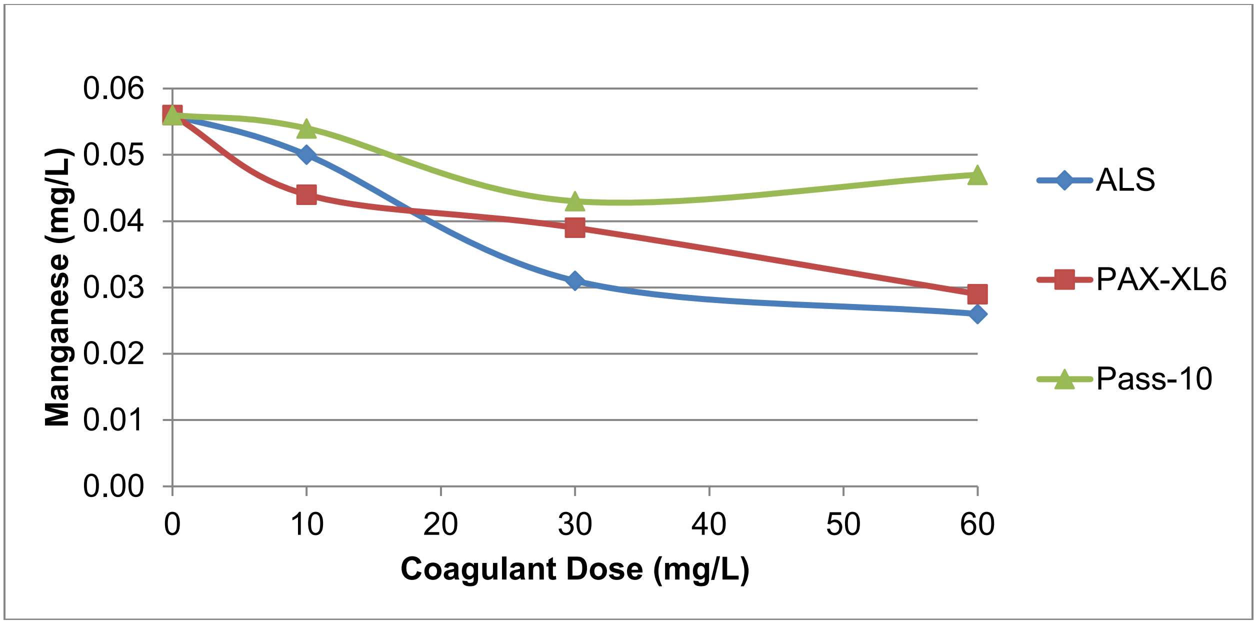

Figure 5.7. Laforce Lake Manganese vs Coagulant Dose

5.1.3 Gibson Lake Jar Test

When evaluating the Gibson Lake data set for turbidity, Figure 5.8 suggests the optimum coagulant dose for ALS was 10 mg/L, PAX-XL6 was 20 mg/L and Pass-10 was 30 mg/L.

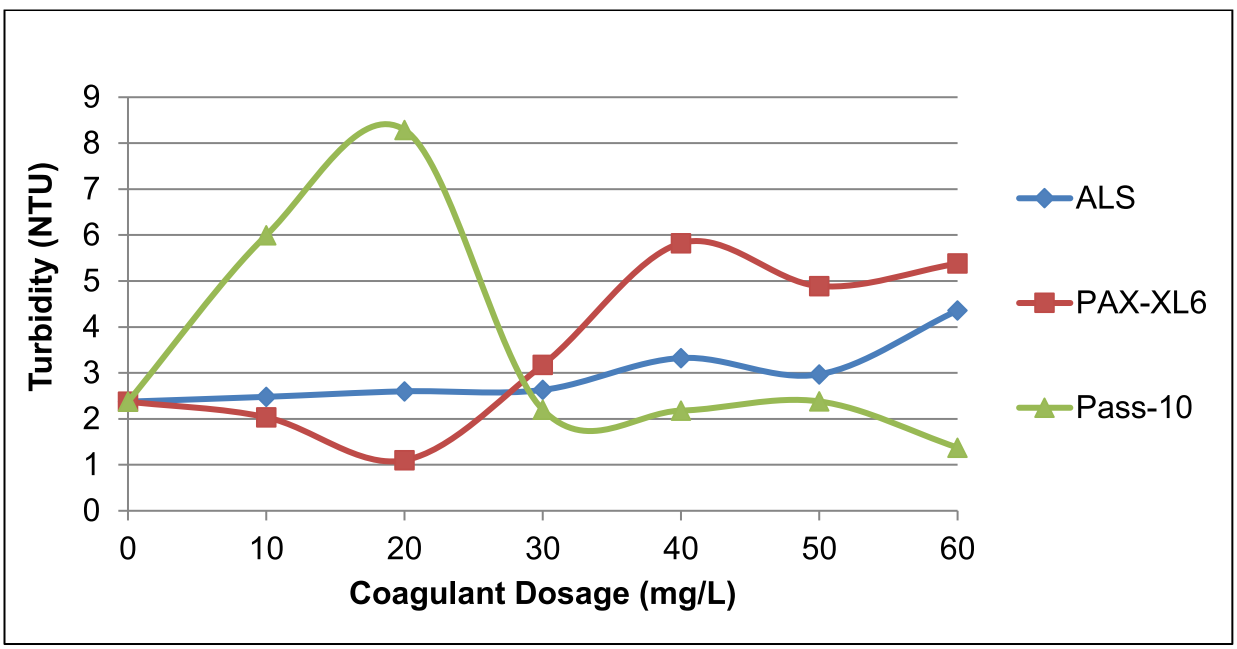

Figure 5.8. Gibson Lake Turbidity vs Coagulant Dose

The SUVA value for Gibson Lake was 3.4, indicating the expected DOC removal would be between 25% - 50% with ALS and likely skewed towards 50%. Figure 5.9 shows UVa also suggests the optimum coagulant dose for ALS was 10 mg/L, PAX-XL6 was 20 mg/L and Pass-10 was 30 mg/L.

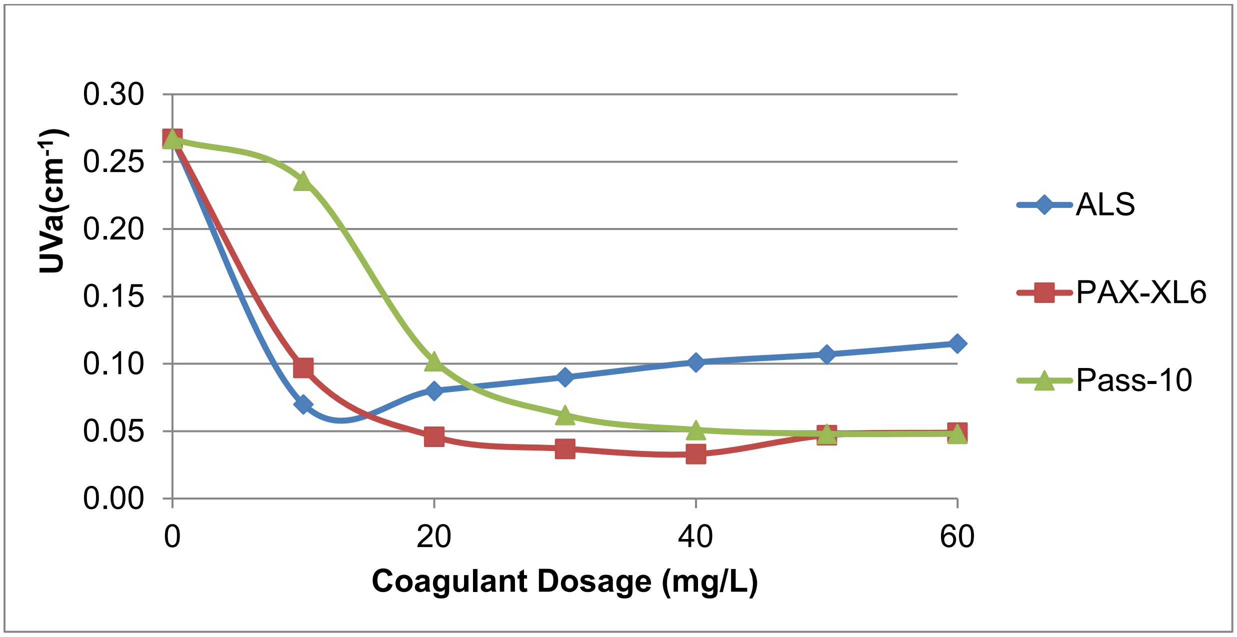

Figure 5.9. Gibson Lake UVa vs Coagulant Dose

The raw water DOC was 7.9 mg/L and was reduced to 3.39 mg/L with 10 mg/L of ALS, a 57% reduction. PAX-XL6 saw a 65% reduction to 2.7 mg/L of DOC at 20 mg/L and Pass-10 achieved 58% removal to 3.30 mg/L at 30 mg/L (Figure 5.10). The Gibson Lake jar test results achieved better than the expected DOC removal based on the SUVA value obtained from the raw water. This suggests that the enhanced coagulation process has been optimized for this water source.

The apparent colour results (Figure 5.11) were variable for the three coagulants as some doses achieved between 40% and 60% reduction, where others increased in apparent colour. The true colour results (Figure 5.12) followed the trend associated with the coagulant dose and the reduction of DOC and UVa. The optimum doses for colour reduction were estimated using the point of diminishing return and appear around 10 mg/L for ALS, 20 mg/L for PAX-XL6, and 30 mg/L for Pass-10.

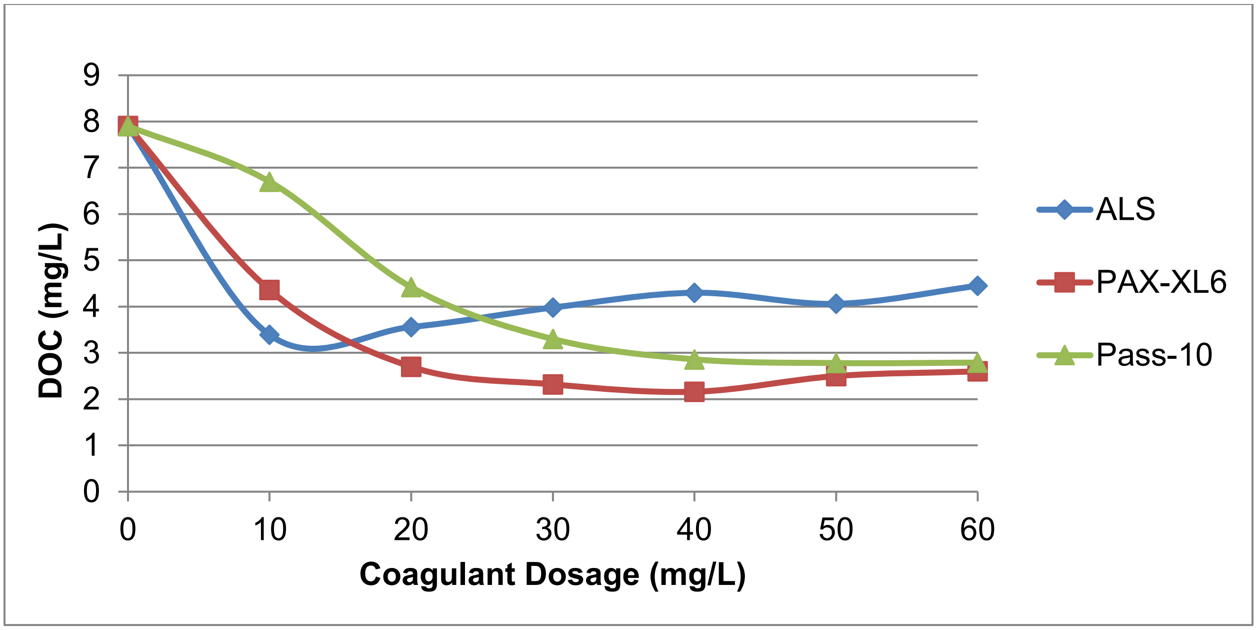

Figure 5.10. Gibson Lake DOC vs Coagulant Dose

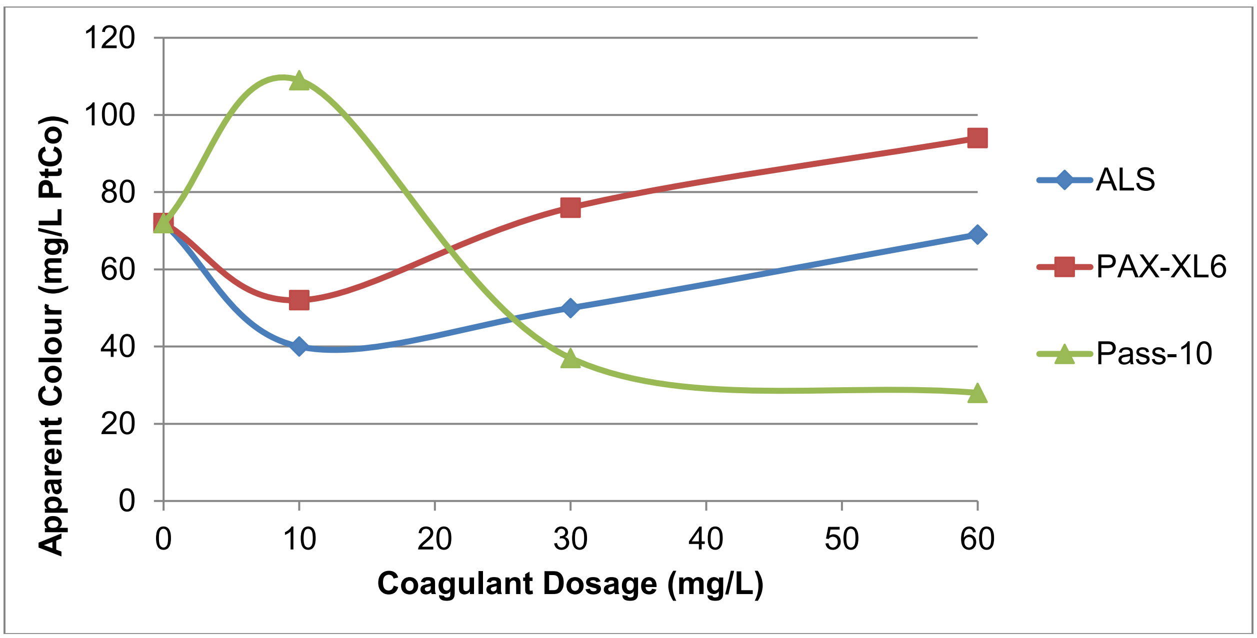

Figure 5.11. Gibson Lake Apparent Colour vs Coagulant Dose

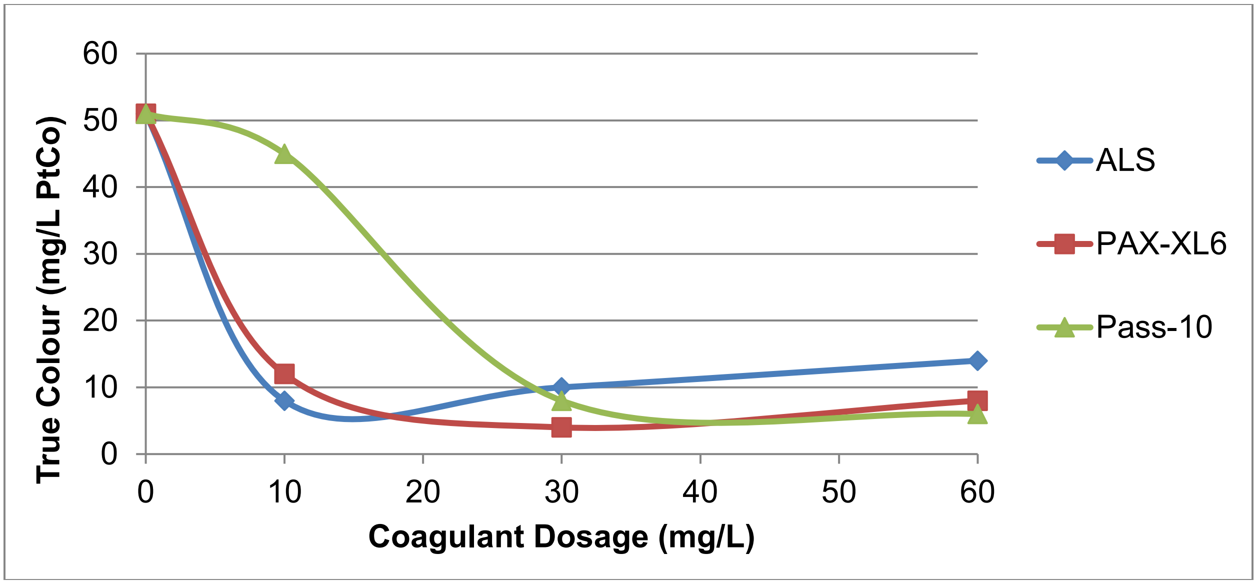

Figure 5.12. Gibson Lake True Colour vs Coagulant Dose

As aluminum is a primary ingredient in the coagulants, measuring the residual aluminum can sometimes help indicate the optimum dose of the coagulant used. For example, the lowest concentration of aluminum residual can indicate when the optimum dose of coagulant has been achieved. As suggested in Figure 5.13, the optimum dose of ALS would be around 10 mg/L, PAX-XL6 would be 20 mg/L and Pass-10 would be 30 mg/L.

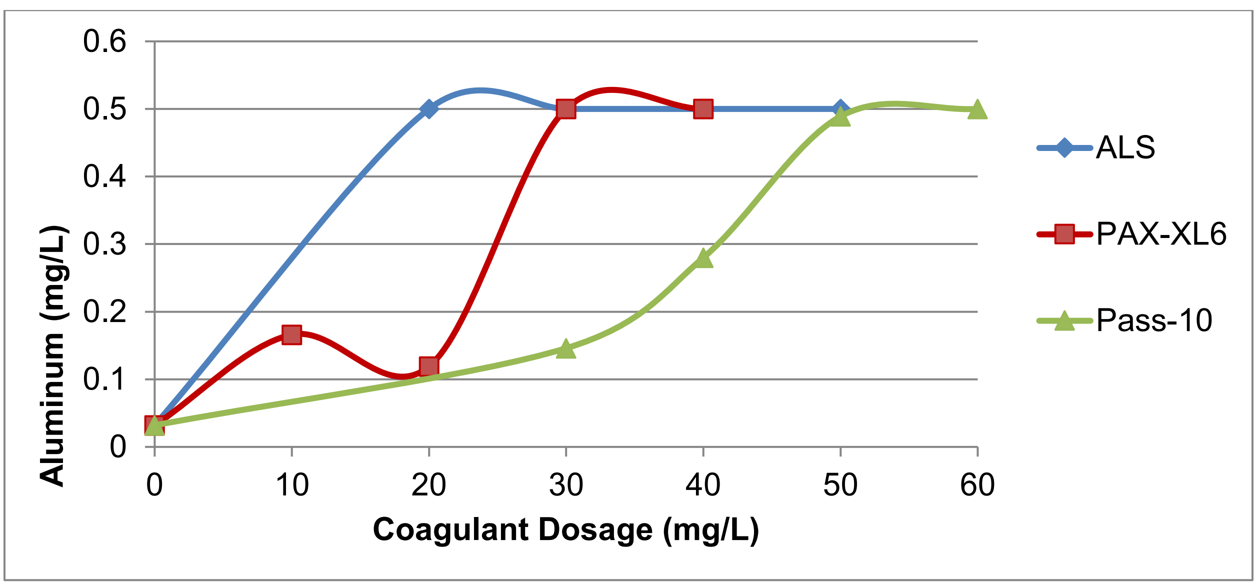

Figure 5.13. Gibson Lake Aluminum Residual vs Coagulant Dose

Iron was measured above the AO at 0.42 mg/L in the raw water and was reduced below the AO in the case of each optimum coagulant dose (Figure 5.14). Manganese was recorded below the AO in the raw water and was further reduced in most cases (Figure 5.15).

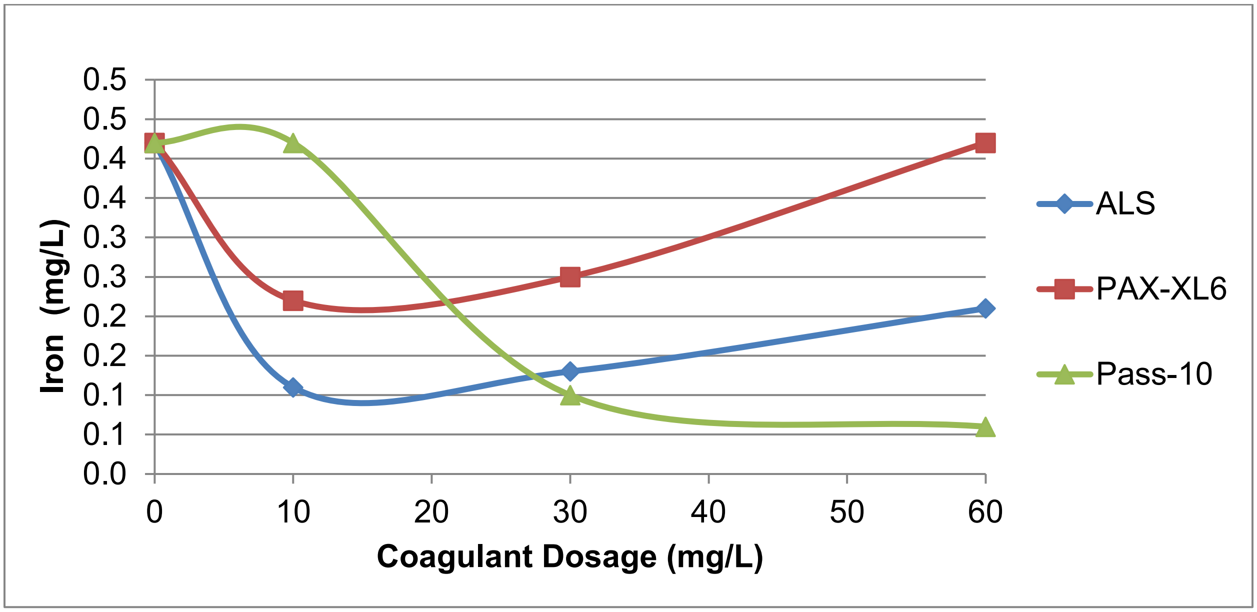

Figure 5.14. Gibson Lake Iron vs Coagulant Dose

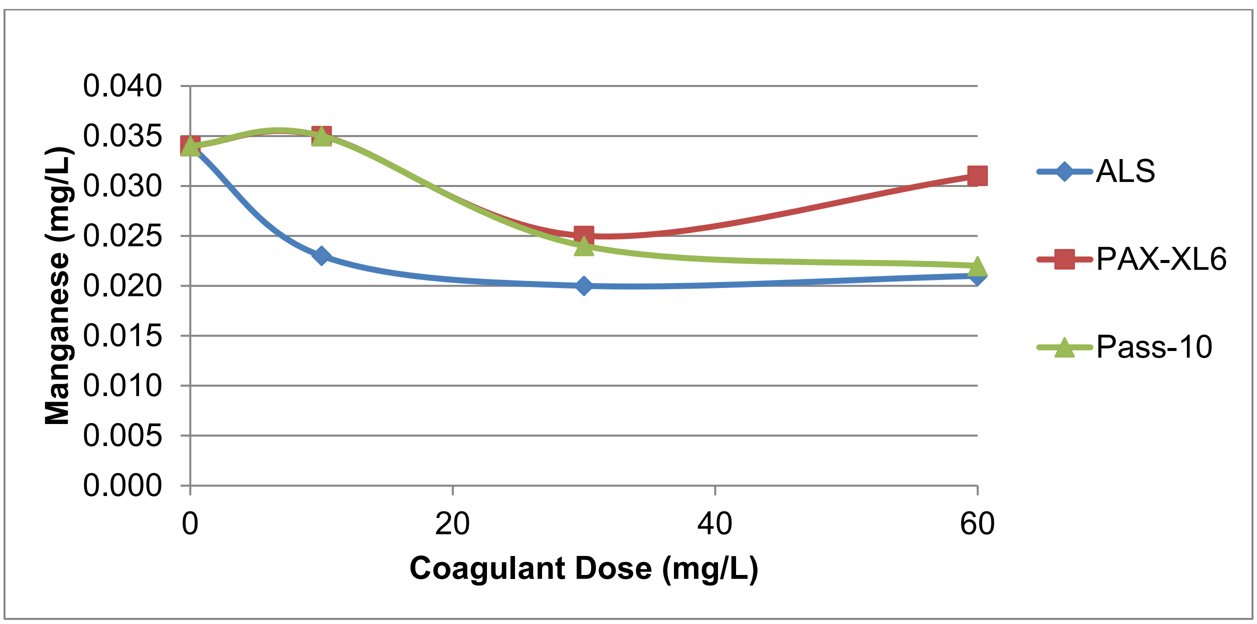

Figure 5.15. Gibson Lake Manganese vs Coagulant

5.1.4 Webster Lake Jar Test

Webster Lake's raw water turbidity was measured at 1.26 NTU and increased in all cases except for 30 and 40 mg/L doses of PAX-XL6, where the turbidity dropped to 1.22 NTU and 0.79 NTU, respectively. When considering reduction of turbidity, Figure 5.16 suggests that the optimum coagulant would be PAX-XL6 at a dose between 30 and 40 mg/L.

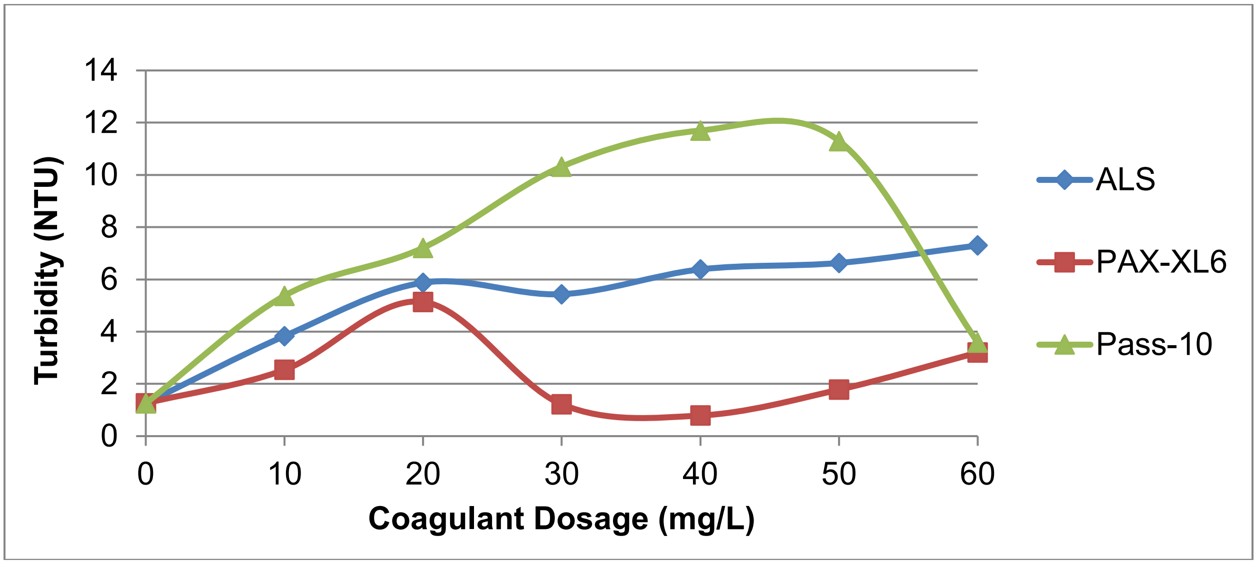

Figure 5.16. Webster Lake Turbidity vs Coagulant Dose

The Webster Lake raw water had 12.20 mg/L of DOC and 0.515 cm^{-1} UVa with a SUVA value of 4.2. It was expected that the optimum dose of coagulant would reduce the DOC by ≥ 50%. ALS reduced the DOC to 5.68 mg/L at a dose of 20 mg/L which is a reduction of 53%. PAX-XL6 reduced DOC by 55% to 5.48 mg/L and by 62% to 4.64 mg/L at a dose of 30 mg/L and 40 mg/L, respectfully. Pass-10 reduced the DOC by 56% to 5.3 mg/L at a dose of 60 mg/L. All the coagulants were able to achieve equal to or better than their expected DOC removal, meaning the enhanced coagulation process was optimized for certain doses (Figure 5.17). The trend for UVa (Figure 5.18) also suggests the same optimal doses for the respective coagulants.

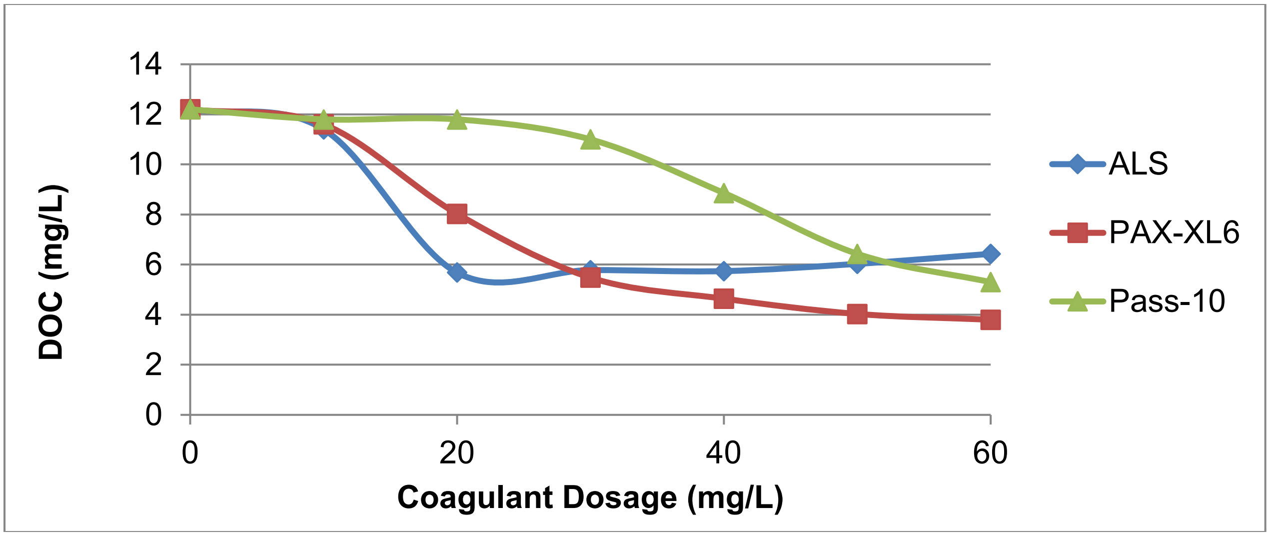

Figure 5.17. Webster Lake DOC vs Coagulant Dose

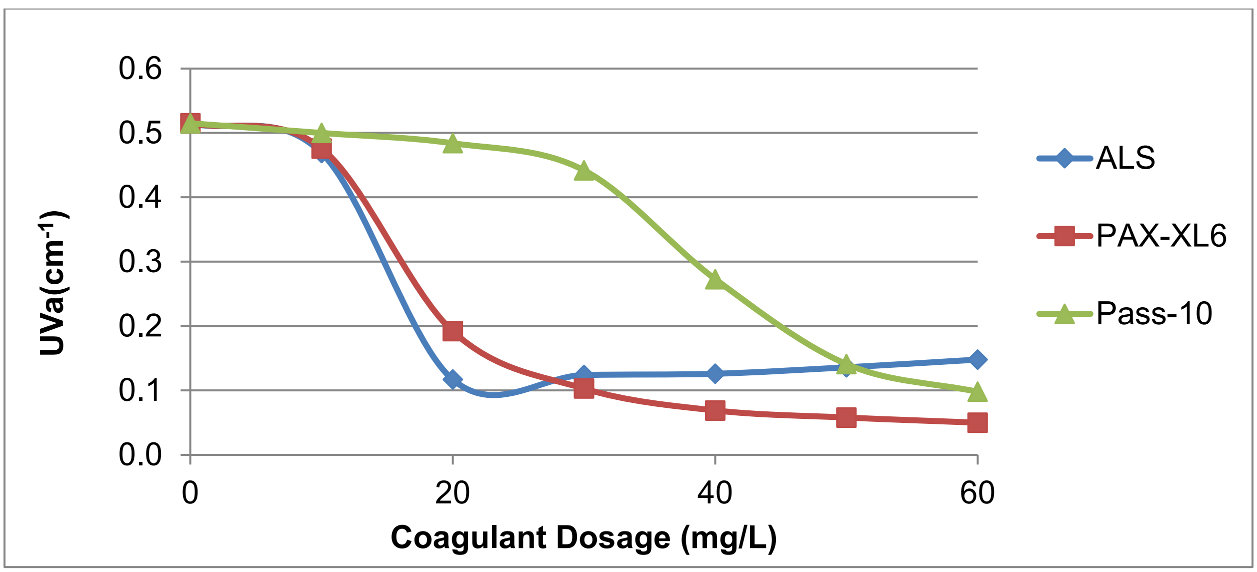

Figure 5.18. Webster Lake UVa vs Coagulant Dose

Both raw water true and apparent colour were measured and had similar results, above 100 Pt-Co, suggesting most of the compounds responsible for colour were dissolved. The true colour reduction measured in Figure 5.19 follows a similar trend as DOC and UVa. True colour was reduced to 12 Pt-Co with ALS, a reduction of 89% at a dose of 30 mg/L. PAX-XL6 reduced colour by 88% to 13 Pt-Co at 30 mg/L and Pass-10 reduced it by 90% at the 60 mg/L dose.

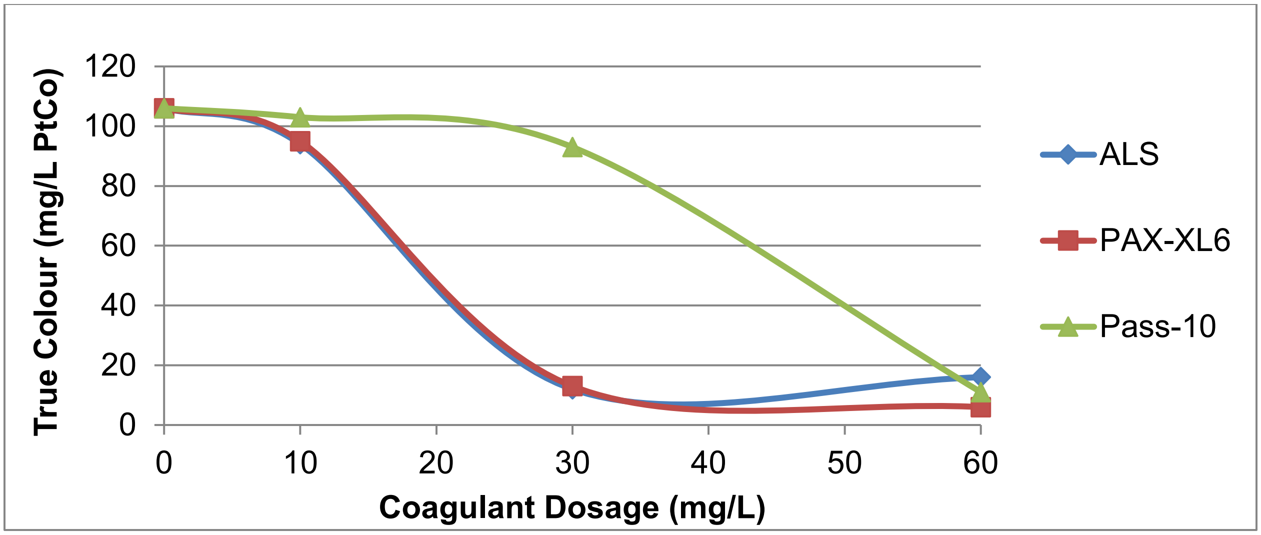

Figure 5.19. Webster Lake True Colour vs Coagulant Dose

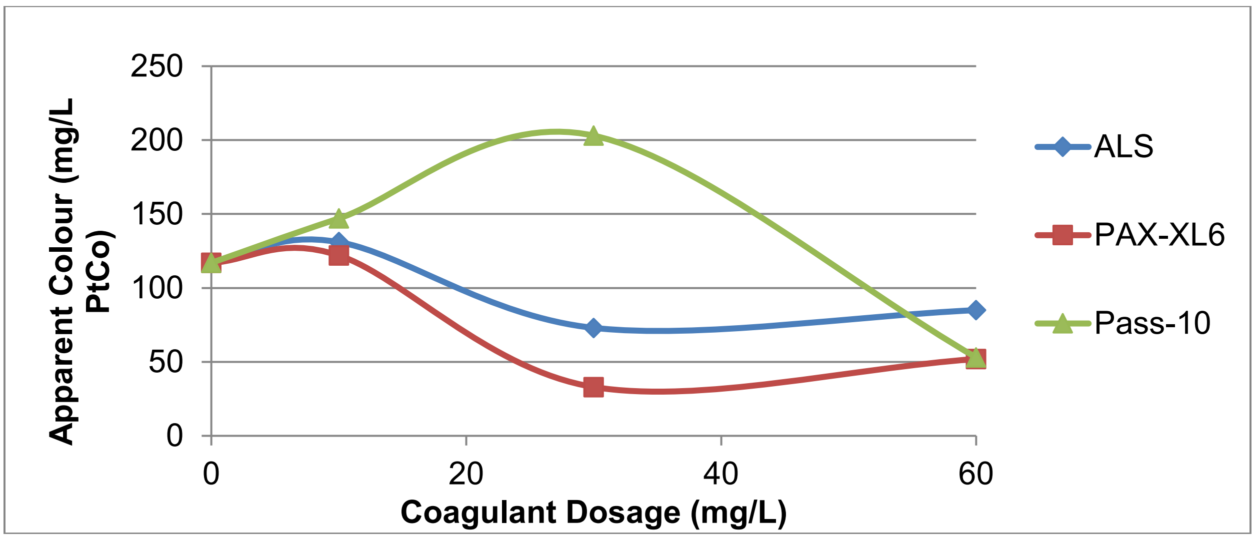

Figure 5.20. Webster Lake Apparent Colour vs Coagulant Dose

The apparent colour coagulant dosages seemed to agree with the respective optimal coagulant doses (Figure 5.20). The iron concentration in the raw water was below the AO for Webster Lake and was reduced to below 0.05 mg/L in several of the jars sampled. Manganese was measured at 0.028 mg/L, also below the AO in the raw water and reduced to nearly half that in some jars.

Webster Lake was removed from further studies by Neegan Burnside due to the additional coagulant needed to treat the water, as determined following the jar tests.

Neegan Burnside concluded additional coagulant would result in increased operation and maintenance costs as well as reduced water quality. WMFN, OFNTSC, and WCWC agreed with this conclusion.

5.2 Spring Samples

5.2.1 Raw Water Characteristics

The results of sampling conducted on May 9th and analysis on May 10th of raw water from the spring sample can be found in Table 5.3. It is expected that the treatment would yield similar results for both the optimum dose and the water quality parameters.

Table 5.3. Spring Raw Water Characteristics

Parameter	Laforce Lake	Gibson Lake
Turbidity (NTU)	3.1	3.6
Aluminum (mg/L)	0.03	0.05
UV Abs (cm^{-1})	0.294	0.311
DOC (mg/L)	7.9	8.4
SUVA (L/mg-m)	3.7	3.7
Alkalinity (mg/L as $CaCO_3$)	10.1	10.5
Hardness (mg/L as $CaCO_3$)	18.1	13.7
Free Ammonia (mg/L)	<0.05	<0.05
Total Ammonia (mg/L)	<0.05	<0.05
Nitrite (mg/L)	<0.005	<0.005
Total Phosphorus (mg/L)	<0.03	<0.03
Total Iron (mg/L)	0.37	0.47
Total Manganese (mg/L)	0.088	0.057
Apparent Colour (Pt-Co)	93	101
True Colour (Pt-Co)	56	62
pH	7.5	7.2
TDS (mg/L)	248	196.4
Sodium (mg/L)	56.4	30.2
Chloride (mg/L)	35	34.9
Fluoride (mg/L)	<0.1	<0.1

Additionally, SUVA was calculated to estimate the expected DOC removal and to compare with the actual DOC removal (Edzwald and Tobiason, 1999; EPA, 1999).

$$Laforce\ Lake\ SUVA = \frac{0.294\ cm^{-1}}{7.9\ \frac{mg}{L}}\ X\ 100\,\frac{cm}{m} \qquad = \qquad 3.7$$

$$Gibson\ Lake\ SUVA = \frac{0.311\ cm^{-1}}{8.40\ \frac{mg}{L}}\ X\ 100\ \frac{cm}{m} \qquad = \qquad 3.7$$

The calculated SUVA results of Laforce Lake and Gibson Lake suggested that enhanced coagulation with ALS would yield between 25 - 50% reduction in DOC.

5.2.2 Laforce Lake Jar Test

Turbidity

Overall, of the two coagulants, PAX-XL6 achieved the best turbidity removal (Figure 5.21) when the optimum dose of PAX-XL6 was applied (20 - 25 mg/L). ALS performed best at 20 mg/L for turbidity removal, but the lowest turbidity was at a dose 5 times higher.

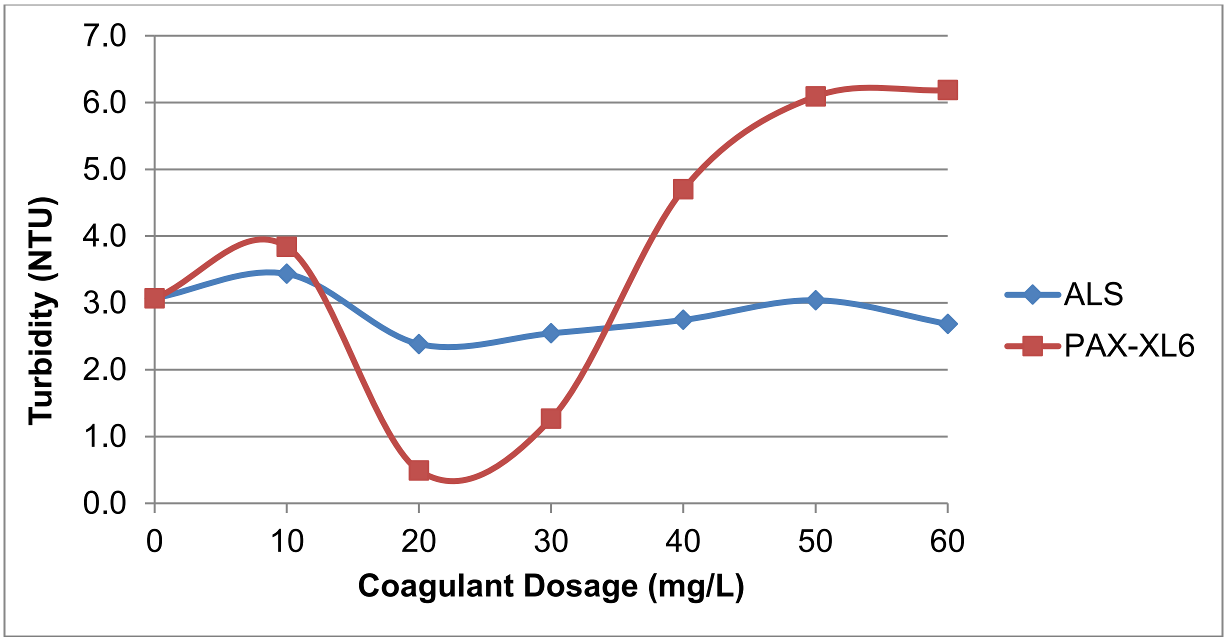

Figure 5.21. Laforce Lake Turbidity vs Coagulant Dose

UVa, DOC, Colour

The results indicated better than expected DOC removal as ALS removed about 59% and PAX-XL6 removed about 63% (Figure 5.22), suggesting the coagulant dose had been optimized.

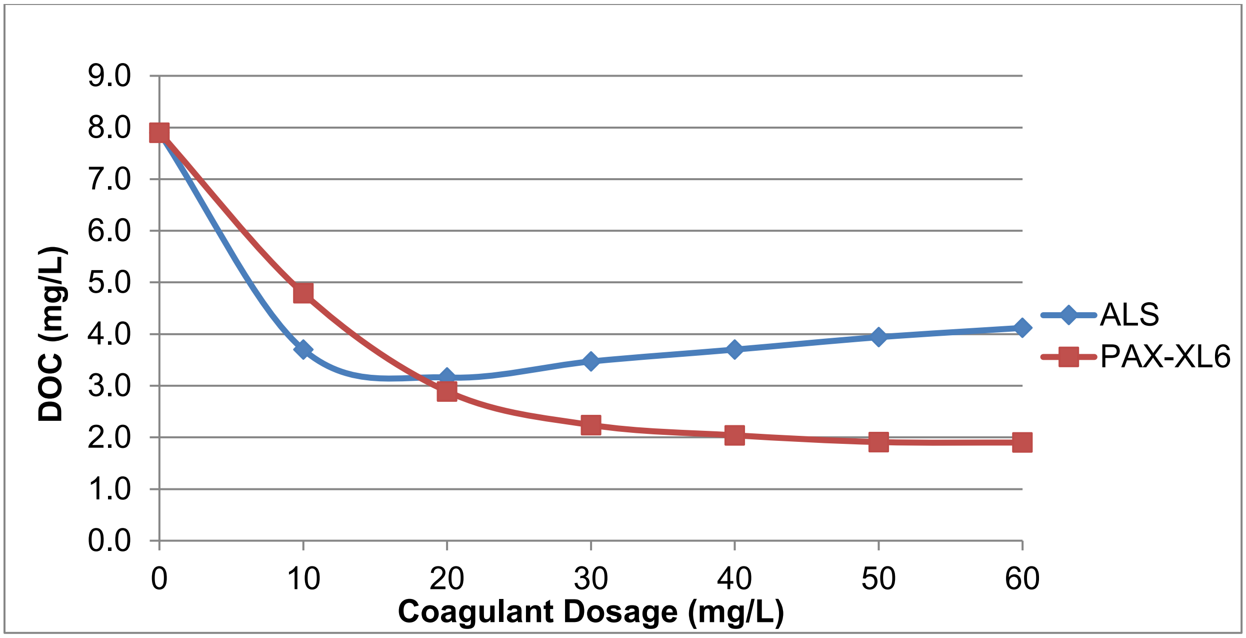

Figure 5.22. Laforce Lake DOC vs Coagulant Dose

PAX-XL6 performed slightly better than ALS for other parameters that represent natural organic matter. The dose of ALS from 10-15 mg/L followed a similar trend to PAX-XL6 for parameters such as UVa (Figure 5.23) and true colour (Figure 5.24) but was not as effective for the removal of apparent colour (Figure 5.25).

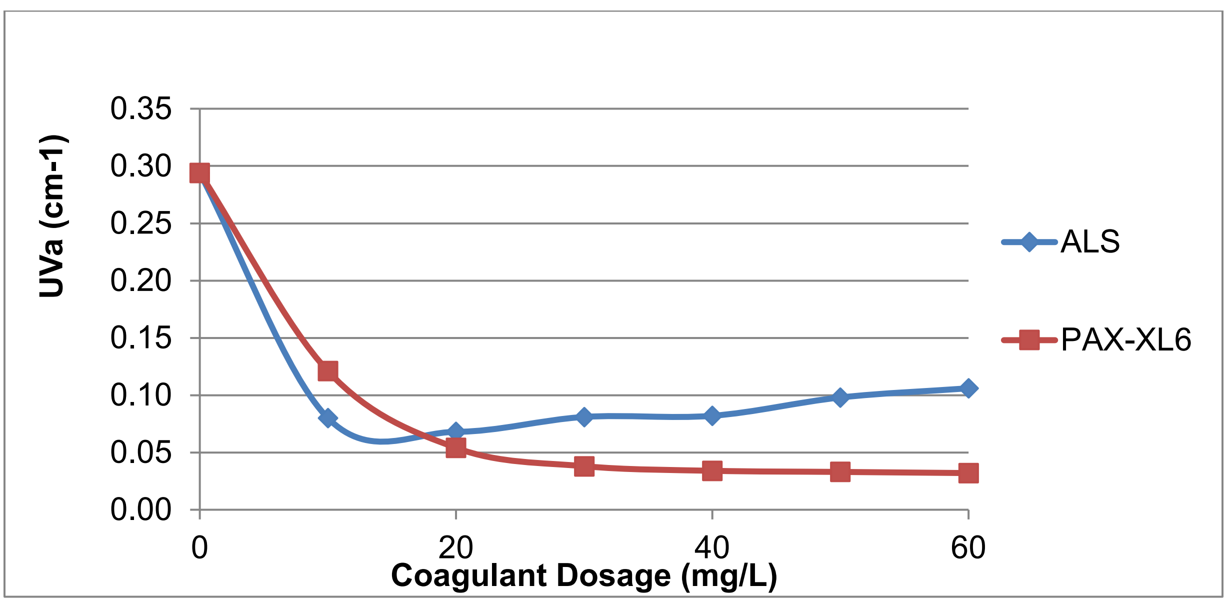

Figure 5.23. Laforce Lake UVa vs Chemical Dose

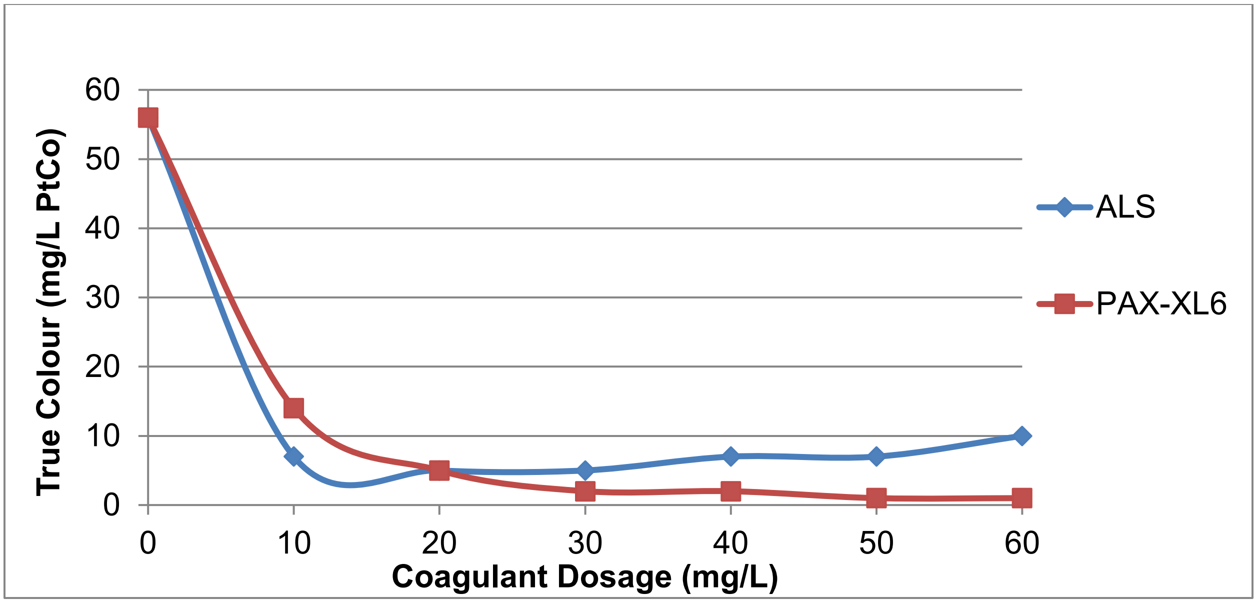

Figure 5.24. Laforce Lake True Colour vs Coagulant Dose

The DOC, UVa and true colour graphs all follow a similar trend with a steep slope at early doses of coagulant before reaching a point of diminishing return. The apparent colour followed the same trend as turbidity, further suggesting the best dose was between 20 - 25 mg/L for PAX-XL6 and 20 mg/L for ALS.

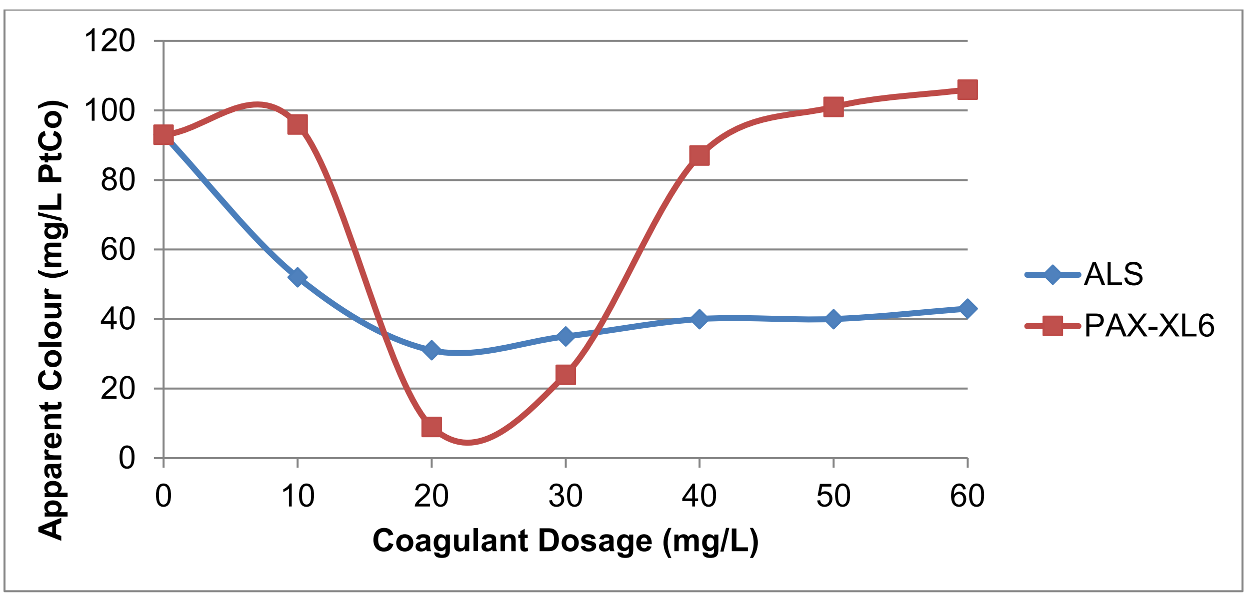

Figure 5.25. Laforce Lake Apparent Colour vs Coagulant Dose

Iron and Manganese

Total iron was measured above the AO at 0.37 mg/L in the raw water but was reduced below the AO when sampled in the jars of the target doses. Total manganese was also found above the AO in the raw water of Laforce Lake but was not reduced below the AO in the jars of the target doses.

pH and Alkalinity

The raw pH of Laforce Lake was measured at 7.5 but fell between 6 and 6.5 for the target doses which would require an adjustment after coagulation for either coagulant to control corrosion in the distribution system. The OG for pH is 6.5 - 8.5 for Ontario (MECP, 2006) and is 7.0 - 10.0 for Canada (Health Canada, 2017). The alkalinity measured near the MDL.

Other Parameters

Sodium was below the AO of 200 mg/L for Laforce Lake (Health Canada, 2017; MECP, 2006), as it measured at 56.4 mg/L. If the community chooses this water source, it would be advisable to notify the community's health authority to inform persons on sodium restricted diets as it is above 20 mg/L (Ontario, 2006).

Free and total ammonia, nitrite, total phosphorus, and fluoride all measured below the MDL. Hardness was measured near the MDL. TDS was measured at 248 mg/L which is below the AO and chloride was measured at 35 mg/L which is below the AO of 250 mg/L (MECP, 2006).

5.2.3 Gibson Lake Jar Test

Turbidity

The Gibson Lake data set for turbidity (Figure 5.26), suggested the optimum coagulant dose for ALS was 20 mg/L and PAX-XL6 was 20 - 25 mg/L. The graph for Gibson Lake had a very similar trend as Laforce Lake turbidity. The most effective doses for each coagulant were similar, around 20 mg/L, but the turbidity was 3.6 times higher for ALS than PAX-XL6.

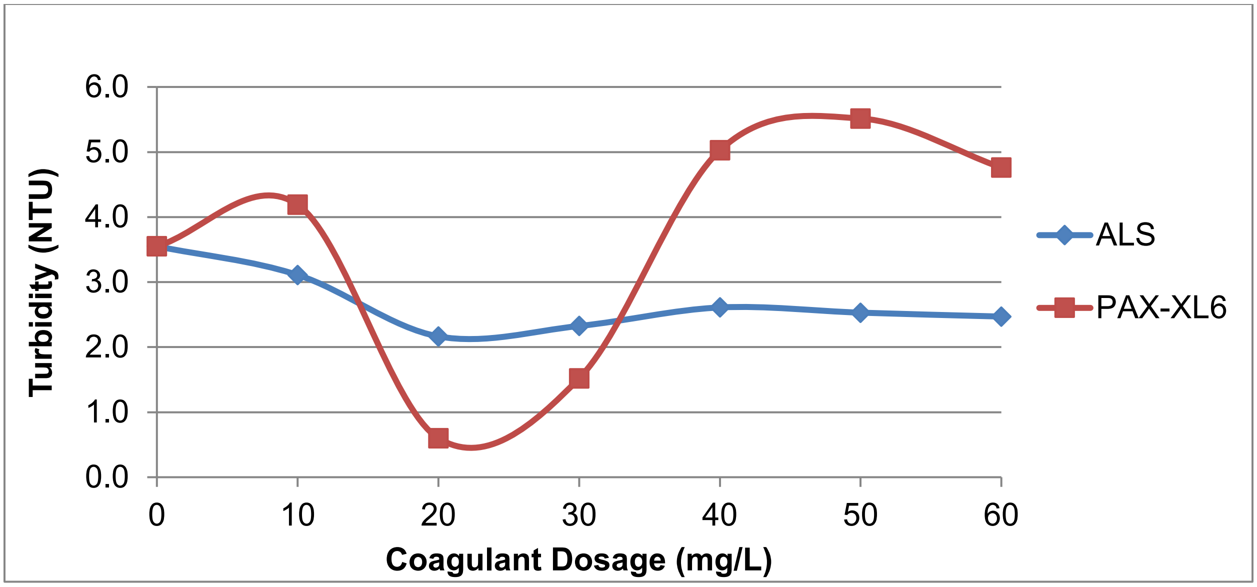

Figure 5.26. Gibson Lake Turbidity vs Coagulant Dose

UVa, DOC, Colour

The SUVA value for Gibson Lake was 3.7, indicating the expected DOC removal would be between 25% - 50% and likely skewed towards 50%. The raw water DOC was 8.4 mg/L and was reduced to 3.7 mg/L with ALS, a 56% reduction. Measurements that represent natural organic matter, such as UVa (Figure 5.27), DOC (Figure 5.28), and true colour (Figure 5.29) show a steep slope for the lower coagulant doses; and as the dose increases, a point of deminishing return occurs where the slope of the line levels off and becomes horizontal. PAX-XL6 provided a 63% reduction to 3.1 mg/L of DOC at 20 mg/L. The Gibson Lake jar test results achieved better than the expected DOC removal based on the SUVA value obtained from the raw water. This suggests that the enhanced coagulation process had been optimized for this water source.

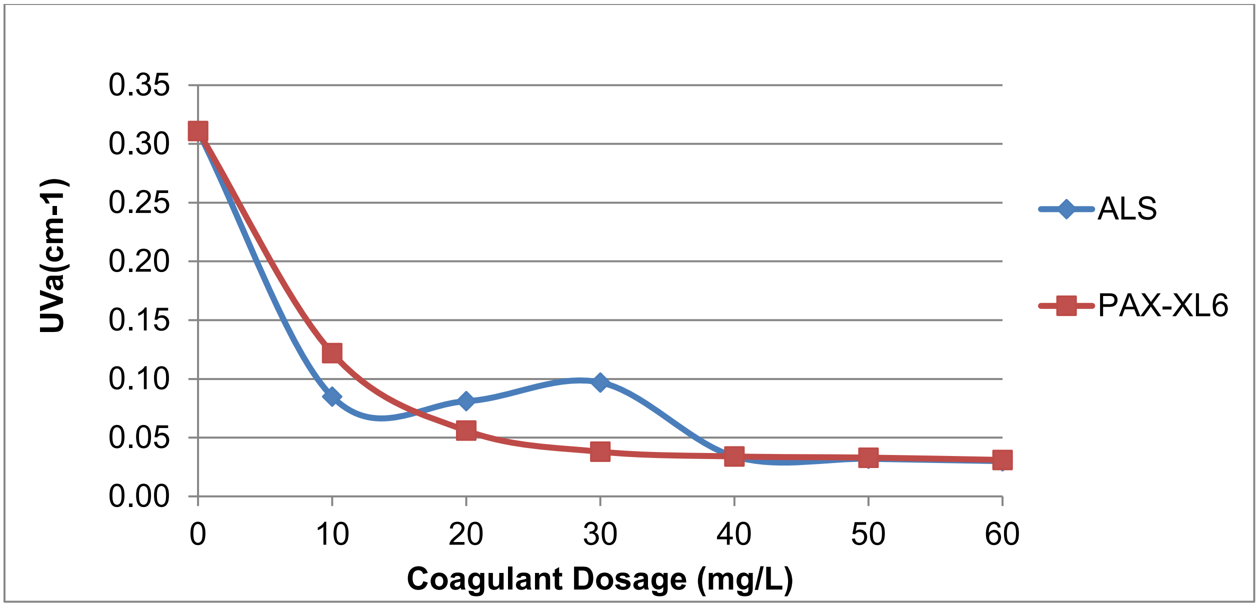

Figure 5.27. Gibson Lake UVa vs Coagulant Dose

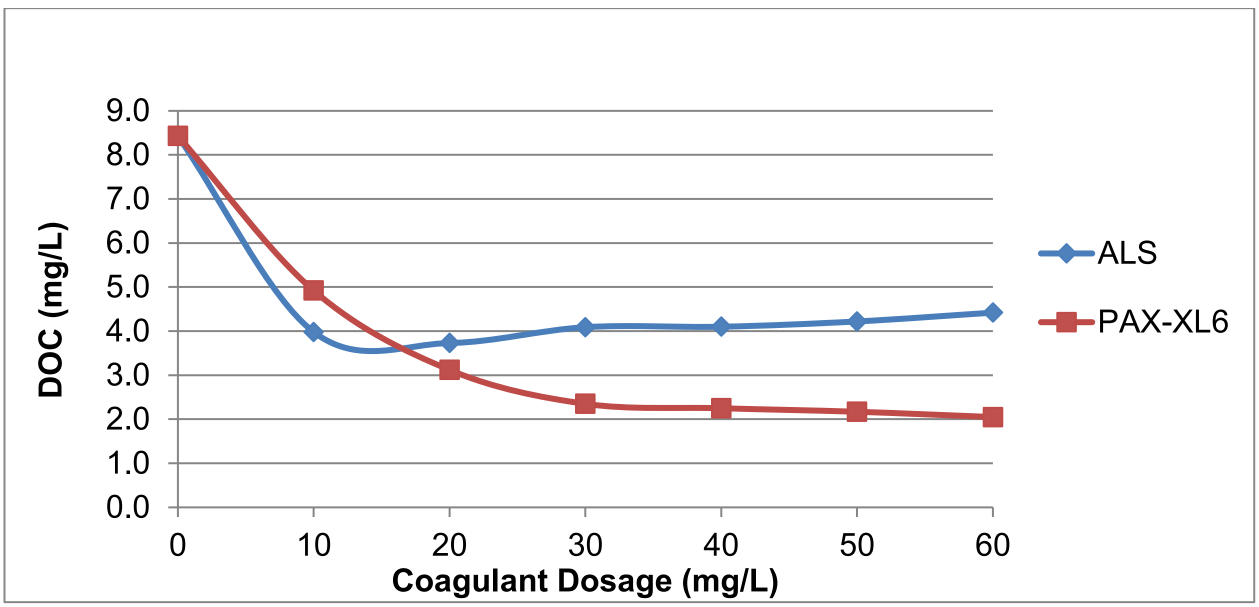

Figure 5.28. Gibson Lake DOC vs Coagulant Dose

The graph showing apparent colour (Figure 5.30) appears to follow the same trend as turbidity for both coagulants and at the same optimum coagulant doses.

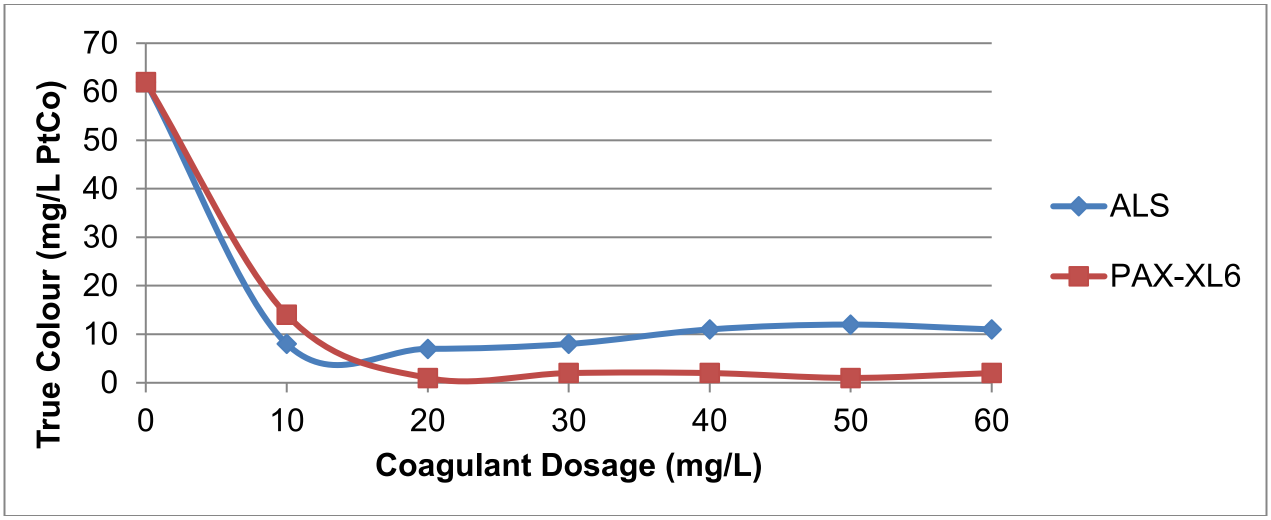

Figure 5.29. Gibson Lake True Colour vs Coagulant Dose

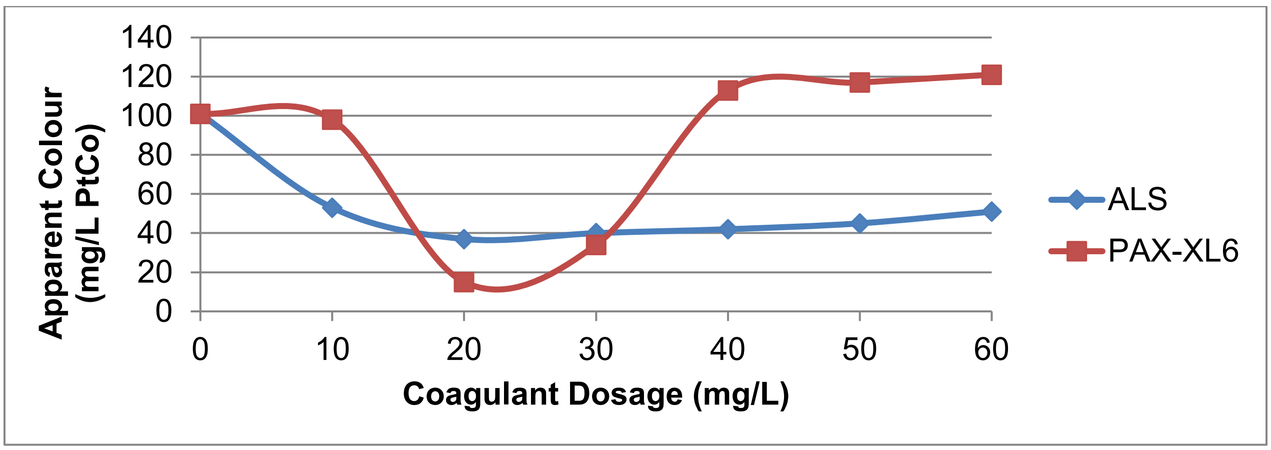

Figure 5.30 Gibson Lake Apparent Colour vs Coagulant Dose

Iron and Manganese

Iron and manganese were measured above the AOs at 0.47 mg/L and 0.057 mg/L, respectively. In the jars of the most effective doses, ALS reduced iron to 0.1 mg/L and manganese to 0.017 mg/L; PAX-XL6 reduced iron to 0.3 mg/L and manganese to 0.017 mg/L.

pH and Alkalinity

The pH of the raw water was measured as 7.2 and fell below the OG to 5.6 with the most effective ALS dose. Whereas PAX-XL6 was measured at 6.7 at its most effective dose, within Ontario's OG (MECP, 2006) but below Canada's OG of 7.0 (Health Canada, 2017). The alkalinity and hardness measured near the MDL.

Other Parameters

Gibson Lake measured below the MDL for free and total ammonia, nitrite, total phosphorus, and fluoride. TDS was measured at 196.4 mg/L and chloride at 34.9 mg/L which were below their respective AO values. Sodium was measured at 30.2 mg/L which is also above 20 mg/L, but is below the AO of 200 mg/L.

6. Conclusions

The following overall conclusions were found in this study:

- The three lakes had similar water quality characteristics such as turbidity, pH, fluoride, and aluminum.
- Webster Lake was discontinued as a potential option due to the elevated DOC compared to the other two sources.
- Parameters such as hardness, alkalinity, orthophosphate, free and total ammonia, and nitrite measured near or below the MDL for all three lakes.
- The final pH and alkalinity of the treated water should be adjusted to fall within operational guidelines to prevent corrosion in the distribution system.

6.1 Laforce Lake

The following conclusions were made for Laforce Lake from fall and spring samples:

- The water quality in Laforce Lake measured between values from the other two lakes tested for parameters such as turbidity, DOC, UVa, true colour, apparent colour, and iron.
- Laforce Lake had the least acidic pH and highest manganese concentration but was like Gibson Lake in terms of low TDS, sodium, and chloride concentrations.

- The jar tests suggest that the optimum dose of ALS as a coagulant was 20 mg/L. For PAX-XL6 it was 20 mg/L and for Pass-10 around 50 mg/L.
- There was 3.38 mg/L of residual DOC in the clarified water when using PAX-XL6 which yielded the best DOC removal of the coagulants tested.

6.2 Gibson Lake

The following conclusions were made for Gibson Lake from fall and spring samples:

- Gibson Lake had the highest turbidity and iron and the lowest DOC, UVa, true and apparent colour. The pH fell between measurements of the other two sources tested.
- The jar test results suggest that the ALS optimum dose was 10 mg/L, the PAX-XL6 dose was 20 mg/L, and the Pass-10 dose was 30 mg/L.
- Of the three coagulants tested, the best DOC reduction occurred with PAX-XL6 at 20 mg/L dose and had a residual 2.7 mg/L of DOC.

6.3 Webster Lake

The following conclusions were made for Webster Lake from fall and spring samples:

- Although Webster Lake had the lowest turbidity, iron and manganese, it was the most acidic and highest in DOC, UVa, true and apparent colour, TDS, sodium, and chloride.
- The jar test results suggest that the optimum dose for ALS was 20 mg/L, PAX-XL6 was 30 mg/L, and Pass-10 was 60 mg/L.
- The coagulant providing the lowest residual DOC was PAX-XL6 at a 30 mg/L dose at 5.48 mg/L.

7. References

APHA, AWWA, WEF [American Public Health Association, American Water Works Association, Water Environmental Association]. (2017). Standard Methods for the Examination of Water and Wastewater: 23rd Edition. *American Public Health Association.*

AWWA [American Water Works Association]. (2011). Manual M37 – Operational Control of Coagulation and Filtration Processes, American Water Works Association, Denver, CO.

ECCC [Environment and Climate Change Canada]. (2017). Canadian Environmental Sustainability Indicators: Phosphorus levels in the offshore waters of the Great Lakes. Retrieved on December 13 2018 from www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=A5EDAE56-1.

Edzwald, J.K. and Tobiason, J.E. (1999). Enhanced Coagulation: US Requirements and a Broader View. *Water Science and Technology, 40*(9), 63-70.

EPA [US Environmental Protection Agency]. (1999). Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual. *Disinfectants and Disinfection Byproducts Rule*. EPA 815-R-99-012.

Gebbie, P. (2006). An Operator's guide to water treatment coagulants. *Earth Tech Engineering*. *31st Annual Qld Water Industry Workshop*. Rockhampton, AU.

Gebbie, P. (2001). Using Polyaluminum coagulants in water treatment. *Fisher Stewart Pty Ltd.*

Health Canada. (2017). Guidelines for Canadian Drinking Water Quality. *Health Canada, Ottawa, Ontario.*

Kemira. (2018a). Kemira ALS [Technical Data Sheet]. Kemira, Atlanta, GA, USA.

Kemira. (2018b). Kemira PAS-8 [Technical Data Sheet]. Kemira, Atlanta, GA, USA.

Kemira. (2018c). Kemira PAX-XL6 [Technical Data Sheet]. Kemira, Atlanta, GA, USA.

MECP [Ministry of Environment, Conservation and Parks]. (2006a). *Procedure for Disinfection of Drinking Water in Ontario*. Retrieved on Dec. 10, 2018 from https://www.ontario.ca/page/procedure-disinfection-drinking-water-ontario

MECP [Ministry of the Environment, Conservation and Parks]. (2006b). Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines. Retrieved on Dec. 10, 2018 from https://cvc.ca/wp-content/uploads/2011/03/std01_079707.pdf

RJBA [RJ Burnside & Associates]. (1994). Community Capital Planning Study: Wahta Mohawks of Wahta Mohawks Territory. *RJ Burnside & Associates Limited.*

SBA [S Burnett & Associates]. (2018). Well Investigation: Wahta Mohawks First Nation. *S Burnett & Associated Limited.*

UMA. (2001). Water Supply, Storage and Distribution System; Pre-Design Report: Wahta Mohawks Core Area. *Uma Engineering LTD*.

USGS [United States Geological Survey]. (2018). *Phosphorus and Water; The USGS Water Science School.* Retrieved on Dec.12, 2018 from https://water.usgs.gov/edu/phosphorus.html.

WALKERTON CLEAN WATER CENTRE

WCWC.CA

TRAINING · PILOT TESTING · RESOURCE LIBRARY · HELPLINE