Memorandum

Date: July 14, 2015

Re: Spray Aeration Equipment Performance Evaluation Summary

**This report was compiled by a third-party Consultant on behalf of a Municipality. Identifying information has been removed by Medora Corporation and is denoted by brackets. [ ]*

1.0 Introduction

In July, 2014 the [City] contracted with Medora, Inc for the purchase and installation of a spray aeration system including: one ventilator, seven SolarBee spray aeration units, and one SolarBee mixer at the [8 MG Reservoir]. Contract requirements for the spray aeration system included a performance evaluation to verify the installed system provided a minimum net reduction of 35% in total trihalomethane for the tank's effluent water quality.

Contract requirements indicated that if the 35% THM reduction was not met, the Contractor could upgrade the system or remove the equipment at Contractor's cost. In order to release payment to the manufacturer, the THM reduction efficiencies required verification. To facilitate testing, the [City] chose to rent an AMS online THM analyzer during the evaluation, in order to track THM trends over the testing period. Additional benchtop samples were run using a borrowed Parker Hannifan unit, or were sent to a [third-party laboratory].

2.0 Protocol

Following installation and startup of the Medora spray aeration system in April, 2015, a performance evaluation protocol described in detail in the project specifications was used to measure the amount of THM reduction achieved with the spray aeration system in operation. THM reduction was calculated based upon differences in THM concentrations in the tank when the spray aeration system was in operation and out of operation.

To briefly summarize the protocol, the spray aeration system was turned on following Medora installation and hydraulic performance verification on April 4, 2015. The system was then operated for 1 month to bring the THM concentrations in the tank to equilibrium, when the system was turned off for 2 weeks. After this 2 week period, the system was turned back on and operated continuously for 2 months. Is accordance to the specified protocol, multiple THM samples were collected during tank filling and draining to benchmark performance.

THM monitoring was performed using three methods. An AMS online THM analyzer was brought online starting April 14. The AMS unit was physically located in the [Pump Station], near the [reservoirs] and automatically pulled sample from the Point of Entry (POE) on the effluent side of the 8 MG reservoir, collecting TTHM measurements every 4 hours from this location. Additionally, manual samples were collected from locations including the influent to the 8 MG reservoir (identified as the CT sample point), the effluent from the 8 MG reservoir (identified as the Vent sample point), and the POE location. Analysis of THMs were performed using the AMS unit, a benchtop Parker-Hannifin THM analyzer, and the [third-party laboratory].

3.0 Results

Results of the testing are summarized below.

3.1 Online THM Monitoring

Figure 1 displays results collected from the on-line THM monitoring AMS unit, located at the POE sampling location, from April 15th through July 13th, 2015. The figure generally displays lower TTHM levels when the aeration system is "on" than when "off". While the AMS unit was not installed until approximately 8 – 10 days after the spray aeration system was turned on, the immediate reduction in TTHMs was observed until plateauing below 20 ppb. The aeration unit was turned off on May 5th for cable replacement, and TTHMs rose quickly throughout May to a plateau of approximately 50 ppb. The aeration system was turned back on May 19th, and THMS were reduced by approximately 10 ppb. As a confirmatory test, the spray aeration system was turned off again on June 25th, and TTHMs immediately quickly increased from approximately 50 ppb to between 85 and 90 ppb. The system was immediately turned back on, and TTHMs were reduced back to approximately 50 ppb.

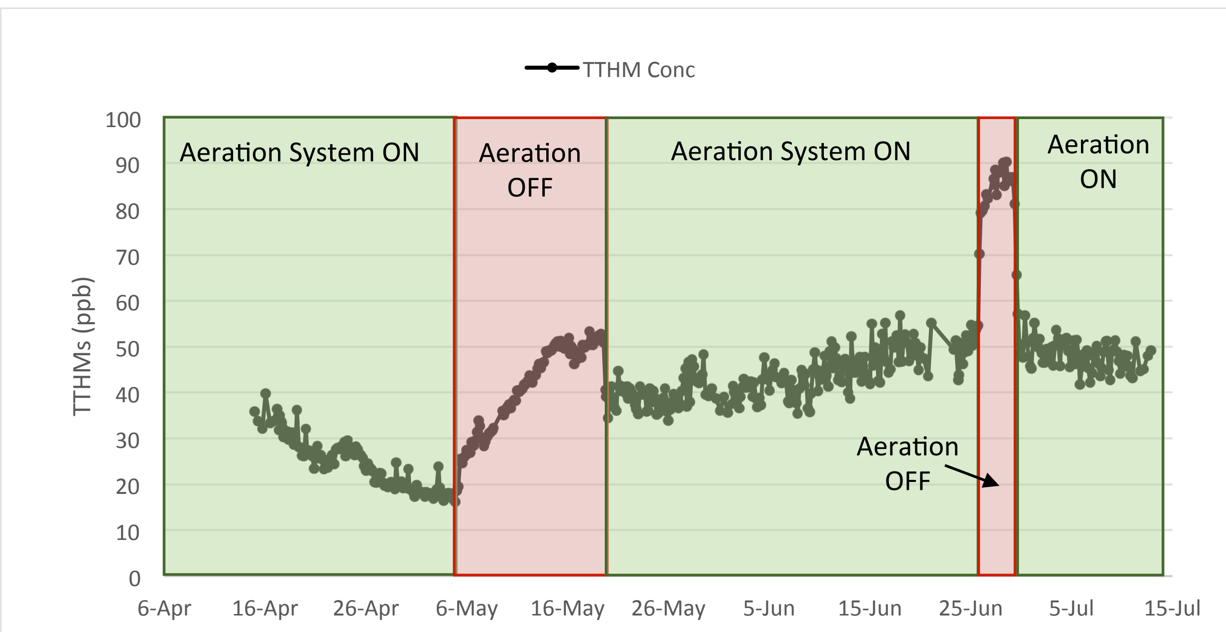

Figure 1: Continuous Measured TTHMs (analyzed with AMS unit at POE sample location).

Contract documents required two on-off cycles to verify THM reduction performance. Table 1 summarizes observed changes in monitored THMs over the testing period when the system was turned on and off.

Table 1: Summary of [8 MG Reservoir] Aeration System Performance Testing Events

Date and Cycling Event Description		Average TTHMs before event (ppb)	Average TTHMs after event (ppb)	% reduction in TTHMs
April 16 – May 5 (Initial reduction)		35.0*	18.2	48%
May 5 – May 18 (System turned off)		18.2	50.2	64%+
May 19 – May 27 (System turned on)		50.2	41.9	17%**
June 25 – June 29 (System turned off)		51.3	87.2	41%+
June 29 – July 13 (System turned on)		87.2	47.1	46%
Average of all events				**43%**

*Reflects THMs measured approximately 1 week after Spray Aeration system turned on.
+% reduction calculated as "removal" using final THMs as the baseline level in "system off" events.
**Rapid water temperature and water quality changes affected TTHM formation during this test event

Average values for before and after events were calculated as the average of two days of TTHM measurements preceding the date (ie the May 5 average TTHMs number of 18.2 ppb consists of the average of all TTHM measurements collected from May 3 – May 5). From these calculations, the average percent reduction for all events was 43%, exceeding the performance criteria of 35% TTHM reduction. All tests indicated the 35% performance reduction goal was met, with the exception of the May 19 – May 27 testing. For this event, a rapid drop in THM concentrations was observed, however, the drop did not exceed 35% reduction when compared to the May 19 data. There were many changing factors leading to elevated THMs in this including: rapid temperature increase in May leading to elevated levels, changes in brominated faction of THMs, and temporary disruptions to PAC feed.

3.2 Benchtop and Laboratory THM Analysis

Manual samples were collected and analyzed by either using a benchtop Parker Hannifin TTHM measurement unit or sent offsite to the [third-party laboratory]. Samples were collected to compare to the on-line samples for validation of the unit, and also for analysis of both the influent and effluent water to the [tank] (collected at the CT location and the Vent location, respectively). A complete list of manual samples collected are shown in Appendix A. Table 2 displays a summary of results of comparative testing between the three analytical methods (on-line or grab AMS, Parker-Hannefin grab, and [third-party laboratory] grab samples). Generally, the grab sample results show agreement with the AMS online unit (generally within 20% which is the acceptable range of error for THM analyses) and substantiate the results provided.

Table 2: Comparison of testing methods

Sample Date	Sample Location	AMS	Parker	Lab	Comparison between AMS and	
					Parker	Lab
April 29, 2015 (on)	CT POE	22.6 20*			N/A	N/A
April 30, 2015 (on)	CT POE	17.5 19*	16.8 14.6*	24.0 21.0	4.0% 19%	30% 9.5%
May 1, 2015 (on)	CT POE	21.1 18.4*	21.3* 17.0*	24.0 21.0	0.1% 7.6%	12% 12%
May 2, 2015 (on)	CT POE	 17.9*	22.0* 17.2*	24.0 21.0	N/A 3.9%	N/A 15%
May 3, 2015 (on)	CT POE	 20.7*	9.3 32.5*	26.0 22.0	N/A 36%	N/A 5/9%
May 15, 2015 (off)	CT POE	 50.5*	39.9 47.8*	48.0 66.0	N/A 5.3%	N/A 23%
May 16, 2015 (off)	CT POE	 49.9*	38.6 41.1*	47.0 53.0	N/A 18%	N/A 5.8%
May 17, 2105 (off)	CT POE	 49.3*	37.8 44.0*	45.0 47.0	N/A 10.7	N/A 4.6%
May 18, 2015 (off)	CT POE	 50.7*	39.8 42.6*	49.0 51.0	N/A 16%	N/A 0.6%

*Average of multiple samples

The grab sample data was used for a second purpose, to evaluate observed differences in the measured THMs at the entrance to the 8 MG reservoir, the exit from the 8 MG reservoir, and at the [Booster Station]. It is known that there is a valve on the inlet side of the 8 MG reservoir, which allows a small portion of treated water (having already achieved required CT in the 4MG tank) to bypass the 8 MG tank. Based upon historical, distribution pressure related concerns, the valve is maintained in a 7-turn "cracked" position, allowing for the flow bypass. Because of this, the [Booster Station] THMs, where the on-line AMS unit sampled, is comprised mostly of flow which has passed through the 8 MG tank, but also of some flow which has bypassed the tank.

An analysis of the data collected from the CT (entrance to 8 MG reservoir), vent (exit from 8 MG reservoir) and POE ([Pump Station]) sampling locations, displayed in Table 3, indicated the bypassed flow slightly impacted the data. The blended water slightly "tempered" the effects of the aeration unit, resulting in slightly higher THMs at the POE location than were observed at the vent location, when the aeration unit was on. Grab samples analyzed on the Parker-Hannifin unit on May 21 and May 22 from the POE significantly differed from the AMS unit results. Of the more than 30 samples run through the Parker Hannifin, these two measurements had the largest discrepancy to the AMS unit. This may indicate a need for recalibration of the unit, a new gas cylinder or sample collection inconsistencies.

Table 3: Comparison of Measured results at CT (entrance to 8 MG reservoir), vent (exit from 8 MG reservoir) and POE ([Booster Station]) sampling locations

Date	AMS			Parker		
	CT	vent	POE	CT	vent	POE
May 19, 2015 (off)	45.4	42.8	52.8	41.8	48.6	45.2
May 20, 2015 (off)	50.9	50.9	41.4	49.2	32.7	39.6
May 21, 2015 (off)	48.4	37.4	40.3	47.5	30.9	17.4
May 22, 2105 (off)	47.8	36.3	40.0	44.1	36.1	20.1
June 8, 2015 (on)	55.2	43.7				
June 23, 2015 (on)	68	38.4	50			
June 24, 2015 (on)	68.4	47	50.7*			
June 25, 2015 (on)	65.4	45.3	52.8*			
June 26, 2015 (off)	73.5	82*				
June 27, 2015 (off)	75.7	87.2*				
June 29, 2015 (on)	74.1	60.9	65.6			
June 30, 2015 (on)	58.1	48.9	53.8*			

*Average of multiple samples

4.0 Conclusions and Recommendations

4.1 Spray Aeration Equipment

Based on performance evaluation procedures detailed in the contract requirements, and the data shown in Figure 1, the Medora spray aeration system installed in the [8 MG reservoir] achieved a minimum 35% removal efficiency during the performance testing period.

4.2 Blending of Clearwell water at [this location]

We will be continuing to work with [City] in the future to try to find other ways to further reduce THMs. One trend revealed when analyzing grab samples collected at the CT, POE and a third “vent” location was that the THMs measured in the POE samples tend to exhibit a blending of the influent (CT) and effluent (vent) THM values. This indicated that the City may further reduce THMs at the POE location (prior to distribution to the rest of the City’s distribution system) if a greater proportion (or ideally all) flow were routed through the 8 MG reservoir. However, due to historical distribution system pressure trends and the condition of the “cracked” isolation valve, it is recommended the City weigh the implications of closing this valve fully and proceed with caution if a change is made.

Appendix A

Benchtop and Laboratory Results

		Aeration System	Field Measurement			THM		Lab Analysis		
Day	29-Apr	ON								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Draw**	12:00	CT				22.6	26.8	N/A	N/A	N/A
Draw**	12:00	POE	1.04	7.36	17.1	20.7	20.9	N/A	N/A	N/A
Last Water	22:00	POE			14.4	19.3	18.4	N/A	N/A	N/A

		Aeration System	Field Measurement			THM		Lab Analysis		
Day	30-Apr	ON								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	8:00	CT			16.2	17.5	16.8	24.0		ND
Fill*	8:00	POE			16.2	19.0	16.2	21.0		1.0
Draw**	12:00	POE			16.2	18.9	8.5	N/A	N/A	N/A
Last Water	20:00	POE			16.2	17.4	19.1	N/A	N/A	N/A

		Aeration System	Field Measurement			THM		Lab Analysis		
Day	1-May	ON								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	0:00	CT			16.7		21.5	24.0		ND
Fill*	0:00	POE			16.7	19.9	16.5	21.0		1.3
Draw**	8:00	CT			16.7	21.1	21.0	N/A	N/A	N/A
Draw**	8:00	POE			16.7	18.1	18.5	N/A	N/A	N/A
Last Water	20:00	POE			16.7	17.3	16.1	N/A	N/A	N/A

		Aeration System	Field Measurement			THM		Lab Analysis		
Day	2-May	ON								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	0:00	CT			14.0		20.9			
Fill*	0:00	POE			14.0	18.3	18.2			
Draw**	8:00	CT			14.0		22.3	24.0		1.1
Draw**	8:00	POE			14.0	18.0	17.3	21.0		1.2
Last Water	20:00	CT			14.0		22.8			
Last Water	20:00	POE			14.0	17.3	16.2	N/A	N/A	N/A

		Aeration System	Field Measurement			THM		Lab Analysis		
Day	3-May	ON								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	4:00	CT			15.8		9.3	26.0		1.1
Fill*	4:00	POE			15.8	23.9	34.4	22.0		ND
Last Water	20:00	POE			15.8	17.5	30.6	N/A	N/A	N/A

		Aeration System	Field Measurement			THM			Lab Analysis	
Day	15-May	OFF								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	0:00	CT			22.3		39.9	48.0	ND	ND
Fill*	0:00	POE			22.3	51.1	46.3	66.0	ND	ND
Draw **	12:00	POE			22.3	49.9	49.2	N/A	N/A	N/A

		Aeration System	Field Measurement			THM			Lab Analysis	
Day	16-May	OFF								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	3:20	CT			22.7		38.6	47.0	ND	1.4
Fill*	3:20	POE			22.7	52.0	43.7	53.0	ND	1.1
Draw**	12:00	POE			22.7	49.6	39.2	N/A	N/A	N/A
Last Water	20:00	POE			22.7	48.2	40.3	N/A	N/A	N/A

		Aeration System	Field Measurement			THM			Lab Analysis	
Day	17-May	OFF								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	0:00	CT			24.8		37.8	45.0	ND	ND
Fill*	0:00	POE			24.8	47.5	43.0	47.0	ND	ND
Draw**	12:00	POE			24.8	50.4	44.1	N/A	N/A	N/A
Last Water	20:00	POE			24.8	50.1	45.0	N/A	N/A	N/A

		Aeration System	Field Measurement			THM			Lab Analysis	
Day	18-May	OFF								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	0:00	CT			23.6		39.8	49.0	ND	ND
Fill*	0:00	POE			23.6	50.5	42.2	51.0	ND	ND
Draw**	12:00	POE			23.6	50.4	42.2	N/A	N/A	N/A
Last Water	21:00	POE			23.6	51.2	43.5	N/A	N/A	N/A

		Aeration System	Field Measurement			THM			Lab Analysis	
Day	19-May	OFF								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	8:00	CT			24.4	45.4	41.8	N/A	N/A	N/A
Fill*	8:00	vent			24.4	42.8	48.6	N/A	N/A	N/A
Fill*	8:00	POE			24.4	52.8	45.2	N/A	N/A	N/A
Day	20-May	OFF								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	8:00	CT			22.7	50.9	49.2	N/A	N/A	N/A
Fill*	8:00	vent			22.7	36.9	32.7	N/A	N/A	N/A
Fill*	8:00	POE			22.7	41.4	39.6	N/A	N/A	N/A
Day	21-May	OFF								
Tank Cycle	Time	Sample Location	Cl Res	pH	Temp	AMS	P-H	THM Lab	Br	TOC
Fill*	8:00	CT			23.4	48.4	47.5	N/A	N/A	N/A
Fill*	8:00	vent			23.4	37.4	30.9	N/A	N/A	N/A
Fill*	8:00	POE			23.4	40.3	17.4	N/A	N/A	N/A

Day	22-May	OFF								
Tank Cycle	**Time**	**Sample Location**	**Cl Res**	**pH**	**Temp**	**AMS**	**P-H**	**THM Lab**	**Br**	**TOC**
Fill*	8:00	CT			21.8	47.8	44.1	N/A	N/A	N/A
Fill*	8:00	vent			21.8	36.3	36.1	N/A	N/A	N/A
Fill*	8:00	POE			21.8	40.0	20.1	N/A	N/A	N/A

*** Fill = Plant in Operation**

**** Draw - Plant out of Operation**