PILOT INVESTIGATIONS FOR:
Moorestown, NJ

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PILOT INVESTIGATIONS FOR:
Moorestown, NJ

CONDUCTED: JULY 29TH THRU SEPTEMBER 29TH, 2015

FEBRUARY 29, 2016

Project: Moorestown, NJ

Pilot #: PL15023
Radium, manganese, TCE and TCP removal
with HMO addition followed by filtration and adsorption with GAC

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EXECUTIVE SUMMARY

Between the period of July 29th and September 29th, 2015, Tonka Water and the Township of Moorestown, NJ, under the supervision of the Alaimo Group, conducted a pilot study to treat the groundwater (Wells #9 and #7) of the Township of Moorestown, in New Jersey, for heightened levels of radium (gross alpha), manganese, trichloropropane (TCP) and trichloroethylene (TCE). This pilot test was conducted to confirm that the radium, manganese, TCP and TCE could be effectively and efficiency removed from the groundwater supply using the proposed treatment system.

The process piloted consisted of oxidation with sodium hypochlorite followed by pH adjustment with sodium hydroxide and hydrous manganese oxide (HMO) addition followed by filtration for radium (gross alpha) and manganese removal. Finally, the filtered water was treated through granular activated carbon (GAC) for trichloropropane and trichloroethylene removal.

The results showed that combined radium, gross alpha and manganese were effectively and consistently removed through the HMO followed by filtration process. The contaminants were removed to below their respective MCLs and SMCL of 5 pCi/L, 15 pCi/L and 0.05 mg/L throughout the entire pilot study. Furthermore, the GAC process removed both the TCP and TCE to below laboratory detection limits of 0.00458 µg/L and 0.32 µg/L, respectively.

Final filter runs times exceeded 250 hours with the piloted process while the GAC process showed no evidence of approaching capacity after the 10 weeks of operation.

An HMO followed by filtration and GAC process provides a viable treatment system for the meeting the Township's treatment goals. A full-scale design to treat Wells #9 and/or #7 should include sodium hypochlorite, sodium hydroxide and HMO feed systems followed by filtration at 3 gpm/ft^2 through Tonka Water's IMAR™ filter media and finally, GAC adsorption columns with at least 10 minutes of EBCT. A simultaneous air/water backwash system (Simul-Wash™) should be utilized in the filter system to minimize radionuclide accumulation and backwash volume.

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1 Introduction

Between the period of July 29th and September 29th, 2015, Tonka Water and the Township of Moorestown, NJ, under the supervision of the Alaimo Group, conducted a pilot study to treat the groundwater (Wells #9 and #7) of the Township of Moorestown, in New Jersey, for heightened levels of radium, manganese, trichloropropane (TCP) and trichloroethylene (TCE). This pilot test was conducted to confirm that the radium, manganese, TCE and TCP could be effectively and efficiency removed from the groundwater supply using the proposed treatment system.

1.1 Radium

Radionuclide contamination of groundwater is generally attributed to sources naturally occurring in the rock formations from which drinking water is attained. Radionuclides have most commonly been found in the water supply in the Midwest and along the east coast. Radionuclides by their very nature are unstable and are continually emitting energy. The three radionuclides that have been identified to be of primary concern are uranium, radium and radon, and the potential carcinogenic impact of these substances is well known. Approximately 80 - 85 % of the radium accumulating in the body deposits in bones and consequently the predominant, although not the only, health hazard with radium is bone cancer.

In December 2000, the final radionuclides rule was published by USEPA with an effective date of December 8, 2003. This rule established maximum contaminant levels (MCL's) for radioactivity from gross alpha, beta & photon emitters, Ra-226 and 228, and uranium. The MCL for combined radium 226 and 228 was set at 5 pico-curies per liter (5 pCi/L), while the MCL for gross alpha was set at 15 pico-curies per liter.

Radium can be removed with a variety of methods but the most common are lime softening, cation exchange softening, RO/NF membranes and HMO addition followed by filtration.

1.2 Manganese

Manganese is commonly found in groundwater sources. Although not considered a health hazard, it can add color to the water and cause staining of household fixtures and clothing. The Environmental Protection Agency has identified a non-enforceable secondary drinking water guideline for manganese of 0.05 mg/L.

Manganese is commonly removed by oxidation to its insoluble forms, followed by media filtration. Manganese is typically oxidized with potassium or sodium permanganate or by contact oxidation on either a catalytic filter media or hydrous manganese oxide (HMO) particulate.

1.3 Trichloropropane (TCP) and Trichloroethylene (TCE)

Trichloropropane (1,2,3-Trichloropropane) or TCP is a colorless liquid formed by the chlorination of propylene that exists only as a product of manufacturing and not as a natural substance. TCP was/is commonly used as a solvent, in paint and varnish removers and as a degreaser. It is also a byproduct and/or intermediate during the manufacturing of various products such as polymers and pesticides. There is currently no EPA maximum contaminant level (MCL) in place for TCP.

Trichloroethylene or TCE is also formed by the chlorination of alkanes just like TCP. It is a colorless liquid with a sweet odor used commonly as a degreaser, solvent and as an ingredient in many consumer products such as paint remover, adhesives and carpet cleaners. In the past, it was even used as a general anesthetic before human exposure concerns were realized. The EPA has established an MCL for TCE of 5 µg/L, while New Jersey has established an MCL for TCE of 1 µg/L.

There are various removal methods for TCP and TCE from water; however, the most widely used method in drinking water is adsorption onto granular activated carbon (GAC).

For this pilot study, the radium was removed by adsorption onto HMO followed by filtration. The manganese was removed by contact oxidation of manganese on the HMO particulate followed by filtration. Finally, TCE and TCP were removed by adsorption onto granular activated carbon (GAC).

2 Objectives

The Township of Moorestown, NJ is planning the installation of a treatment system for the groundwater supply from the town's wells. Both radium and gross alpha concentrations in the raw water have nominally exceeded the USEPA National Primary Drinking Water Regulations' Maximum Contaminant Level (MCL); and the manganese concentrations have exceeded the USEPA Secondary Drinking Water Standards (SMCL). Although the raw water TCE levels do not exceed the EPA's MCL, the Township is looking to further reduce the levels along with the unregulated concentrations of TCP that have been detected. The pilot testing was conducted to verify that the process of HMO addition followed by conventional media filtration and granulated activated carbon (GAC) would provide the desired effluent quality while achieving favorable filter and GAC run capacities.

The pilot was conducted with water from two (2) of the Township's wells, #7 and #9. Well #9 was used from July 29th to August 21st while Well #7 was used from August 21st to the end of the pilot on September 29th. The change from Well #9 to Well #7 was done because according to laboratory results, levels of TCP were below detection limits in Well #9. The average raw water qualities for each well as observed during the pilot duration are presented in Tables 2.1 and 2.2.

Table 2.1. Average Raw Water Quality - Well #9

	pH	Total Hardness (mg/L as $CaCO_3$)	Total Alkalinity (mg/L as $CaCO_3$)	Iron (mg/L)	Manganese (mg/L)
Field	4.98	-	-	0.73	0.187
Laboratory	-	34	5.4	0.38	0.163
	Radium 226 (pCi/L)	Radium 228 (pCi/L)	Gross Alpha (pCi/L)	TCP (µg/L)	TCE (µg/L)
Laboratory	2.43	3.32	15.33	N/A	N/A

Note: Water temperature average = 16.8 °C.

Table 2.2. Average Raw Water Quality - Well #7

	pH	Total Hardness (mg/L as $CaCO_3$)	Total Alkalinity (mg/L as $CaCO_3$)	Iron (mg/L)	Manganese (mg/L)
Field	4.89	-	-	0.04	0.122
Laboratory	-	-	-	0.12	0.118
	Radium 226 (pCi/L)	Radium 228 (pCi/L)	Gross Alpha (pCi/L)	TCP (µg/L)	TCE (µg/L)
Laboratory	0.85	1.76	12.69	0.069	1.71

Note: Water temperature average = 16.3 °C.

The primary objectives of the pilot study were to determine the following:

1. The ability of the system to achieve an effluent combined radium (Ra226+Ra228) level as low as possible by feeding of approximately 1 mg/L HMO (as Mn). The effluent combined radium activity must be less than the MCL of 5.0 pCi/L at all times.

2. The ability of the system to achieve a gross alpha level effluent as low as possible by feeding of approximately 1 mg/L HMO (as Mn). The effluent gross alpha activity must be less than the MCL of 15.0 pCi/L at all times.

3. The ability of the system to consistently achieve effluent manganese levels of < 0.05 mg/L.

4. The ability of GAC to lower the trichloropropane (TCP) to below non-detectable levels (<0.0045 µg/L).

5. The trichloroethylene (TCE) removal capability of granular activated carbon (GAC).

6. The chemical feed rates required for radium and manganese removal.

7. Filter head loss as a function of run time.

8. Approximate filter run length.

3 Methods

3.1 Equipment Description

Enough chemical feed equipment were provided to allow for chlorine and hydrous manganese oxide (HMO) addition. The chemical feed systems consisted of LMI diaphragm type chemical metering pumps (0.42 gph), solution mix tanks and an HMO chemical mixer with stand. The chemical feed systems were setup to inject chlorine followed by the HMO upstream of the filter. A static mixer was installed immediately after the chemical injections to ensure the chemicals were properly mixed with the raw water prior to entering the filter.

Above: chemical feed mix tanks, pumps and containment

A single 8 inch diameter by 7 ft tall filter was used for radium and manganese removal. The filter incorporated a simultaneous air/water backwash system, underdrain system, air release valve, rate control meters, sample taps and filter media. The filter provided a total of 0.35 ft^2 of surface area, which, when operated at a loading rate of 3 gpm/ft^2., correlates to an equivalent flow rate of 1.05 gpm. The filter was bedded with 30 inches of Tonka IMAR™, a specially sized media consisting of anthracite and silica sand developed for removal of iron, manganese, arsenic and radium. The filter system also included an air compressor to provide the air supply for the simultaneous air/water wash process. The backwash system included a backwash supply storage tank fed with clean water from the GAC effluent and a backwash waste holding tank for purposes of collecting and treating the backwash waste for discharge to the sewer as well as to serve as an equalization tank for waste sample collection. Backwash waste treatment is detailed in section 4.8.

A single 6 inch diameter by 7 ft tall column was used for TCE and TCP removal. The column incorporated an underdrain system, air release valve, rate control meter, sample taps at various media depths and adsorptive media. The column provided a total of 0.20 ft^2 of surface area and was bedded with 5 ft of coal based granular activated carbon (0.8-1.0 mm effective size,

U.C. < 2.1) to provide 20 minutes of empty bed contact time when operated at 0.37 gpm. The surface loading rate at 0.37 gpm was 1.85 gpm/ft^2.

Above: 8" dia. filter column (L) and 6" dia. GAC column (R).

A differential pressure gauge was provided on the filter and GAC system for monitoring differential pressure across each vessel. Rate of flow control and meters were piped into the filter effluent of each filter column so as to maintain a constant treatment flow rate through the filters. Prior to starting each of the vessels and after the filter/GAC media had been installed, each vessel was backwashed to remove fines and to cleanse the media.

3.2 Operation

The pilot influent source water was pulled from either Well #9 or Well #7 at a flow rate of 1.05 gpm. The raw water was injected with sodium hypochlorite and then HMO (with NaOH added) before passing through an inline static mixer to ensure the chemicals were thoroughly mixed with the raw water. After mixing, the raw water with chemical added passed through the 8 inch diameter granular filter at a rate of 3 gpm/ft^2. The filter effluent piping and valves were setup to allow for 0.37 gpm of the 1.05 gpm of the filter effluent to be diverted to the GAC column while the remaining 0.68 gpm was sent to the filtered water tank where it was collected and periodically pumped to waste with an automatic sump pump. The 0.37 gpm sent to the GAC column passed through the GAC vessel at 1.85 gpm/ft^2 before emptying into the backwash

supply storage tank. Once full, the backwash supply storage tank overflowed into the filter water tank where it was periodically pumped to waste with the automatic sump pump. See the Pilot Schematic in Appendix C for a visual of the pilot system flow.

A filter backwash was initiated by either high differential pressure ("head loss") (200 in. W.C.) or by manganese (or iron) breakthrough. The filter was backwashed using a simultaneous air/water backwash process called Simul-Wash™. The backwash sequence, flow rates and step durations are detailed in Figure Table 3.1 below.

Table 3.1. Backwash Parameters – 8" Filter Column

Step	Fluid	Loading Rate (Air: cfm/ft^2 Water: gpm/ft^2)	Flow Rate (Air: cfm Water: gpm)	Duration (Minutes)	Waste Volume (Gallons)
Draindown	Water	N/A	N/A	N/A	N/A
Simul-Wash™	Air	3.0	1.0	10	N/A
	Water	3.0	1.0		10.0
Air Purge	Water	3.0	1.0	2	2.0
Restratification	Water	10.0	3.5	3	10.5
			Totals	**15**	**22.5**

3.3 Sampling and Analysis

Field Analyses: During the pilot testing, field analyses for manganese, free and total chlorine, and iron were performed using a Hach DR-890 colorimeter. Field sampling points included the raw water, filter influent (post chemical feed), filter effluent and backwash waste.

The field testing protocol used during the piloting is presented in Table 3.2 below.

Table 3.2. Field Testing Protocol

Parameter	Frequency	Location
pH	2x/run	Raw Water
	2-4x/run	Post HMO Feed – Filter Influent
	2-4x/run	Filter Effluent
	2-4x/run	Backwash waste (sample backwash near the start, middle, end, and a composite)
Temperature	2x/run	Raw Water
Free Chlorine	4-10x/run	Filter Effluent
Total Chlorine	2-5x/run	Filter Effluent
Total Iron	2x/run	Raw Water
	4x/run	Filter Effluent
Total Manganese	2-3x/run	Raw Water
	2-3x/run	Post HMO Feed – Filter Influent*
	4-10x/run	Filter Effluent
Ammonia	1-3x/pilot	Raw Water (only if free and total chlorine differ)

* HMO control check; Soluble Mn after 0.45 µ filtering (<0.050 mg/L) and Total Mn without filtering of sample (~1.0 mg/L).

Laboratory Analyses: Coincidental with the field testing, periodic samples were drawn for independent laboratory testing to periodically confirm field test results as well as to quantify radium activity and TCE/TCP concentrations since there are no field testing methods for radium or TCE/TCP. Since radium adsorbs onto the manganese dioxide solids, manganese field tests were used as a surrogate for radium removal performance during the pilot. Laboratory testing was performed at both EMSL Analytical, Inc in Cinnaminson, NJ and Eurofins in South Bend, IN. Initially, all samples were analyzed at EMSL; however, unreliable results were received from EMSL for TCP so TCP samples were later (9/14/15) analyzed at Eurofins Laboratory. See Appendix B for all laboratory reports.

The laboratory testing protocol used during the pilot is presented in Table 3.3 below.

Table 3.3. Laboratory Testing Protocol

Parameter	Frequency[a/]	Location
Total Iron	1x/run	Raw Water
	2x/run	Filter Effluent
Total Manganese	2-3x/run	Raw Water
	1x/run	Post HMO Feed – Filter Influent
	2-3x/run	Filter Effluent
Radium 226 & Radium 228	3x/run	Raw Water
	3x/run	Filter Effluent
	Four	Backwash Water
Gross Alpha	3x/run	Raw Water
	3x/run	Filter Effluent
	Four	Backwash Water
Trichloropropane (TCP)	1x/run	Raw Water
	1x/run	Filter Effluent
	1x/run	GAC Sampling Depths of 3", 15", 21", 39", 48" and 60" (GAC Effluent)
Trichloroethylene (TCE)	1x/run	Raw Water
	1x/run	Filter Effluent
	1x/run	GAC Sampling Depths of 3", 15", 21", 39", 48" and 60" (GAC Effluent)
Sulfide, Hardness, Alkalinity	1-3x/pilot	Raw Water

a/ Run is based on HMO – IMAR™ filtration

In addition to the field and laboratory analyses, flow rates and the differential pressures across both the filter and GAC column were recorded at the time of the field samples. Also, backwash events and details of chemical preparation and chemical feed pump settings were recorded throughout the pilot.

4 Results, Observations and Discussion

4.1 Manganese Removal

Hypochlorite and HMO addition followed by conventional filtration effectively removed the raw water manganese to below the SMCL of 0.05 mg/L. The raw water had an average manganese concentration of 0.164 mg/L over the pilot period with Well #9 having a higher average of 0.187 mg/L and Well #7 averaging 0.122 mg/L. The filter influent manganese concentration averaged 0.983 mg/L as a result of the HMO (Mn) addition. The pilot filter process produced a filter effluent manganese average of 0.041 mg/L over the entire pilot duration. This average effluent was deceiving as it includes results from the beginning of the pilot when the effluent levels were high as a result of a low treatment pH. The adjusted effluent average was 0.015 mg/L when only the results after July 30th are considered. This was the date when the pilot influent pH adjustment began and satisfactory manganese removal performance was first established. After the pH was increased to above 6.3 the filter system was able to achieve effluent manganese levels of < 0.05 mg/L. The manganese effluent results never exceeded the SMCL of 0.05 mg/L with a range from non-detect (< 0.01 mg/L) to 0.041 mg/L reported after the pH adjustment was made. Laboratory samples confirm the effluent field data with none of the eight (8) lab samples exceeding the method detection limit of 0.015 mg/L.

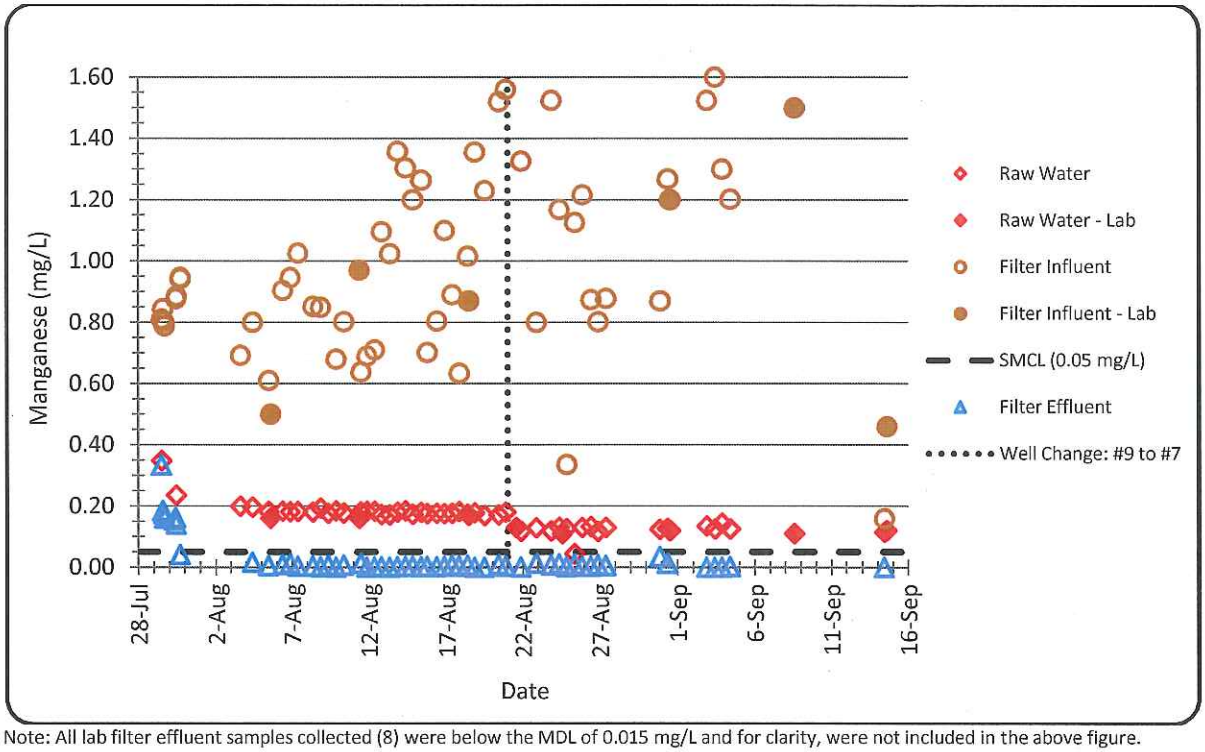
A summary of all the manganese results are presented in Table 4.1 below while a graphical summary of the manganese results are shown in Figure 4.1.

Table 4.1. Results Summary - Manganese Removal

	Raw Water (mg/L)	Filter Influent (Post Chemical) (mg/L)	Filter Effluent (mg/L)
Field	0.044-0.348 (0.164 avg)	0.159-1.600 (0.984 avg)	<0.020-0.333 (0.0344 avg)
Laboratory	0.110-0.170 (0.135 avg)	0.460-1.500 (0.917 avg)	< 0.015

Note: The field method detection limit was 0.020 mg/L. See laboratory reports for reported MDL for each sample.

Figure 4.1. Manganese Removal



Note: All lab filter effluent samples collected (8) were below the MDL of 0.015 mg/L and for clarity, were not included in the above figure.

4.2 Radium and Gross Alpha Removal

The HMO process consistently removed the radium from the raw water to levels below the MCL of 5.0 pCi/L. The raw water combined radium (Ra226+Ra228) activity averaged 3.95 pCi/L over the entire pilot duration. However, during the pilot, the raw water source was changed from Well #9 to Well #7. Well #9 had a higher radium activity with an average of 5.75 pCi/L when compared to Well #7 at 2.61 pCi/L. Nonetheless, the HMO process lowered the radium levels in both wells with an effluent average of 1.04 pCi/L over the pilot period and individual well averages of 1.16 pCi/L and 0.94 pCi/L for Wells #9 and #7, respectively. This corresponds to a ~80% removal for Well #9 and ~64% removal for Well #7. These removals were likely better than the calculated values since all the results were at or below the method detection limits for radium 226 and radium 228. Quantification of radium activity and removals at these levels is difficult given that the uncertainty for each sample were 50-100% of the reported values for the effluent samples. This uncertainty is inherent to the radionuclide analytical method because the radium levels are determined by measuring the amount of alpha emission that results from radioactive decay of both radium 226 and radium 228. So, each sample has a quantified uncertainty as reported for the specific sample analysis. Nonetheless, the results show that radium has been effectively removed in each of the collected samples.

None of the seven (7) lab samples taken over the duration of the pilot ever exceeded the MCL of 5.0 pCi/L as all samples had results near the method detection limit (MDL). No additional

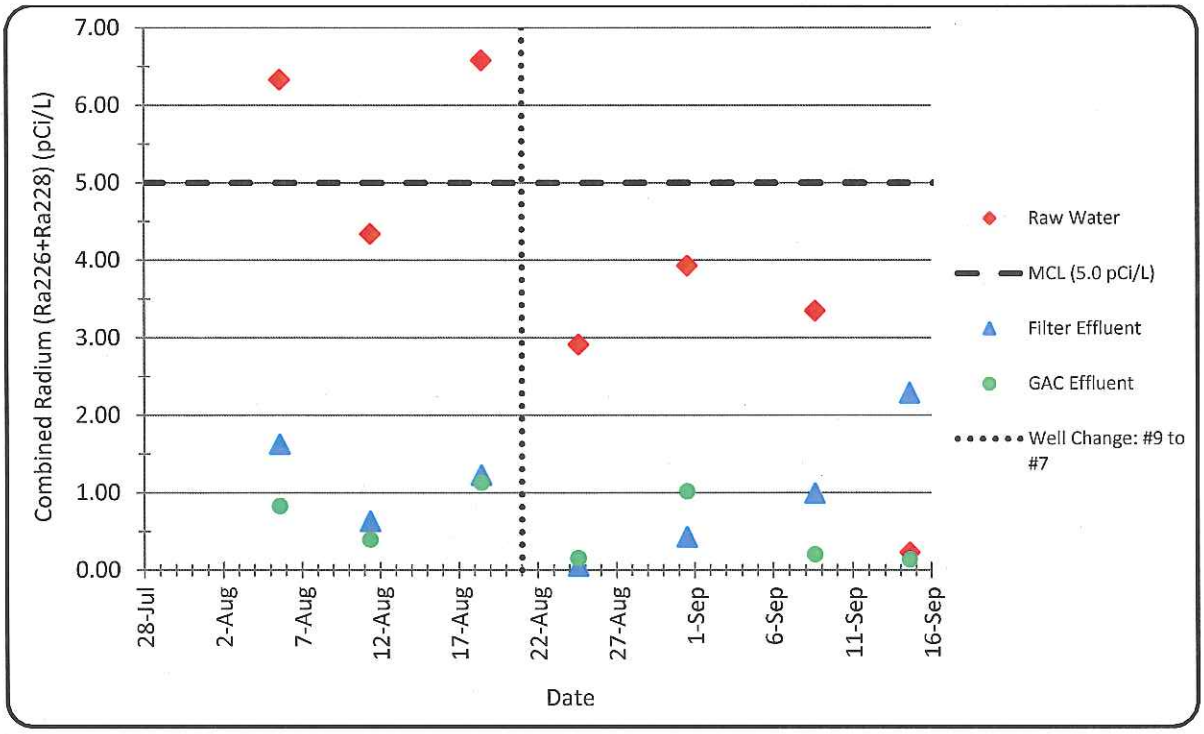
radium removal was measured through the GAC column, as expected. Table 4.2 summarizes the radionuclide removal performance while Figure 4.2 provides a graphical summary of the radium removal trends reported over the pilot study.

Table 4.2. Results Summary - Radionuclide Removal

Raw Water		Filter Effluent		GAC Effluent	
Combined Radium (pCi/L)	Gross Alpha (pCi/L)	Combined Radium (pCi/L)	Gross Alpha (pCi/L)	Combined Radium (pCi/L)	Gross Alpha (pCi/L)
0.23-6.58 (3.95 avg)	10.44-19.90 (13.82 avg)	0.05-2.29 (1.04 avg)	0.84-2.39 (1.39 avg)	0.14-1.13 (0.55 avg)	0.64-1.71 (1.10 avg)

Note: Some of the reported values are less than laboratory method detection limits. See the laboratory reports in Appendix B for individual sample detection limits and estimated error values.

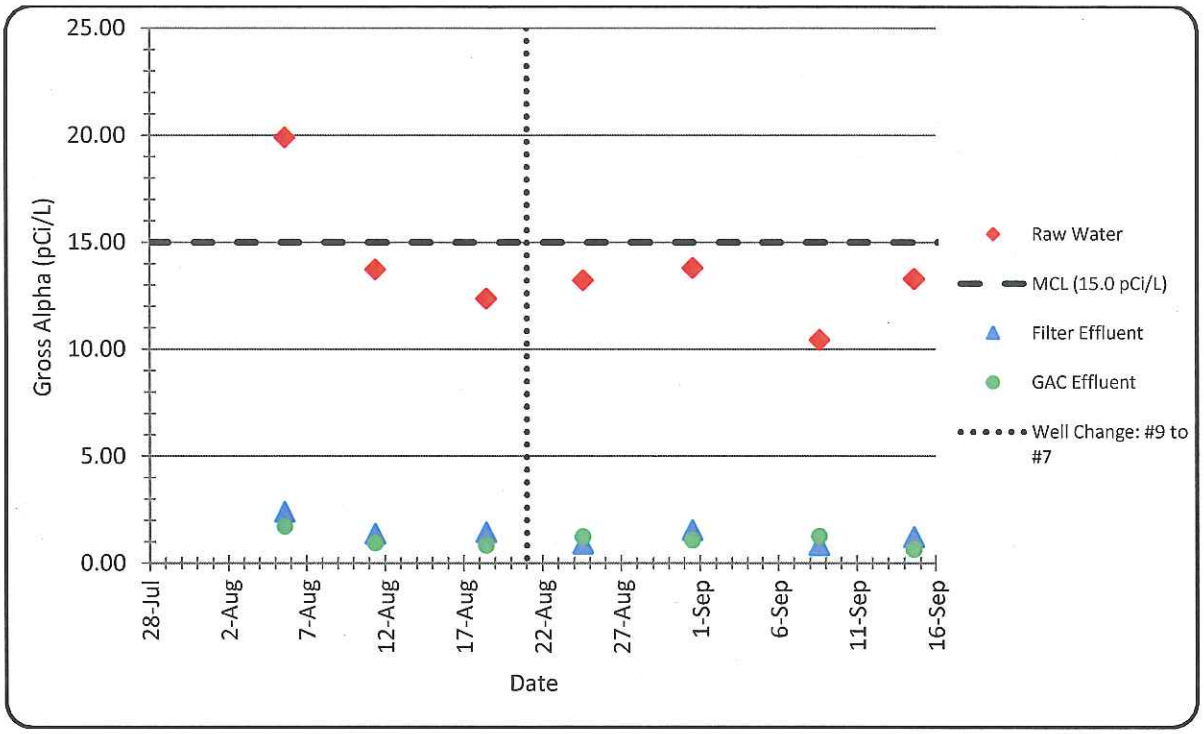
Figure 4.2. Radium Removal



As expected, the removal of radium from the raw water resulted in a reduction of gross alpha levels. The raw water gross alpha levels averaged 13.82 pCi/L over the pilot period with individual well averages of 15.33 pCi/L for Well #9 and 12.69 pCi/L for Well #7. Well #9 had multiple samples exceed the gross alpha MCL of 15.0 pCi/L while Well #7 levels hovered just below the MCL. The effective removal of radium from both wells resulted in low effluent gross alpha levels for both water sources. The filter effluent gross alpha levels averaged 1.39 pCi/L over the entire pilot study, far less than the MCL of 15.0 pCi/L. Due to there being no measurable removal of radium through the GAC column, it was no surprise that no significant

gross alpha reduction was reported through the GAC system. Figure 4.3 below gives a graphical summary of the gross alpha removal trends.

Figure 4.3. Gross Alpha Removal



4.3 TCP and TCE Removal

TCP and TCE levels were monitored throughout the entirety of the pilot study; however, early in the pilot there were inconsistencies in the results and incorrect analytical methods applied to the TCP analyses. As result, the TCP and TCE data from the early parts of the pilot were unreliable and; therefore, were not included in these final results analyses. All TCP samples taken on or after 9/14/15 from the Eurofins laboratory are considered accurate and reliable and were used in this analyses. As for TCE, all samples taken on or after 8/24/15 were considered accurate and reliable and were used in these analyses.

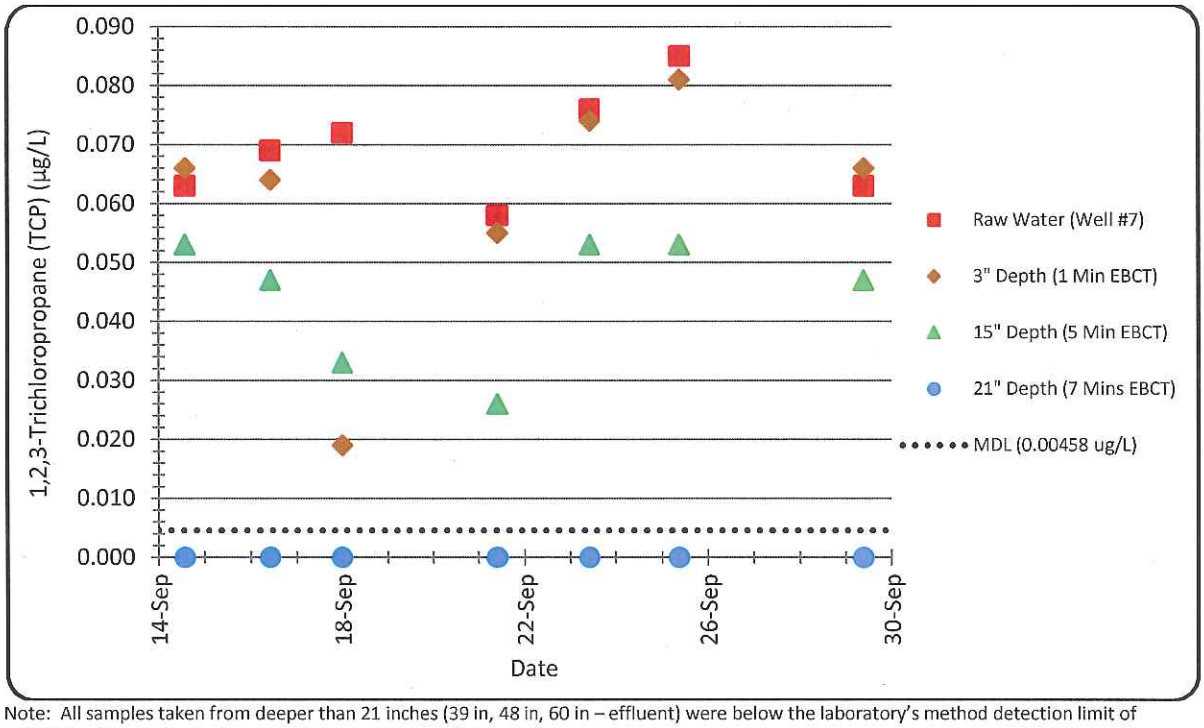
TCP levels in the raw water (Well #7) averaged 0.069 µg/L over the seven (7) samples taken from 8/24/15 to 9/29/15. The results of the GAC column sampling showed a repeatable trend in TCP removal as the water moves down through the column – see Figure 4.4 below. According to the lab results, nearly complete TCP removal is achieved through the first 21 inches of GAC or 7 minutes of empty bed contact time (EBCT). The vertical depth TCP averages were 0.061 µg/L for 3 inches (1 minute EBCT) and 0.045 µg/L 15 inches (5 minutes EBCT). At 21 inches (7 minute EBCT), 39 inches (13 minutes EBCT), 48 inches (16 inches) and the effluent at 60 inches (20 minutes of EBCT) all of the seven (7) samples collected had TCP levels below the laboratory

detection limit (MDL) of 0.00458 µg/L. Table 4.3 summarizes the TCP and TCE removals while Figures 4.4 and 4.5 illustrates the removal of both constituents at various depths in the 60 inch deep GAC bed.

Table 4.3. Results Summary - TCP & TCE Removals

Raw Water (Well #7)		GAC Effluent	
TCP (µg/L)	TCE (µg/L)	TCP (µg/L)	TCE (µg/L)
0.058-0.085 (0.069 avg)	1.30-2.00 (1.71 avg)	< 0.00458	< 0.32

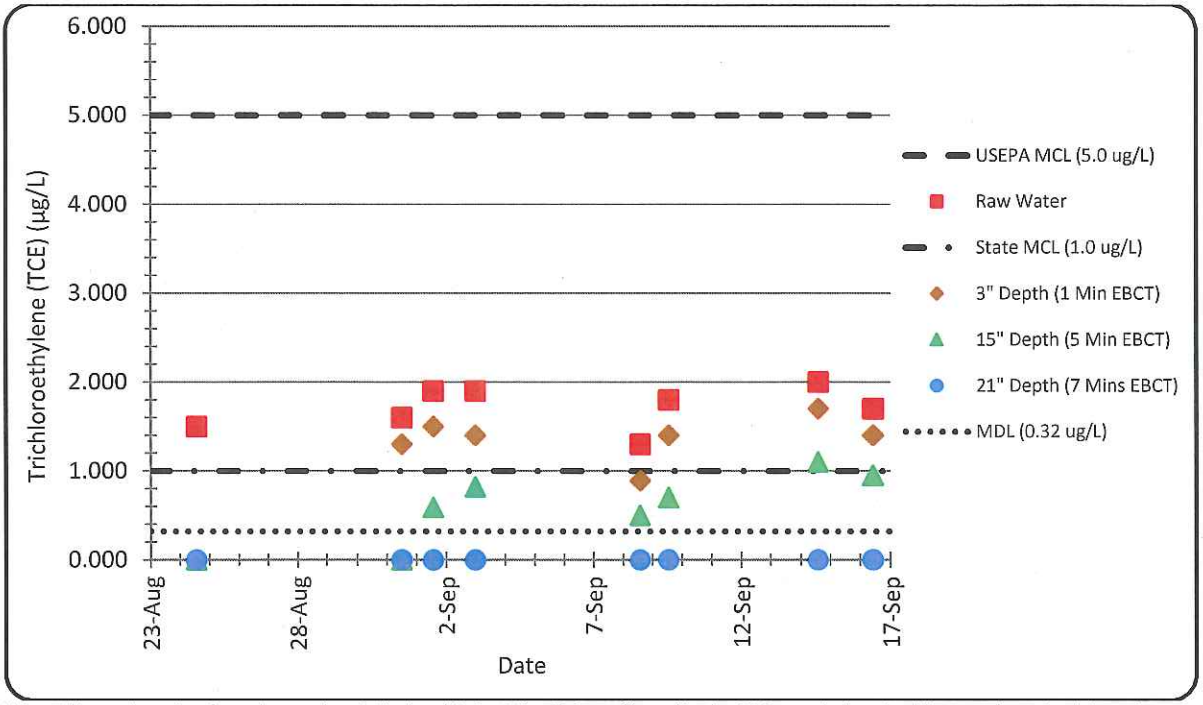
Figure 4.4. TCP Removal



Note: All samples taken from deeper than 21 inches (39 in, 48 in, 60 in – effluent) were below the laboratory's method detection limit of 0.00458 µg/L. For clarity, these results were not included in the figure above.

The TCE removal trend was very similar to that of TCP with levels falling below the laboratory's detection limit of 0.32 µg/L by the 21 inch (7 EBCT) mark. The raw water (Well #7) TCE concentrations averaged 1.7 µg/L, a level below the USEPA MCL of 5.0 µg/L with the depth averages of 1.2 µg/L and 0.6 µg/L for 3 inches and 15 inches, respectively. All samples taken at the 21 inch or deeper depths were less than the lab's detection limit of 0.32 µg/L and well below both the USEPA MCL of 5.0 µg/L and the New Jersey MCL of 1.0 µg/L.

Figure 4.5. TCE Removal



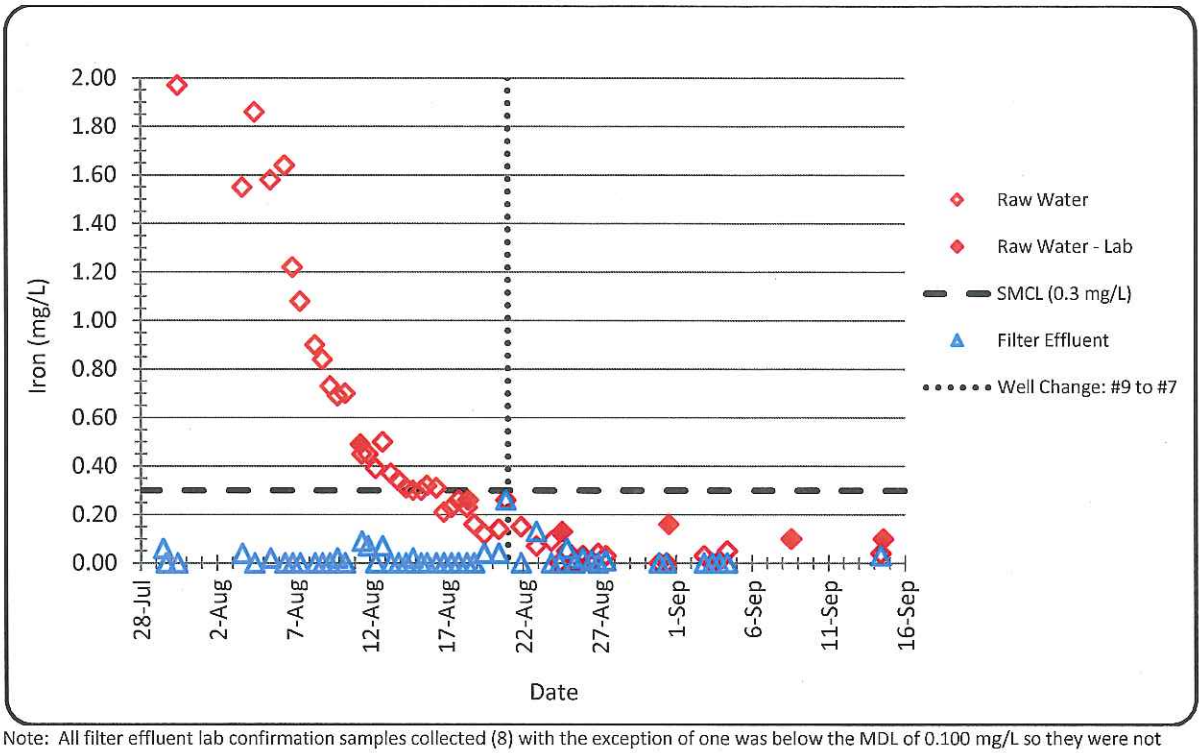
Note: All samples taken from deeper than 21 inches (39 in, 48 in, 60 in – effluent) in the GAC were below the laboratory's method detection limit of 0.32 µg/L. For clarity, these results were not included in the figure above.

4.4 Other Water Quality Trends

Additional water parameters were monitored throughout the pilot to ensure that the full scale process would produce water suitable for discharge to distribution and; ultimately, human consumption. Iron and pH were water parameters that were regularly monitored while total hardness, total alkalinity, sulfides and ammonia were sampled once to determine their effects on water stability, chemical demand, and overall aesthetics.

Raw water iron levels averaged 0.73 mg/L for Well #9 and 0.035 mg/L for Well #7 according to field testing. Oxidation with chlorine and filtration effectively and consistently removed the iron to average levels of 0.02 mg/L over the entire pilot study as well as for the individual wells. The effluent iron never exceeded the SMCL of 0.3 mg/L during the pilot period. The laboratory results were in agreement with the field results with nearly all of the eight (8) confirmation samples falling below the method detection limit of 0.100 mg/L. Figure 4.6 provides a graphical representation of the iron removal observed over the course of the pilot study.

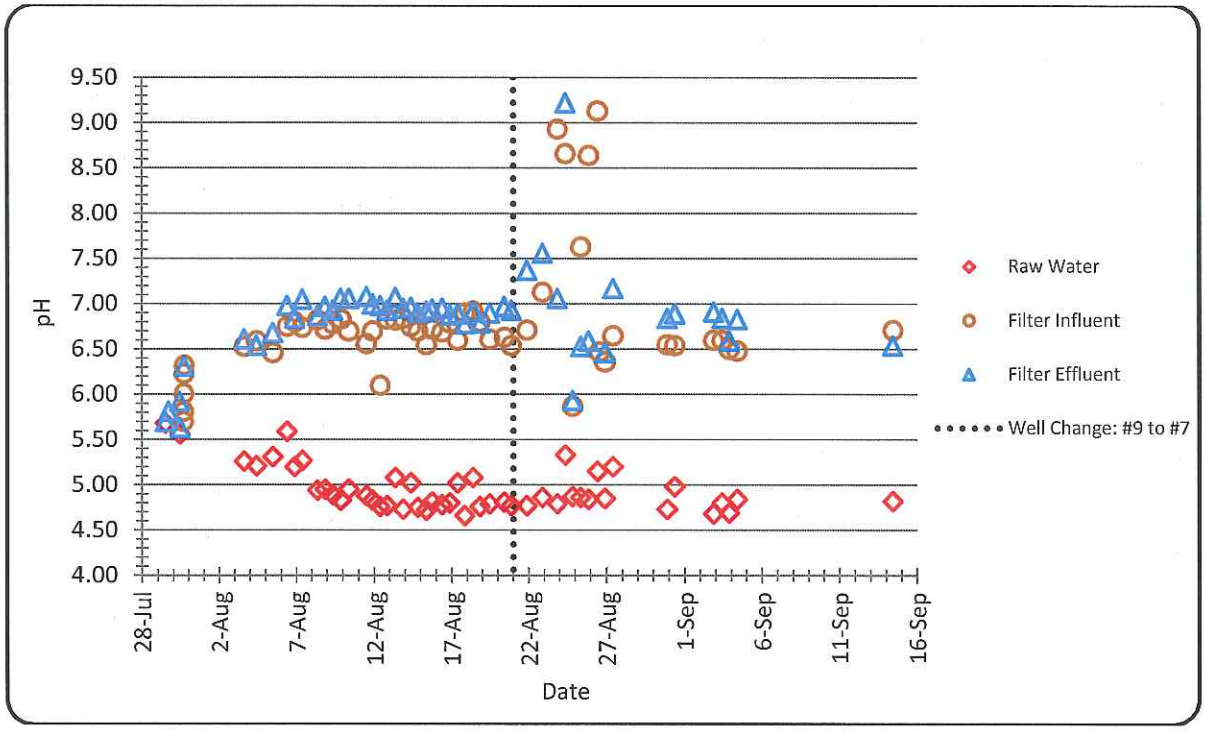
Figure 4.6. Iron Removal



Note: All filter effluent lab confirmation samples collected (8) with the exception of one was below the MDL of 0.100 mg/L so they were not included in the figure above for clarity.

The pH of the raw water was very low for a ground water, with a field average of 4.98 for Well #9 and 4.89 for Well #7. As a result, in order to prevent the HMO particulate from dissolving in the raw water, the pH was adjusted to above 6.3 to ensure radium and manganese removal was achieved. The pH adjustment was made by adding sodium hydroxide to the HMO feed tank – see the chemical feed section (section 4.5) for more on the NaOH addition. The pH adjustment started on day two of the pilot on 7/30/15. The filter influent pH from 7/30/15 to the end of the filter runs on 9/14/15 averaged 6.77. The pH held fairly steady through the filter as the effluent pH averaged 6.88 over the course of the pilot. Periodic fluctuations observed in the filter influent and effluent samples were the result of the HMO pump running dry, losing prime or a change in chemical feed solution strength. These events were short lived relative to the length of the pilot study as shown in Figure 4.7 below.

Figure 4.7. pH Trends



A raw water sample from Well #9 was collected and sent to the lab for analysis of total hardness, total alkalinity, sulfide and ammonia in order to predict what other steps may be required to prepare this water source for treatment and discharge into the distribution system once a full-scale system is in place. The total hardness of 34 mg/L as $CaCO_3$ and total alkalinity of 5.4 mg/L as $CaCO_3$ were not unexpected considering the very low raw water pH levels observed. No effluent analyses were performed for these constituents so final water suitability could not be determined. However, given the low pH, hardness (calcium) and alkalinity of the raw water sources, pH and/or alkalinity adjustments will be necessary to stabilize the corrosivity of the water prior to discharge into a distribution system. This can be achieved by increasing the pH of the treated water by adding a base such as sodium hydroxide or lime or increasing the alkalinity with the addition of soda ash.

The sulfide and ammonia levels were assessed in order to determine if additional oxidant (sodium hypochlorite) demand would exist in the system. Both of the constituent's levels were below the lab's MDLs of 0.2 mg/L and 0.59 mg/L, respectively, in the single sample collected from Well #9. From these results, no significant oxidant demand would be expected. The chlorine demand in this water source was in agreement with these results – see section 4.5 for more on chemical demand and dosaging.

4.5 Chemical Feed

The pilot chemical feed systems consisted of sodium hypochlorite followed by HMO with sodium hydroxide addition immediately before the filter. The sodium hypochlorite was added to oxidize the raw water iron and to maintain a charge on the HMO particulate so it could contact oxidize the raw water manganese and effectively adsorb the radium.

Table 4.4. Chemical Feed Summary

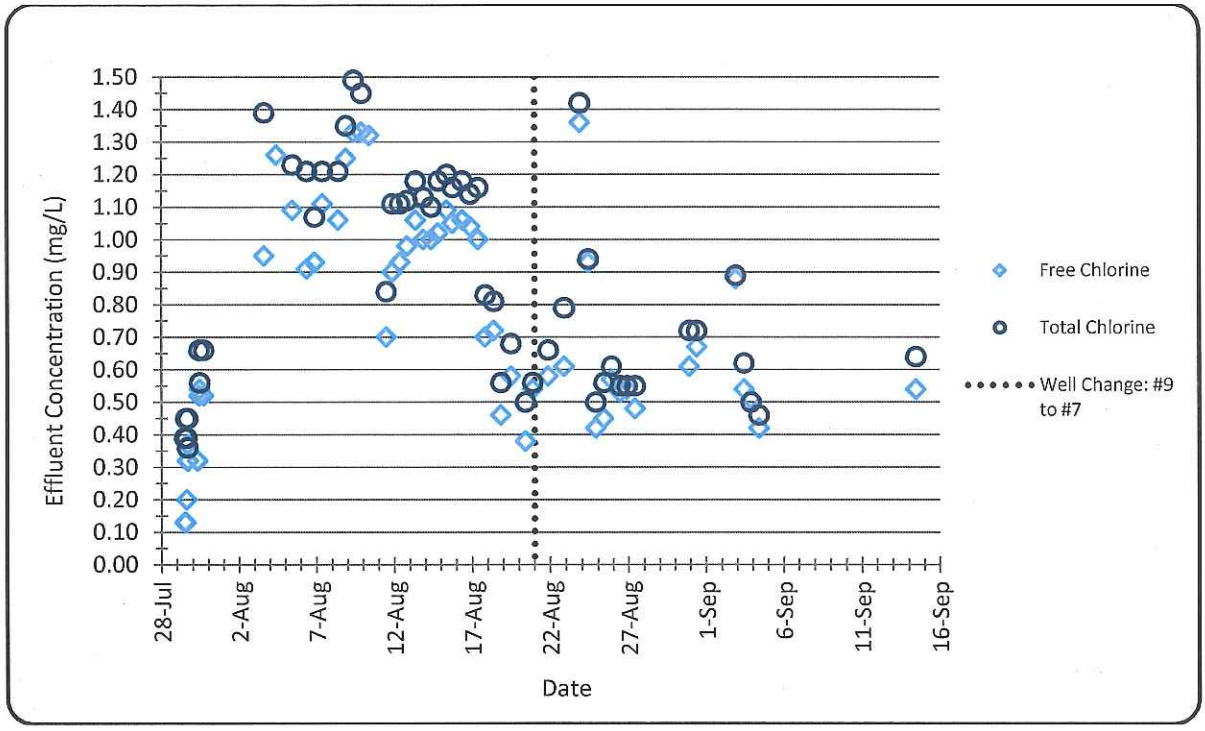
Chemical	Dosage (mg/L)	Free Chlorine (mg/L)	Total Chlorine (mg/L)
NaOCl	1.1-5.7* (W9 Final = 5.7 W7 Final = 2.2)	0.13-1.36 (0.75 avg)	0.36-1.70 (0.89 avg)
HMO (as Mn)	0.044-1.475 (0.838 avg)		
NaOH (in the HMO)	20*		

*Values calculated from chemical feed strength and feed pump settings.

Sodium hypochlorite (NaOCl) was added at a calculated concentration of between 1.1 mg/L and 5.7 mg/L throughout the pilot. Early anticipated dosages proved to be too low so the dosage progressively increased as the pilot progressed while running Well #9. The final dosage was calculated at 5.7 mg/L. Once the switch to Well #7 was made, the previous dosage of 5.7 mg/L resulted in a higher than desirable free chlorine concentration so the feed was adjusted down. The final free chlorine concentration was 2.2 mg/L. The higher concentration calculated for Well #9 operation does not match the expected demand, based on the known water quality. However, the calculated sodium hypochlorite concentrations have historically been high in pilot studies. The higher calculated dosages versus actual applied concentrations are likely due to the stock solutions being weaker than reported as well as variability in chemical feed pump outputs. Neither the hypochlorite stock solution strength nor chlorine pump performance were verified during the pilot study.

The sodium hypochlorite was fed at a rate necessary to achieve a free chlorine residual of between 0.5 and 1.0 mg/L. This range ensured complete oxidation of iron, maintained the charge on the HMO, and prevented any biology from developing in the filter. The total chlorine levels were very close to the free chlorine levels as shown in Figure 4.8 below. This is indicative that there were very little, if any, chloramines or other undesirable chlorinated compounds that were forming from the point of injection to the filter effluent.

Figure 4.8. Filter Effluent Free and Total Chlorine Trends



The HMO (manganese dioxide) fed to the raw water adsorbs the radium 226 and 228 in the water and allows for these contaminants to be filtered along with the HMO particulate. As a result, manganese removal was used as a surrogate to measure radium removal performance. That is, as long as the HMO was fed at the appropriate rate and the filter removed the manganese, the radium was presumed to be removed as well. A dilute HMO stock solution was fed immediately after the sodium hypochlorite addition to maintain a filter influent manganese concentration of ~1.0 mg/L. It is Tonka Water's experience that an HMO dosage of 1.0 mg/L (as Mn) typically achieves 80%+ radium removal - literature supports these findings. The actual HMO concentration fluctuated throughout the pilot study (see Table 4.4 and Figure 4.1) due to the inherent variance in the sampling procedure and a few instances where either the HMO pump lost prime or the HMO tank was empty. Nevertheless, the average filter influent manganese concentration over the pilot period was 0.984 mg/L according to field analyses and 0.917 mg/L based on lab testing. No optimization was performed during this pilot study because of time and analytical constraints. Radium analyses and reporting takes approximately 40 days so real-time feedback on radium removal versus HMO dosage could not be assessed. The HMO optimization can be done on the full-scale system over an extended period of time once a baseline performance is established.

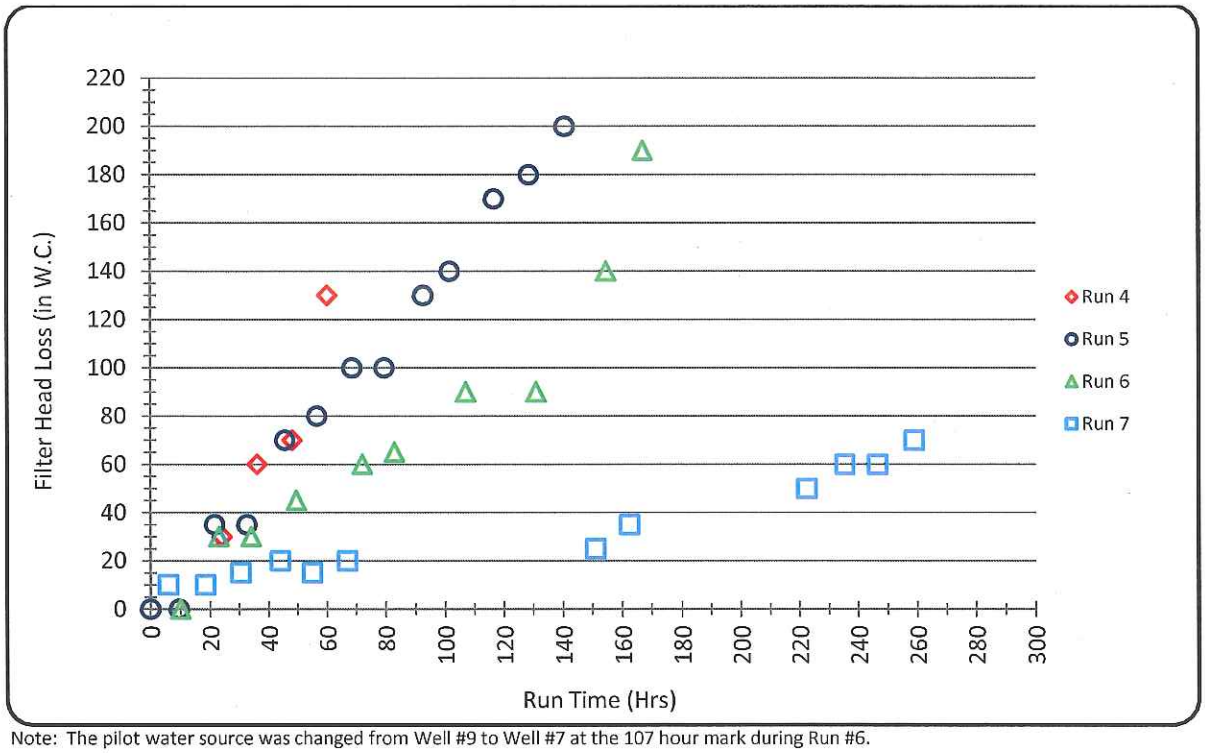
The filter was not removing manganese at startup of the pilot. It wasn't until the second day that it was determined that the lower pH was dissolving the HMO and allowing free manganese through the filter. As a result, sodium hydroxide (NaOH) was added to the HMO tank to move the raw water pH up to above 6.3 to prevent dissolution of the manganese. Late in the day on

7/30/15 the pH of the HMO solution was gradually increased until the HMO feed brought the raw water pH above 6.3. Thereafter, manganese removal to below 0.05 mg/L was observed. The final dosage of NaOH necessary to elevate the pH and ensure that the system operates at a pH of above 6.3 was calculated to be ~20 mg/L. The filter influent pH ranged between 6.6 and 7.0 during the period after the NaOH feed was established with the exception of a few instances in late August where there was an unexplainable rise in pH.

4.6 Filter (and GAC Column) Head Loss and Filter Run Times

At the time of every field sample, the filter and GAC column head loss levels were monitored and recorded. The filter was continuously loaded with iron and manganese (HMO) solids so the head loss grew with each sample, as expected, before reaching a final head loss of 200 inches of water column and was shutdown and backwashed. The filter's starting head loss was < 20 inches after a backwash. There were eight (8) individual filter runs over the course of the pilot. The filter head loss versus run time plot is shown in Figure 4.9 below for the runs performed after the chemical feed had been optimized and the runs were well enough established to provide sufficient data to discern head loss versus run time trends.

Figure 4.9. Filter Head Loss vs. Run Time



Note: The pilot water source was changed from Well #9 to Well #7 at the 107 hour mark during Run #6.

As the run data shows, the filter head loss is highly linear with run time. The early runs experienced a much higher rate of head loss development than the later runs. This is likely due to a few factors. First, the earlier runs had not been subjected to as many backwashes as the later runs. Backwashing the filter gradually removes very small media fragments, commonly

referred to as "fines", from the filter bed. These fines naturally fill the small void spaces between the filter media which leads to a "tighter" filter. The restricted void space equates to greater resistance to flow as well as having less places for solids to move to through the depth of the filter. As a result, the filter plugs faster. However, with each proceeding backwash more of these fines are removed, thereby reducing the filter resistance and increasing the filter's ability to achieve depth filtration.

Secondly, the iron loading on the filter during the earlier runs was much more significant than with early runs – see Figure 4.6. As a result, the filter would plug faster than during the later portion of the pilot when the filter experienced very low iron levels. A reduction in Well #9's iron levels was observed through the first few runs. The rapid reduction in head loss development observed been Runs 6 and 7 is likely due to the change in wells (from #9 to #7) late in Run 6. Well #7 had very low iron in comparison to Well #9 – see Figure 4.6. The average HMO solids loading from run to run were very similar so there should have been no significant effect on the head loss change associated with the HMO feed.

All of the filter runs after the initial run were terminated due to high head loss and not contaminant (manganese or iron) breakthrough. As described above, the rate of the head loss development decreased with each run and as a result, each new run would run longer before the high head loss mark of 200 in. W.C. was achieved. The four runs above had filter run times of approximately 74, 140, 167 and 259 hours, respectively.

The GAC column was loaded with very low solids water (filter effluent) over the duration of the pilot study. Consequently, no head loss was reported until the very last day of testing, approximately 10 weeks after commissioning of the pilot. Therefore, the GAC column was not backwashed beyond the initial backwash prior to commissioning to clean the GAC media.

4.7 Filter Backwash

The filter was backwashed before the start of pilot as well as after each completed run. The backwash was conducted using the parameters detailed in Table 3.1. Each filter backwash created approximately 23 gallons of water that was collected in a waste tank for waste treatment testing. The protocol called for a sample from each backwash to be collected, sampled and analyzed for radium and gross alpha. However, rather than the backwash waste being collected, the backwash supply water (GAC effluent) was collected. Thus, the radionuclide activity of the backwash waste after each run could not be assessed during the pilot. Fortunately, the filter column was not backwashed before being returned to Tonka Water's facility so the column was backwashed and the waste collected, sampled and sent out for radionuclide analyses. The results of the backwash sample analysis are presented in Table 4.5.

Table 4.5. Backwash Waste Sample Analysis

Fe (mg/L)	Mn (mg/L)	Ra226 (pCi/L)	Ra228 (pCi/L)	Gross Alpha (pCi/L)
1.5	6.000	19.6	21.1	35.8

As described below, the results of the backwash waste were much lower than anticipated based on a material balance for a 115 hour filter run on Well #7. The combined radium levels were 40.7 pCi/L while the iron and manganese concentrations were only 1.5 mg/L and 6.00 mg/L, respectively. Using the average iron, manganese and radium raw water and effluent levels collected during the pilot's operation with Well #7, along with the average HMO dosage of 1.057 mg/L (as Mn) for the same period, we would have expected approximately 6 mg/L of iron, 340 mg/L of manganese and 540 pCi/L in the backwash waste after an approximate 115 hour filter run. Given the much lower than expected results, there could only be one of two explanations. First, the column was backwashed sometime after the 115 hours of run time and not noted in the field log or the HMO chemical feed was not on during most of the last run.

If the column had gone through a backwash prior to the column being returned to Tonka Water the contaminant levels in the second backwash would have been very low, as we observed in the laboratory results. On the other hand, had the chemical feed not be operated properly or the HMO tanks allowed to run dry then we would expect to see low manganese and radium levels in the backwash waste, as observed. The only field sample reported during the final run showed that there was no additional manganese (HMO) in the filter influent. The laboratory results showed that nearly none of the raw radium had been captured through the filter, supporting the possibility that the HMO was not being fed at that time or possibly at all during this final run. Finally, the last noted chemical (HMO and chlorine) preparation had taken place 11 days prior to the final field sample; however, the volume prepared (5 gallons) could only sustain ~48 hours of operation. Unfortunately, we cannot confirm either scenario; however, given the evidence provided by the field data, it would seem the second scenario is more likely.

The projected radionuclide activities in the captured solids and filter backwash are provided in Tables 4.6 and 4.7 based on the average radium removal performance during the operation of Well #9 and Well #7 and the noted backwash parameters.

Table 4.6. Projected Filter Backwash Radium Activity - Well #9

Filter Run Time (Hours)	Filter Combined Radium Activity (pCi)	Backwash Combined Radium Activity (pCi/L)
4	4,378	51
8	8,756	103
12	13,134	154
24	26,268	308
48	52,536	617
100	109,451	1,285
150	164,176	1,928
200	218,902	2,570
250	273,627	3,213

Note: Calculations based on the Well #9 raw water average combined radium of 5.75 pCi/L and an average filter effluent of 1.16 pCi/L.

Table 4.7. Projected Filter Backwash Radium Activity – Well #7

Filter Run Time (Hours)	Filter Combined Radium Activity (pCi)	Backwash Combined Radium Activity (pCi/L)
4	1,593	19
8	3,186	37
12	4,779	56
24	9,557	112
48	19,115	224
100	39,822	468
150	59,733	701
200	79,644	935
250	99,555	1,169

Note: Calculations based on the Well #7 raw water average combined radium of 2.61 pCi/L and an average filter effluent of 0.94 pCi/L.

4.8 Waste Treatment

A critical part of the pilot study was to determine if the precipitated manganese (HMO) in the backwash waste could be effectively re-dissolved in order to re-solubilize the radium before discharge to the sewer system. Previous Tonka Water pilots had utilized sodium metabisulfite to maintain manganese in solution. The dissolution of manganese solids with sodium metabisulfite was found to be more rapid than with citric acid and without the pH issues associated with a reducing acid. In order to determine the effectiveness of re-dissolving the manganese solids, the backwash waste was collected in a large tank and samples drawn for testing with a reducing agent, sodium metabisulfite. The samples were dosed with the

metabisulfite to try and change the precipitated manganese dioxide back into the dissolved manganese form and return the adsorbed radium back into solution. Bench-scale testing at Tonka Water's facility prior to the pilot study determined that a dose of 0.5% by weight SBS (or ~2.5 grams in 500 mL) added to a 3% HMO mixture effectively re-dissolved the manganese solids. Therefore, this dosage was applied to the backwash waste from the pilot study. The results showed that after 4 hours the backwash samples went from a dark brown to a clear yellow color and the manganese solids were no longer observed in the sample.

To confirm the onsite field results, the backwash waste from the final backwash conducted at Tonka Water's facility was tested using both 0.5% and 0.1% sodium metabisulfite concentrations. As with the onsite testing, the manganese solids re-dissolved in a 4-hour period in both samples but a slight yellow color remained. The color dissipated when the samples were allowed to settle overnight. The solids appeared to be a granular substance, most likely fine sand/silt from the filter or well(s). This fine sand/silt appears to be the source of the color in the sample as the yellowish color re-emerges when the sample is swirled and the particulate re-suspended.

As a final step to ensure that all the manganese (HMO w/ radium) solids were being re-dissolved with the metabisulfite addition, an excessive amount of metabisulfite was added to the 0.5% sample and allowed to sit overnight. After the lengthy soak, the sample was re-examined and there was no noticeable change in the sample's appearance in comparison to the 0.5% and 0.1% samples at the 4 hour mark, indicating that there was little or no remaining precipitated manganese dioxide (or iron) in the sample. The photos below show the backwash composite sample immediately before the metabisulfite was added (exhibit a), 10 minutes after the 0.5% metabisulfite addition (exhibit b), after 4 hours (exhibit c) and overnight (12+ hours, exhibit d). The final photo shows the 0.5% and 0.1% metabisulfite samples side-by-side after 12+ hours (exhibit e). Finally, the last photo shows the granular material at the bottom of the 0.5% sample after settling (exhibit f).

Figure 4.10. Backwash Waste Treatment Testing Photos

(a) Backwash Waste

(b) 0.5% $Na_2S_2O_5$ after 10 minutes


(c) 0.5% $Na_2S_2O_5$ after 4 hours

(d) 0.5% $Na_2S_2O_5$ after 12+ hours

(e) 0.5% (L) and 0.1% (R) after 12+ hours

(f) Granular material in settled sample

4.9 Filter Media

Once the pilot study was complete and the equipment returned to Tonka Water, a final backwash was performed to clean the media and to collect a backwash waste sample. The column was then disassembled and a sample of the media collected and sent to a laboratory for radionuclide analysis. The results of the filter media analysis showed that the residual combined radium on/in the filter media was very low. The Ra226 levels were 0.38 pCi/g while the Ra228 levels were 0.75 pCi/g for a total combined radium of 1.13 pCi/g. This level is below the EPA's general landfill disposal guideline of 3.0 pCi/g of radium or less. Additional backwashing of the filter material would likely have removed more of the residual manganese solids, and as a result, further reduced the radium activity. The filter media testing laboratory report can be found in Appendix B.

5 Conclusions

- HMO addition of 1 mg/L (as Mn) followed by filtration at 3 gpm/ft^2 effectively and consistently removes combined radium (Ra226+Ra228) to below the MCL of 5.0 pCi/L. The overall average filter effluent combined radium activity was 1.04 pCi/L over the course of the pilot.

- As a result of effective radium removal, the filter is capable of significantly reducing the gross alpha levels in the filter effluent to well below the MCL of 15.0 pCi/L. The overall average filter effluent gross alpha activity was 1.39 pCi/L.

- Sodium hypochlorite followed by HMO and NaOH addition and filtration effectively removes manganese from the raw water to levels below the SMCL of 0.05 mg/L. The overall average filter effluent manganese concentration was 0.034 mg/L over the course of the pilot study.

- Granular activated carbon operated with at least 7 minutes of empty bed contact time effectively removed TCP and TCE to levels below the laboratory detection limits of 0.00458 µg/L and 0.32 µg/L, respectively from Well #7. The treated TCE levels are well below the USEPA MCL of 5.0 µg/L and the New Jersey MCL of 1.0 µg/L.

- The TCP and TCE removal profile through the first 21 inches of the GAC depth was consistent throughout the nearly 10 weeks of piloting. As a result, the capacity of the GAC for the TCP and TCE could not be determined. However, it is anticipated that the GAC run times will far exceed the 10 weeks demonstrated over the pilot study.

- Sodium hypochlorite fed at a maximum of 5.7 mg/L is sufficient to oxidize the iron, keep a charge on the HMO to facilitate radium removal while maintaining a free chlorine residual of 0.5-1.0 mg/L through the filter for the purposes of preventing biological growth. The actual applied sodium hypochlorite dosage is likely lower as the water chemistry suggests the actual chlorine demand to be in the range of 1.0-2.0 mg/L for both Wells #9 and #7.

- HMO dosed at 1.0 mg/L is sufficient to remove combined radium and gross alpha to well below the respective MCLs of 5.0 pCi/L and 15.0 pCi/L. Lower HMO feed rates would likely be effective at reducing the combined radium to below the MCL; however, optimization of the HMO dose was not performed during this pilot.

- Sodium hydroxide added at approximately 20 mg/L will raise the pH of Wells #9 and #7 to above 6.3 before filtration. Additional NaOH may be necessary to further stabilize the corrosivity of the water before discharging to distribution. Water stability testing was not included as part of this pilot study.

- Filter head loss developed linearly as expected throughout each run performed during the pilot. Furthermore, the rate at which the filter developed was proportionate to the level of raw water iron. In addition to the higher level of iron, the early runs would have developed head loss faster as a result of the filter having more media "fines" within the bed. With each backwash the fines will gradually backwash out of the column and the effects on the head loss with diminish. Using one of the later runs in the pilot study (Run 7 from Figure 4.9), the filter is projected to run beyond the one week maximum recommended by Tonka Water. Tonka Water recommends that the filter be backwashed at least once per week to maintain filter performance.

- The filter runs were terminated due to high head loss and not contaminant breakthrough on all eight (8) runs. As discussed, the run lengths increase with each run as a result of lower solids loading. Run 7 lasted approximately 260 hours before it was backwashed to start a new run. Again, Tonka Water does not advise running a filter more than a week between backwashes. Therefore, one backwash per week is easily attainable while operating either well under the piloted conditions.

- The manganese dioxide (HMO) and iron in the backwash waste can be re-solubilized with sodium metabisulfite at a concentration of 0.1% or higher when given at least 4 hours to react. The dissolution of the HMO solids will put the radium back into solution for discharge into the sewer system. Effective dissolution of the manganese and iron may occur at lower metabisulfite concentrations than 0.1%; however, optimization of the waste treatment was not performed during this pilot study.

- The results of the backwash waste analysis were not representative of normal backwash waste; and therefore, were unable to confirm the levels projected by field and laboratory results collected during piloting.

- The filter media residual combined radium levels were insignificant after the approximately 10 weeks of operation. The total combined radium on/in the filter media was 1.13 pCi/g, a level below the general EPA guideline for conventional landfill disposal of 3.0 pCi/g or less. In the full scale system, extended backwashing can be utilized at the time of the material disposal to minimize the radium activity on the filter material before it is extracted from the vessels and disposed of in a landfill.

6 Recommendations

- The full-scale process to removal combined radium (Ra226 + Radium 228) and manganese should include sodium hydroxide, sodium hypochlorite and HMO addition followed by filtration.

- The filter should be designed for a surface loading rate of 3.0 gpm/ft^2 and bedded with 30 inches of Tonka Water's IMAR™ filter media to maximize removals and while minimizing radium accumulation.

- The filter system should include a simultaneous air/water backwash system (Tonka Simul-Wash™) to thoroughly clean the filter media during each backwash so as to minimize the radium accumulation in the filter media. Furthermore, the Simul-Wash™ uses sub-fluidization water rates in combination with air to vigorously clean the filter media; thereby, reducing backwash waste volumes by up to 50% when compared to conventional backwash methods.

- The sodium hydroxide injection system should be sized to deliver 20 mg/L of sodium hydroxide, at minimum, in order to adjust the raw water pH to above 6.5 for effective manganese (and radium) removal as well as to meet EPA secondary standards. If further stabilization of the filter effluent is required, the feed system should be sized accordingly.

- The sodium hypochlorite feed system should be sized to deliver at least 5.7 mg/L of sodium hypochlorite so as to meet chlorine demand and provide up to 1 mg/L of free chlorine residual. Although the feed system should be capable of these levels, it would be advisable

to minimize the free chlorine in the filter effluent since the water will proceed to additional treatment through the GAC system. The GAC system will de-chlorinate the water so maintaining a free chlorine residual through the filter process in excess of what is required to achieve full metals oxidation, maintain HMO charge and prevent biological activity in the filter provides no extra benefit and will only result in wasted hypochlorite. Therefore, it is recommended that the free chlorine residual through the filter be set high enough to measure with field test equipment yet low enough to minimize hypochlorite wasted. A target residual of around 0.3 mg/L is advisable.

- The HMO feed system (TonkaBlend™) should be sized to deliver at least 1 mg/L of HMO (as Mn) to meet the pilot performance for radium and gross alpha removal. A dosage lower than 1 mg/L of HMO (as Mn) may still allow you to achieve effluent radium and gross alpha goals. However, Tonka Water does not recommend optimization of this chemical feed until a baseline performance is well established.

- There should be a means of delivering sodium metabisulfite to the backwash waste storage tank to achieve a maximum concentration of 0.1% in the full-scale system. The metabisulfite will resolubilize the HMO (and iron) and return the radium to solution before discharge to the sewer system.

- The full-scale process to remove TCP and TCE should consist of adsorption with GAC (after pre-filtration for metals removal). The GAC column should provide for a minimum of 10 minutes of empty bed contact time with a minimum surface loading rate of 1.85 gpm/ft^2. Higher EBCTs would provide for longer durations between GAC change outs. An ideal design surface loading rate for the GAC system is 3-5 gpm/ft^2.

- The GAC used in the TCP and TCE adsorption system should be steam activated, coal based material having an effective size of 0.8-1.0 mm and a U.C. < 2.1 to ensure the same adsorption kinetic and hydraulic performance as the material used during the pilot.

- Tonka Water will provide more design specific recommendations separate from this pilot study report.

7 Appendices

APPENDIX A

Field Data Logs

TONKA WATER - FIELD DATA LOG (TOTAL COMPILED)

Pilot: Moorestown, NJ (PL15023)
Filter A - IMAR (8")
Flow rate @ 3 gpm/ft² is 1.05 GPM

Date; Time	Run Time (Hrs)	RAW WATER				PRE-FILTER (Post Chem.)		FILTER EFFLUENT - IMAR							GAC COLUMN		FILTER BACKWASH	Notes (pump settings, lab samples, when chemical feedstocks are made- time & mix quantities, start stop times, backwashes, etc.)
		pH	Temp	Fe	Mn	pH	Mn (HMO)	pH	Fe	Mn	Flow	Free Cl2	Total Cl2	Delta P	Flow	Delta P	pH	
7/29/15 10:00																		Both the filter and GAC column was backwashed
7/29/15 10:45																		System started; chlorine batch created: 138.6 mL in 5 gals distilled water; Cl2 pump @ 50x50
																		HMO batch created: 191.2 mL in 5 gals distilled water; HMO pump to 50x50
7/29/15 11:20	0.58	5.68	19.2	2.83	0.348		0.810	5.7	0.06	0.333	1.05	0.13	0.39	0	0.37	0		
7/29/15 12:00																		chlorine pump to 85x85
7/29/15 13:10	2.42						0.844			0.184	1.05	0.13	0.45		0.37			
7/29/15 14:15																		chlorine pump to 100x100
7/29/15 14:30	3.75						0.802			0.161	1.05	0.2	0.39		0.37			
7/29/15 15:40							0.788		0.00	0.174	1.05	0.32	0.36		0.37			chlorine pump still at 100x100
7/29/15 16:00	5.58							5.81	0.00	0.161	1.05	0.37	0.45	0		0		
7/29/15 17:00										0.16	1.05	0.32			0.37			
7/30/15 7:00										0.154	1.05	0.32			0.37			Ran Overnight
7/30/15 8:00																	5.92	Started backwash of IMAR filter; membrane filters tear before filter;
																		digital scale not working - estimated 2.5 g SBS into backwash water
																		unfiltered BW water: Fe = 4.44, Mn = 4.87; After 15 mins - no color change; after 30 mins - no change
7/30/15 8:45																		Started new run; created new chlorine batch: 277.2 mL in 5 gals distilled water; pump @ 80x80
7/30/15 9:30	0.75						0.877	5.92		0.161	1.05	0.52	0.66					
7/30/15 10:15		5.56	18.7	1.97	0.235		0.885	5.63	0.00	0.14	1.05	0.54	0.56	0	0.37	0		
7/30/15 15:40						5.7												ADDED 50 GRAMS OF CAUSTIC TO HMO FEED; post chemical feed pH = 5.70
7/30/15 15:55						5.81												ADDED 30 GRAMS OF CAUSTIC TO HMO FEED (80 total); post chemical feed pH = 5.81
7/30/15 16:15						6.01	0.946											ADDED 30 GRAMS OF CAUSTIC TO HMO FEED (110 total); post chemical feed pH = 6.01
7/30/15 16:25						6.23	0.942	6.31		0.041	1.05	0.52	0.66	0	0.37	0		ADDED 30 GRAMS OF CAUSTIC TO HMO FEED (140 total); post chemical feed pH = 6.23
7/30/15 16:45						6.32												ADDED 20 GRAMS OF CAUSTIC TO HMO FEED (160 total); post chemical feed pH = 6.32
						6.45				0.02								ADDED 30 GRAMS OF CAUSTIC TO HMO FEED (190 total); post chemical feed pH = 6.45
7/30/15 17:22																		ADDED 30 GRAMS OF CAUSTIC TO HMO FEED (220 total); well pump quit
8/3/15 14:40		5.26	18.3	1.55	0.199	6.53	0.692	6.61	0.04			0.95	1.39				6.62	
8/4/15 10:00		5.21	17.1	1.86	0.196	6.59	0.800	6.54	0.00	0.016		1.26	1.7				7.04	
8/5/15 11:00		5.31	17.5	1.58	0.182	6.46	0.610	6.68	0.02	0.005	1.05	1.09	1.23		0.37	0	7.11	
8/5/15 16:30																		Filter backwash
8/6/15 9:00	16.5	5.59	16	1.64	0.183	6.75	0.904	6.98	0.00	0.009	1.05	0.91	1.21	50	0.37	0	7.4	Mixed new chlorine: 277.2 mL in 5 gallons water; HMO: 220 gr NaOH + 191.2 mL NaOCl in 5 gals
8/6/15 21:00		5.2	16	1.22	0.181	6.8	0.946	6.84	0.00	0.013	1.05	0.93	1.07	20	0.37	0	7.26	
8/7/15 9:00	40.50	5.27	16.5	1.08	0.182	6.74	1.026	7.05	0.00	0.003	1.05	1.11	1.21	130	0.37	0	7.27	
8/7/15 21:00																		Filter backwashed
8/7/15 21:30																		New Run started

8/8/15 9:00		4.94	16.9	0.9	0.18	6.82	0.852	6.87	0.00	0.004	1.05	1.06	1.21	25	0.37	0	6.93	
8/8/15 21:00	24.00	4.95	15.5	0.84	0.193	6.72	0.849	6.97	0.00	0.001	1.05	1.25	1.35	30	0.37	0	6.89	Mixed new chemical: chlorine: 277.2 mL in 5 gals; HMO: 220 gr NaOH + 191 mL HMO
8/9/15 9:00	36.00	4.89	16.2	0.73	0.176	6.78		6.93	0.00	0.007	1.05	1.33	1.49	60	0.37	0	7.01	
8/9/15 14:00																		Mixed HMO: 220 gr NaOH + 191.2 mL HMO
8/9/15 21:00	48.00	4.83	15.7	0.69	0.184	6.83	0.680	7.06	0.02	0	1.05	1.33	1.45	70	0.37	0	6.92	
8/10/15 9:00	60.00	4.95	16.5	0.7	0.177	6.7	0.802	7.06	0.00	0.007	1.05	1.32	1.53	130	0.37	0	7.08	
8/11/15 11:00	74.00																	Filter Backwash
8/11/15 11:30	0.00	4.88	18.5	0.45	0.181	6.66	0.638	7.08	0.09	0.013	1.05	0.7	0.84	0	0.37	0	7.06	Started new run; mixed new chemicals: chlorine = 221.76 mL in 4 gals; HMO = 191 mL + 220 gr NaOH
8/11/15 21:00	9.50	4.83	16.9	0.45	0.183	6.7	0.690	7	0.07	0	1.05	0.9	1.11	0	0.37	0	7.02	
8/12/15 9:00	21.50	4.76	16.5	0.39	0.183	6.1	0.710	6.98	0.00	0.001	1.05	0.93	1.11	35	0.37	0	7.02	Mixed new chemicals: chlorine = 277.2 mL in 5 gallons; HMO = 191.2 mL + 220 gr NaOH in 5 gals
8/12/15 20:00	32.50	4.77	16.1	0.5	0.172	6.83	1.096	6.93	0.07	0.002	1.05	0.98	1.12	35	0.37	0	6.95	Mixed new HMO: 191.2 mL + 220 gr NaOH in 5 gals
8/13/15 9:00	45.50	5.08	16.2	0.37	0.171	6.82	1.024	7.07	0.00	0	1.05	1.06	1.18	70	0.37	0	7.07	
8/13/15 21:00	56.50	4.73	15.96	0.34	0.18	6.84	1.358	6.95	0.00	0.002	1.05	1	1.13	80	0.37	0	6.85	
8/14/15 9:00	68.50	5.02	16.1	0.31	0.184	6.75	1.304	6.96	0.00	0.003	1.05	1	1.1	100	0.37	0	6.96	Mixed new chemicals: chlorine = 166.32 mL in 3 gals water; HMO = 191.2 mL + 220 gr in 5 gals
8/14/15 20:00	79.50	4.75	16.4	0.3	0.173	6.7	1.200	6.9	0.02	0.004	1.05	1.02	1.18	100	0.37	0	6.8	
8/15/15 9:00	92.50	4.72	17.3	0.3	0.179	6.55	1.264	6.92	0.00	0.002	1.05	1.09	1.2	130	0.37	0	6.89	Mixed chemicals: chlorine = 221.76 mL in 4 gals; HMO = 262.68 mL + 308 gr in 7 gals
8/15/15 18:00	101.50	4.81	16.9	0.32	0.175	6.72	0.702	6.94	0.00	0.003	1.05	1.05	1.16	140	0.37	0	6.88	
8/16/15 9:00	116.50	4.78	17.1	0.31	0.176	6.69	0.804	6.95	0.00	0.002	1.05	1.06	1.18	170	0.37	0	6.87	Mixed chemicals: chlorine = 221.76 mL in 4 gals; HMO = 262.68 + 308 gr NaOH in 7 gals
8/16/15 21:00	128.50	4.8	16.2	0.21	0.175	6.79	1.100	6.88	0.00	0.003	1.05	1.04	1.14	180	0.37	0	6.87	
8/17/15 9:00	140.50	5.02	16.9	0.23	0.176	6.6	0.890	6.89	0.00	0.008	1.05	1	1.16	200	0.37	0	6.86	Mixed chemicals: chlorine = 221.76 mL in 4 gals; HMO = 344.16 mL + 396 gr NaOH in 9 gals
8/17/15 9:30																		Filter Backwash
8/17/15 10:00																		Started New Run
8/17/15 20:00	10.00	4.66	16.6	0.26	0.182	6.9	0.634	6.78	0.00	0.004	1.05	0.7	0.83	0	0.37	0	6.75	
8/18/15 9:00	23.00	5.08	16.7	0.23	0.173	6.92	1.016	6.92	0.00	0.007	1.05	0.72	0.81	30	0.37	0	6.93	Mixed chemicals: chlorine = 166.32 mL in 3 gals; HMO = 191.2 mL + 220 gr NaOH in 5 gals
8/18/15 20:00	34.00	4.76	16.3	0.16	0.178	6.8	1.356	6.79	0.00	0	1.05	0.46	0.56	30	0.37	0	6.88	
8/19/15 11:30	49.50	4.79	17	0.12	0.169	6.61	1.230	6.9	0.04	0	1.05	0.58	0.68	45	0.37	0	6.92	
8/20/15 10:00	72.00	4.81	17.9	0.14	0.171	6.63	1.520	6.97	0.04	0.009	1.05	0.38	0.5	60	0.37	0	6.96	Mixed chemicals: chlorine = 277.2 mL in 5 gals; HMO = 267.68 mL + 308 gr NaOH in 7 gals
8/20/15 21:00	83.00	4.77	16.9	0.26	0.18	6.54	1.560	6.93	0.26	0.004	1.05	0.54	0.56	65	0.37	0	6.92	
8/21/15 21:00	107.00	4.77	16.2	0.15	0.118	6.71	1.326	7.37	0.00	0.001	1.05	0.58	0.66	90	0.37	0	6.94	Mixed chemicals: chlorine = 277.2 mL in 5 gals; HMO = 267.68 mL + 308 gr NaOH in 7 gals
																		CHANGED WELL FROM #9 TO #7 (Before sampling?)
8/22/15 21:00	131.00	4.88	16.3	0.07	0.129	7.13	0.800	7.56	0.13	0.014	1.05	0.61	0.79	90	0.37	0	7.27	
8/23/15 20:30	154.50	4.79	15.7	0.09	0.119	8.93	1.524	7.06	0.00	0.008	1.05	1.36	1.42	140	0.37	0	9.06	HMO/NaOH tanks ran dry overnight (pump ran dry). Tanks refilled before sampling.

																		Mixed chemicals: chlorine = 443.52 mL to 8 gals; HMO = 382.4 mL + 440 gr NaOH to 10 gals
																		Turned chlorine feed pump from 60% down to 55% then to 50%.
8/24/15 9:00	167.00	5.33	15.7	0	0.131	8.66	1.168	9.22	0.00	0.012	1.05	0.93	0.94	190	0.37	0	7.89	
8/24/15 13:30																		Lab Sample collected and then Filter Backwash
8/24/15 14:30																		Started New Run
8/24/15 20:30	6.00	4.87	16.5	0.05	0.126	5.87	0.336	5.93	0.06	0.002	1.05	0.42	0.5	10	0.37	0	6.91	Mixed chemicals: chlorine = 277.2 mL in 5 gals; HMO = 191.2 mL + 220 gr NaOH in 5 gals
8/25/15 9:00	18.50	4.86	16.6	0	0.044	7.63	1.126	6.53	0.00	0.01	1.05	0.45	0.56	10	0.37	0	6.6	HMO/NaOH pump was not pumping - bled air and adjusted pump rate.
8/25/15 21:00	30.50	4.84	15.8	0.03	0.13	8.64	1.216	6.59	0.02	0.004	1.05	0.57	0.61	15	0.37	0	6.9	
8/26/15 10:30	44.00	5.15	17	0.01	0.133	9.13	0.874	9.95	0.01	0.004	1.05	0.53	0.55	20	0.37		7.68	Mixed chemicals: chlorine = 332.64 mL in 6 gals; HMO = 305.92 mL + 352 gr NaOH in 8 gals
																		Decreased HMO pump settings (new settings?)
8/26/15 13:30						6.47												
8/26/15 21:30	55.00	4.85	15.4	0.04	0.117	6.36	0.802	6.46	0.00	0.009	1.05	0.54	0.55	15	0.37	0	7.57	
8/27/15 9:30	67.00	5.2	15.9	0.03	0.13	6.65	0.878	7.17	0.01	0.006	1.05	0.48	0.55	20	0.37		6.95	
8/30/15 21:30	151.00	4.73	17.3	0	0.124	6.55	0.870	6.84	0.00	0.035	1.05	0.61	0.72	25	0.37	0		
8/31/15 9:00	162.50	4.98	15.7	0	0.127	6.54	1.268	6.89	0.00	0.013	1.05	0.67	0.72	35	0.37			
9/2/15 21:00	222.50	4.68	16.6	0.03	0.135	6.6	1.524	6.91	0.00	0	1.05	0.88	0.89	50	0.37	0	6.8	
9/3/15 10:00	235.50	4.8	16.4	0	0.125	6.6	1.600	6.84	0.00	0	1.05	0.54	0.62	60	0.37	0	6.87	
9/3/15 21:00	246.50	4.69	17.2	0.01	0.144	6.5	1.300	6.59	0.00	0	1.05	0.51	0.5	60	0.37	0	6.67	Mixed chemicals: chlorine = 277.2 mL in 5 gals; HMO = 191.2 mL + 240 gr NaOH in 5 gals
9/4/15 9:30	259.00	4.84	16.9	0.05	0.125	6.48	1.202	6.83	0.00	0.002	1.05	0.42	0.46	70	0.37	0	6.7	Increased chlorine pump (after testing?)
9/14/15 10:00	115.00	4.82	15.9	0.04	0.115	6.71	0.159	6.54	0.03	0	1.05	0.54	0.64	40	0.37	10	6.91	

APPENDIX B

Laboratory Reports and Laboratory Data Summary

MOORESTOWN TOWNSHIP
NORTH CHURCH STREET WATER TREATMENT PLANT
PILOT PLANT RADIOLOGICAL SAMPLING RESULTS

	Raw Water					Filter Effluent					Backwash Supply (GAC Effluent)				
Collection Date & Time	Gross Alpha 48-Hour	Gross Alpha Final	Radium 226	Radium 228	**Combined**	Gross Alpha 48-Hour	Gross Alpha Final	Radium 226	Radium 228	**Combined**	Gross Alpha 48-Hour	Gross Alpha Final	Radium 226	Radium 228	**Combined**
8/5/15 14:30	19.90	19.01	3.32	3.01	**6.33**	2.39	-	0.64	0.99	**1.63**	1.71	-	0.07	0.76	**0.83**
8/11/15 9:05	13.73	14.72	1.62	2.72	**4.34**	1.37	-	0.21	0.42	**0.63**	0.94	-	0.07	0.33	**0.40**
8/18/15 10:40	12.37	11.98	2.36	4.220	**6.58**	1.44	-	0.42	0.808	**1.23**	0.82	-	0.65	0.48	**1.13**
8/24/15 13:30	13.22	10.17	0.43	2.48	**2.91**	0.91	-	0.24	-0.19	**0.05**	1.24	-	0.21	-0.05	**0.16**
8/31/15 12:30	13.80	14.09	1.51	2.42	**3.93**	1.54	-	0.12	0.31	**0.43**	1.07	-	0.54	0.48	**1.02**
9/8/15 14:00	10.44	11.10	1.39	1.96	**3.35**	0.84	-	0.49	0.51	**0.99**	1.27	-	-0.10	0.31	**0.21**
9/14/15 14:00	13.29	11.19	0.07	0.17	**0.23**	1.22	-	0.25	2.04	**2.29**	0.64	-	-0.20	0.34	**0.14**

MOORESTOWN TOWNSHIP
NORTH CHURCH STREET WATER TREATMENT PLANT
PILOT PLANT TCP & TCE SAMPLING RESULTS

Date Samples Collected	Date Samples Analyzed	Laboratory	TCP Results											Comments
			Raw Water	IMAR Filter Eff.	3" GAC	15" GAC	21" GAC	39" GAC	48" GAC	60" GAC	Blank	EPA Method	MDL (ug/l)	
8/5/15 0:00	8/15/2015	EMSL	ND	-	ND	ND	ND	ND	ND	ND	-	524.2	0.32	
8/11/15 0:00	8/21/2015	EMSL	ND	-	ND	ND	ND	ND	ND	ND	-	524.2	0.32	
8/18/15 0:00	8/24/2015	EMSL	ND	-	ND	ND	ND	ND	ND	ND	-	525.2	0.32	
8/24/15 0:00	8/27/2015	EMSL	ND	-	ND	ND	ND	ND	ND	ND	-	524.2	0.32	
8/24/15 0:00	9/10/2015	EMSL	-	-	0.045	0.031	-	-	-	ND	-	504.1	0.02	Reassessed
8/31/15 0:00	9/10/2015	EMSL	0.047	ND	ND	0.032	0.096	0.074	0.14	0.085	-	504.1	0.02	
9/1/15 0:00	9/9/2015	EMSL	0.071	0.024	0.040	0.032	0.063	0.039	0.061	0.061	-	504.1	0.02	
9/3/15 0:00	9/8/2015	EMSL	0.093	0.047	0.054	0.040	0.060	0.054	0.066	0.086	-	504.1	0.02	
9/8/15 0:00	9/10/2015	EMSL	0.10	0.039	0.038	0.057	0.11	0.071	0.091	0.12	-	504.1	0.02	
9/9/15 0:00	9/23/2015	EMSL	0.059	0.055	0.057	0.053	ND	ND	ND	ND	-	504.1	0.02	
9/14/15 0:00	9/27/2015	EMSL	0.078	0.032	ND	0.038	ND	ND	ND	ND	ND	504.1	0.02	
9/16/15 0:00	9/26/2015	EMSL	0.05	0.034	0.055	0.049	ND	ND	ND	ND	ND	504.1	0.02	
														Split Sampling
9/14/15 13:45	9/18/2015	QC	0.063	0.069	0.066	0.053	0	ND	ND	ND	ND	504.1	0.00458	
9/16/15 10:00	9/19/2015	QC	0.069	0.075	0.064	0.047	0	ND	ND	ND	ND	504.1	0.00458	
9/18/15 0:00	9/25/2015	QC	0.072	-	0.019	0.033	0	ND	ND	ND	ND	504.1	0.00458	Running
9/21/15 9:45	9/23/2015	QC	0.058	-	0.055	0.026	0	ND	ND	ND	ND	504.1	0.00458	through
9/23/15 10:00	9/29/2015	QC	0.076	-	0.074	0.053	0	ND	ND	ND	ND	504.1	0.00458	Carbon
9/25/15 9:00	9/30/2015	QC	0.085	-	0.081	0.053	0	ND	ND	ND	ND	504.1	0.00458	Column
9/29/15 9:30	10/2/2015	QC	0.063	-	0.066	0.047	0	ND	ND	ND	ND	504.1	0.00458	Only.

Date Samples Collected	Date Samples Analyzed	TCE Results									EPA Method	MDL (ug/l)
		Raw Water	IMAR Filter Eff.	3" GAC	15" GAC	21" GAC	39" GAC	48" GAC	60" GAC	Blank		
8/5/2015	8/15/2015	ND	-	ND	ND	ND	ND	ND	ND	-	524.2	0.32
8/11/2015	8/21/2015	ND	-	ND	ND	ND	ND	ND	ND	-	524.2	0.32
8/18/2015	8/24/2015	ND	-	ND	ND	ND	ND	ND	ND	-	524.2	0.32
8/21/2015	8/25/2015	1.6	-	-	-	-	-	-	-	-	524.2	0.32
8/24/15 13:30	8/27/2015	1.50	1.5	0	0	0	ND	ND	ND	-	524.2	0.32
8/31/15 12:30	9/4/2015	1.60	1.5	1.3	0	0	ND	ND	ND	-	524.2	0.32
9/1/15 13:10	9/8/2015	1.90	1.6	1.5	0.59	0	ND	ND	ND	-	525.2	0.32
9/3/15 0:00	9/8/2015	1.90	1.8	1.4	0.82	0	ND	ND	ND	-	525.2	0.32
9/8/15 14:00	9/10/2015	1.30	1.2	0.89	0.5	0	ND	ND	ND	-	524.2	0.32
9/9/15 13:15	9/15/2015	1.80	1.7	1.4	0.7	0	ND	ND	ND	-	524.2	0.32
9/14/15 14:00	9/24/2015	2.00	2.0	1.7	1.1	0	ND	ND	ND	ND	524.2	0.32
9/16/15 10:15	9/29/2015	1.70	1.8	1.4	0.95	0	ND	ND	ND	ND	524.2	0.32

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LABORATORY REPORT

If you have any questions concerning this report, please do not hesitate to call us at (800) 332-4345 or (574) 233-4777.

STATE CERTIFICATION LIST

State	Certification	State	Certification
Alabama	40700	Montana	CERT0026
Alaska	IN00035	Nebraska	E87775
Arizona	AZ0432	Nevada	IN000352015-1
Arkansas	IN035	New Hampshire*	2124
California	2920	New Mexico	IN00035
Colorado	IN035	New Jersey*	IN598
Colorado Radiochemistry	IN035	New York*	11398
Connecticut	PH-0132	North Carolina	18700
Delaware	IN035	North Dakota	R-035
Florida (Primary AB)*	E87775	Ohio	87775
Georgia	929	Oklahoma	D9508
Hawaii	IN035	Oregon*	IN200001
Idaho	IN00035/E87775	Pennsylvania*	68-00466
Illinois*	200001	Puerto Rico	IN00035
Illinois Microbiology	200001	Rhode Island	LAO00241
Indiana Chemistry	C-71-01	South Carolina	95005
Indiana Microbiology	M-76-07	South Dakota	IN00035
Iowa	098	Tennessee	TN02973
Kansas*	E-10233	Texas*	T104704187-14-7
Kentucky	90056	Texas/TCEQ	TX207
Louisiana*	LA150003	Utah*	IN00035
Maine	IN00035	Vermont	VT-8775
Maryland	209	Virginia*	00127
Massachusetts	M-IN035	Washington	C837
Michigan	9926	West Virginia	9927 C
Minnesota*	018-999-338	Wisconsin	999766900
Mississippi	IN035	Wyoming	IN035
Missouri	880		

*NELAP/TNI Recognized Accreditation Bodies

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South Bend, IN 46617
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1 800 332 4345

Laboratory Report

Client: Tonka Equipment

Attn: Charles Mahady
13305 Water Tower Circle
Plymouth, MN 55441

Copies to: None

Report: 353396
Priority: Standard Written
Status: Final
PWS ID: Not Supplied
MN Lab ID: 018-999-338

Sample Information

EEA ID #	Client ID	Method	Collected Date / Time	Collected By:	Received Date / Time
3362644	Moorestown, NJ B.W. Waste	7110 B	11/18/15 11:30	Client	11/20/15 09:45
3362645	Moorestown, NJ B.W. Waste	7500-Ra B	11/18/15 11:30	Client	11/20/15 09:45
3362645	Moorestown, NJ B.W. Waste	7500-Ra D	11/18/15 11:30	Client	11/20/15 09:45
3362646	Moorestown, NJ B.W. Waste	200.8	11/18/15 11:30	Client	11/20/15 09:45
3362646	Moorestown, NJ B.W. Waste	200.7	11/18/15 11:30	Client	11/20/15 09:45

Report Summary

Note: The samples submitted for Methods 200.7 and 200.8 analyses were poured off upon receipt.

Detailed quantitative results are presented on the following pages. The results presented relate only to the samples provided for analysis.

We appreciate the opportunity to provide you with this analysis. If you have any questions concerning this report, please do not hesitate to call Traci Chlebowski at (574) 233-4777.

Note: This report may not be reproduced, except in full, without written approval from EEA.

Traci Chlebowski ASM — 12/15/2015

Authorized Signature — Title — Date

Client Name: Tonka Equipment
Report #: 353396

Client Name: Tonka Equipment

Report #: 353396

Sampling Point: Moorestown, NJ B.W. Waste

PWS ID: Not Supplied

Metals

Analyte ID #	Analyte	Method	Reg Limit	MRL†	Result	Units	Preparation Date	Analyzed Date	EEA ID #
7439-89-6	Iron	200.7	0.3 ^	0.020	**1.5**	mg/L	11/23/15 11:30	11/24/15 14:38	3362646
7439-96-5	Manganese	200.8	50 ^	2.0	**6000**	ug/L	11/23/15 11:30	11/24/15 14:33	3362646

Radionuclides

Analyte ID #	Analyte	Method	Reg Limit	MDA 95**	MRL	Result	Units	Preparation Date	Analyzed	EEA ID #
---	Gross Alpha	7110 B	15 *	1.2	3.0	**35.8 ± 4.1**	pCi/L	12/02/15 17:00	12/02/15 23:08	3362644
13982-63-3	Radium-226	7500-Ra B	---	0.1	1.0	**19.6 ± 1.6**	pCi/L	11/30/15 12:50	12/07/15 14:06	3362645
15262-20-1	Radium-228	7500-Ra D	---	0.4	1.0	**21.1 ± 1.1**	pCi/L	11/30/15 11:01	12/10/15 16:53	3362645
---	Combined Radium	calc.	5 *	0.4	1.0	**40.7 ± 1.9**	pCi/L	11/30/15 12:50	12/10/15 16:53	3362645

** Minimum Detectable Activity (MDA95) shall be that concentration which can be counted with a precision of plus or minus 100% at the 95 % confidence level.

† EEA has demonstrated it can achieve these report limits in reagent water, but can not document them in all sample matrices.

Reg Limit Type:	MCL	SMCL	AL
Symbol:	*	^	!

Lab Definitions

Continuing Calibration Check Standard (CCC) / Continuing Calibration Verification (CCV) / Initial Calibration Verification Standard (ICV) / Initial Performance Check (IPC) - is a standard containing one or more of the target analytes that is prepared from the same standards used to calibrate the instrument. This standard is used to verify the calibration curve at the beginning of each analytical sequence, and may also be analyzed throughout and at the end of the sequence. The concentration of continuing standards may be varied, when prescribed by the reference method, so that the range of the calibration curve is verified on a regular basis. CCL, CCM, and CCH are the CCC standards at low, mid, and high concentration levels, respectively.

Internal Standards (IS) - are pure compounds with properties similar to the analytes of interest, which are added to field samples or extracts, calibration standards, and quality control standards at a known concentration. They are used to measure the relative responses of the analytes of interest and surrogates in the sample, calibration standard or quality control standard.

Laboratory Duplicate (LD) - is a field sample aliquot taken from the same sample container in the laboratory and analyzed separately using identical procedures. Analysis of laboratory duplicates provides a measure of the precision of the laboratory procedures.

Laboratory Fortified Blank (LFB) / Laboratory Control Sample (LCS) - is an aliquot of reagent water to which known concentrations of the analytes of interest are added. The LFB is analyzed exactly the same as the field samples. LFBs are used to determine whether the method is in control. FBL, FBM, and FBH are the LFB samples at low, mid, and high concentration levels, respectively.

Laboratory Method Blank (LMB) / Laboratory Reagent Blank (LRB) - is a sample of reagent water included in the sample batch analyzed in the same way as the associated field samples. The LMB is used to determine if method analytes or other background contamination have been introduced during the preparation or analytical procedure. The LMB is analyzed exactly the same as the field samples.

Laboratory Trip Blank (LTB) / Field Reagent Blank (FRB) - is a sample of laboratory reagent water placed in a sample container in the laboratory and treated as a field sample, including storage, preservation, and all analytical procedures. The FRB/LTB container follows the collection bottles to and from the collection site, but the FRB/LTB is not opened at any time during the trip. The FRB/LTB is primarily a travel blank used to verify that the samples were not contaminated during shipment.

Matrix Spike Duplicate Sample (MSD) / Laboratory Fortified Sample Matrix Duplicate (LFSMD) - is a sample al6iquot taken from the same field sample source as the Matrix Spike Sample to which known quantities of the analytes of interest are added in the laboratory. The MSD is analyzed exactly the same as the field samples. Analysis of the MSD provides a measure of the precision of the laboratory procedures in a specific matrix. SDL, SDM, and SDH / LFSMDL, LFSMDM, and LFSMDH are the MSD or LFSMD at low, mid, and high concentration levels, respectively.

Matrix Spike Sample (MS) / Laboratory Fortified Sample Matrix (LFSM) - is a sample aliquot taken from field sample source to which known quantities of the analytes of interest are added in the laboratory. The MS is analyzed exactly the same as the field samples. The purpose is to demonstrate recovery of the analytes from a sample matrix to determine if the specific matrix contributes bias to the analytical results. MSL, MSM, and MSH / LFSML, LFSMM, and LFSMH are the MS or LFSM at low, mid, and high concentration levels, respectively.

Quality Control Standard (QCS) / Second Source Calibration Verification (SSCV) - is a solution containing known concentrations of the analytes of interest prepared from a source different from the source of the calibration standards. The solution is obtained from a second manufacturer or lot if the lot can be demonstrated by the manufacturer as prepared independently from other lots. The QCS sample is analyzed using the same procedures as field samples. The QCS is used as a check on the calibration standards used in the method on a routine basis.

Reporting Limit Check (RLC) / Initial Calibration Check Standard (ICCS) - is a procedural standard that is analyzed each day to evaluate instrument performance at or below the minimum reporting limit (MRL).

Surrogate Standard (SS) / Surrogate Analyte (SUR) - is a pure compound with properties similar to the analytes of interest, which is highly unlikely to be found in any field sample, that is added to the field samples, calibration standards, blanks and quality control standards before sample preparation. The SS is used to evaluate the efficiency of the sample preparation process.

eurofins | Eaton Analytical

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South Bend, IN 46617
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F: 1.574.233.8207

Order # 286640
Batch # 353396

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CHAIN OF CUSTODY RECORD

Page ____ of ____

REPORT TO:	SAMPLER (Signature)	PWS ID #	STATE (sample origin)	PROJECT NAME	PO#
Charles Mahady	Tyd Sdl		MN	NJ Moorestown	
BILL TO: Tonka Water	COMPLIANCE MONITORING: Yes ____ No ____	POPULATION SERVED	SOURCE WATER		

LAB Number	COLLECTION DATE	COLLECTION TIME	AM	PM	SAMPLING SITE	TEST NAME	SAMPLE REMARKS	CHLORINATED YES	CHLORINATED NO	# OF CONTAINERS	MATRIX CODE	TURNAROUND TIME
1 286640	11/18/15	11:30	✓		Moorestown, NJ B.W. Waste	Gross Alpha 7110B	3362644		2	2	SS	11-20-15
2 286640	11/18/15	11:30	✓		Moorestown, NJ B.W. Waste	Ra 226/228	645			2		
3						Fe, Mn SS 11-20-15	646			1		
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												

RELINQUISHED BY:(Signature)	DATE	TIME	RECEIVED BY:(Signature)	DATE	TIME
Tyd Sdl	11/19/15	12:00 AM PM			AM PM
RELINQUISHED BY:(Signature)	DATE	TIME	RECEIVED BY:(Signature)	DATE	TIME
		AM PM			AM PM
RELINQUISHED BY:(Signature)	DATE	TIME	RECEIVED FOR LABORATORY BY:	DATE	TIME
		AM PM	SRegan	11-20-15	0945 AM PM

LAB RESERVES THE RIGHT TO RETURN UNUSED PORTIONS OF NON-AQUEOUS SAMPLES TO CLIENT

LAB COMMENTS

Liters Received = 10

Fe, Mn poured off upon receipt SS 11-20-15

CONDITIONS UPON RECEIPT (check one):

___ Iced: Wet/Blue ___X___ Ambient ___ °C Upon Receipt ___X___ N/A

MATRIX CODES:

DW-DRINKING WATER
RW-REAGENT WATER
GW-GROUND WATER
EW-EXPOSURE WATER
SW-SURFACE WATER
PW-POOL WATER
WW-WASTE WATER

TURN-AROUND TIME (TAT) - SURCHARGES

SW = Standard Written: (15 working days)	-0%	IV* = Immediate Verbal: (3 working days)	100%
RV* = Rush Verbal: (5 working days)	50%	IW* =Immediate Written: (3 working days)	125%
RW* = Rush Written: (5 working days)	75%	SP* = Weekend, Holiday	CALL
		STAT* = Less than 48 hours	CALL

* Please call, expedited service not available for all testing

Samples received unannounced with less than 48 hours holding time remaining may be subject to additional charges.

RSSI

6312 Oakton Street
Morton Grove, IL 60053-2723
847-965-1999
Fax 847-965-1991

Monday, December 07, 2015

Tyler Skarolid
Tonka Water
13305 Watertower Circle
Plymoth, MN 55441

RE: Filter Media

Dear Mr. Skarolid:

A summary of gamma spectroscopy results for our sample number G150589 is in Table 1. Tonka Water identified the sample as Filter Media. The table below lists the concentrations of the two radionuclides specified by Tonka Water: radium-226 (Ra-226) and radium-228 (Ra-228). Values with a less-than symbol ("<") indicate a concentration below RSSI's minimum detectable concentration (MDC). Additional identified radionuclides are in the complete gamma spectroscopy reports.

Table 1. High-resolution Gamma Spectroscopy Results [pCi/g]

Radionuclide (Surrogate)	Sample
	G150589
	Filter Media
Ra-226 (Average of Pb-214 and Bi-214)	0.38
Ra-228 (Ac-228)	0.75
Total Radium	1.13

The radionuclides of interest, Ra-226 and Ra-228, are difficult to identify and quantify directly at low concentrations with reasonable counting intervals. The concentrations of surrogates with more abundant photons represent the concentrations of these radionuclides. The successful use of surrogates depends upon the radionuclides in each series being in equilibrium.

Ra-226, in the uranium series, has only one significant photon at 186.21 keV with a gamma fraction slightly greater than 0.03. Gamma fraction is the fraction of decays that produce a photon of a given energy. Analysis for Ra-226 using this energy is difficult because of the presence of U-235, which emits an interfering 185.72 keV photon with a 0.57 gamma fraction, and protactinium-234 (Pa-234) which emits an interfering 186.15 keV photon with a 0.02 gamma fraction. Bismuth-214 (Bi-214) and

RSSI

lead-214 (Pb-214), in the uranium series, are used as surrogates for Ra-226 when these radionuclides are in equilibrium. The equilibrium between Ra-226 and its surrogates may be disturbed when samples are collected; radon-222 (Rn-222), a short-lived (half-life of 3.8 days) gaseous Ra-226 decay product, can be released. Pb-214 and Bi-214 return to equilibrium with the Ra-226 in a sample after an in-growth period of 30 days in standard protocols. Equilibrium is reestablished within seven half-lives of Rn-222. In standard protocols, samples are held for a 30-day in-growth period to reestablish equilibrium. This sample was analyzed as-received and was not held for an in-growth period of at least 30 days.

Ra-228, in the thorium series, emits photons with very low gamma fractions at very low energies. Actinium-228 (Ac-228) is usually in equilibrium with Ra-228 when collected and is used as a surrogate.

The complete spectroscopy analysis results are attached. Please call me at 847-965-1999 if you have any questions.

Sincerely,

Aaron D. Morris

Aaron Morris

Attachment

ORTEC g v - i (1087) Env32 G53W4.22 07-DEC-2015 13:54:37
RSSI Spectrum name: G150589.An1

Sample description
G150589 Tonka Water, Filter Media, 696.2 g

Spectrum Filename: H:\GammaVision\User\Spectra\G150589.An1

***** S U M M A R Y O F N U C L I D E S I N S A M P L E *****

Nuclide		Time of Count Activity uCi/g	Uncertainty 1 Sigma Counting	Total
PB-214		3.7935E-07	5.099E+00%	5.664E+00%
BI-214		3.9039E-07	5.466E+00%	5.924E+00%
AC-228		7.4823E-07	6.605E+00%	6.945E+00%
K-40		8.6997E-06	2.708E+00%	4.353E+00%
Pb-212		3.9523E-07	3.740E+00%	4.775E+00%
Bi-212		6.0553E-07	1.863E+01%	1.877E+01%
Tl-208		1.4468E-07	7.511E+00%	7.849E+00%
Th-234	<	2.6655E-07		
Tl-210	<	2.0691E-09		
Pb-210	<	3.9045E-06		
Ra-223	<	2.0947E-08		
Pa-234m	<	6.0930E-07		
Pa-234	<	1.0591E-08		
U-235	<	4.3127E-08		
Th-227	<	2.8619E-08		
Rn-219	<	3.6377E-08		
Ra-224		4.7493E-07	3.145E+01%	3.159E+01%

< - MDA value printed.
A - Activity printed, but activity < MDA.
B - Activity < MDA and failed test.
C - Area < Critical level.
F - Failed fraction or key line test.
H - Halflife limit exceeded

---------- S U M M A R Y ----------

Total Activity (270.1 to 1761.4 keV) 1.184E-05 uCi/g
This section based on library: Natural 2015-10.Lib

ORTEC g v - i (1087) Env32 G53W4.22 07-DEC-2015 13:54:37
RSSI Spectrum name: G150589.An1

Sample description
G150589 Tonka Water, Filter Media, 696.2 g

Spectrum Filename: H:\GammaVision\User\Spectra\G150589.An1

***** S U M M A R Y O F L I B R A R Y P E A K U S A G E *****

- Nuclide - Name	Code	Average Activity uCi/g	Peak Energy keV	Activity uCi/g		MDA Value uCi/g		COMMENTS
PB-214	N	3.7935E-07						
			351.93	3.856E-07	(	1.147E-08	5.10E+00	G
			295.22	4.438E-07	+	3.452E-08	8.66E+00	G
			242.00	3.479E-07	(	6.064E-08	1.86E+01	G
BI-214	N	3.9039E-07						
			609.31	3.904E-07	(	9.713E-09	5.47E+00	G
			1120.29	5.252E-07	+	6.619E-08	1.16E+01	G
			1764.49	0.000E+00	=	0.000E+00	0.00E+00	G
			768.36	5.930E-07	&	1.316E-07	2.70E+01	G
			1238.11	7.059E-07	+	1.565E-07	2.52E+01	G
			934.06	7.117E-07	+	2.122E-07	3.64E+01	G
			1377.67	6.497E-07	+	1.762E-07	2.74E+01	G
AC-228	N	7.4823E-07						
			911.20	7.494E-07	(	2.126E-08	6.60E+00	G
			968.97	6.728E-07	(	3.509E-08	9.91E+00	G
			338.32	8.097E-07	*(	3.606E-08	8.99E+00	G
			964.77	8.741E-07	+	1.701E-07	2.30E+01	G
			463.00	8.410E-07	(	1.099E-07	2.04E+01	G
			209.25	9.064E-07	+	1.232E-07	1.21E+01	G
			270.25	4.935E-07	-	1.336E-07	3.70E+01	G
			129.06	7.730E-07	(	2.018E-07	3.73E+01	G
K-40	N	8.6997E-06						
			1460.82	8.700E-06	(	4.374E-08	2.71E+00	G
Pb-212	N	3.9523E-07						
			238.63	3.952E-07	(	1.003E-08	3.74E+00	G
			300.09	7.990E-07	+	1.557E-07	2.53E+01	G
			115.18	0.000E+00		1.976E-08	0.00E+00	G
Bi-212	N	6.0553E-07						
			727.33	6.263E-07	(	6.965E-08	1.86E+01	G
			785.37	4.796E-07	&(	2.988E-07	7.07E+01	G
			288.20	0.000E+00		4.535E-08	0.00E+00	G
			1620.50	1.725E-06	+	4.191E-07	1.62E+01	G
			328.03	0.000E+00		1.359E-07	0.00E+00	G
Tl-208	N	1.4468E-07						
			583.19	1.447E-07	@(	5.405E-09	7.51E+00	G
			277.35	1.241E-07	-	6.765E-08	6.27E+01	G
			860.56	3.029E-07	+	5.944E-08	2.43E+01	G
Th-234	N	0.0000E+00						
			92.38	0.000E+00	&	2.666E-07	1.00E+03	G
			92.80	0.000E+00	%	2.750E-07	1.00E+03	G
			63.29	0.000E+00	%	2.802E-07	1.00E+03	G
Tl-210	N	0.0000E+00						
			298.00	0.000E+00	%	2.069E-09	1.00E+03	G
			799.70	0.000E+00	%	5.343E-09	1.00E+03	G
			1316.00	0.000E+00	%	2.580E-08	1.00E+03	G
			1210.00	0.000E+00	%	1.277E-08	1.00E+03	G

ORTEC g v - i (1087) Env32 G53W4.22 07-DEC-2015 13:54:37
RSSI Spectrum name: G150589.An1

Sample description
G150589 Tonka Water, Filter Media, 696.2 g

Spectrum Filename: H:\GammaVision\User\Spectra\G150589.An1

			1070.00	0.000E+00	&	3.093E-08	1.00E+03	G	
			97.90	0.000E+00	%	8.817E-08	1.00E+03	G	
			356.00	0.000E+00	%	1.133E-07	1.00E+03	G	
			860.00	0.000E+00	%	7.156E-08	1.00E+03	G	
Pb-210	N	0.0000E+00							
			46.54	0.000E+00	&	3.904E-06	1.00E+03	G	
Ra-223	N	0.0000E+00							
			269.46	0.000E+00	%	2.095E-08	1.00E+03	G	
			154.21	0.000E+00	%	9.344E-08	1.00E+03	G	
			144.23	0.000E+00	%	1.468E-07	1.00E+03	G	
			323.87	0.000E+00	&	7.346E-08	1.00E+03	G	
Pa-234m	N	0.0000E+00							
			1001.03	0.000E+00	%	6.093E-07	1.00E+03	G	
			766.38	0.000E+00	%	1.258E-06	1.00E+03	G	
			258.23	0.000E+00	&	5.065E-06	1.00E+03	G	
			742.81	0.000E+00	&	7.326E-06	1.00E+03	G	
			98.43	0.000E+00	%	2.706E-06	1.00E+03	XA	
Pa-234	N	0.0000E+00							
			131.30	0.000E+00	%	1.059E-08	1.00E+03	G	
			152.72	0.000E+00	%	6.616E-08	1.00E+03	G	
			227.25	0.000E+00	&	7.379E-08	1.00E+03	G	
			946.00	0.000E+00	%	2.241E-08	1.00E+03	G	
			569.50	0.000E+00	%	2.355E-08	1.00E+03	G	
			226.50	0.000E+00	%	1.017E-07	1.00E+03	G	
			98.43	0.000E+00	%	2.706E-06	1.00E+03	XA	
			99.85	0.000E+00	&	1.953E-07	1.00E+03	G	
U-235	N	0.0000E+00							
			143.76	0.000E+00	%	4.313E-08	1.00E+03	G	
			163.36	0.000E+00	%	6.937E-08	1.00E+03	G	
			205.31	0.000E+00	&	8.446E-08	1.00E+03	G	
Th-227	N	0.0000E+00							
			235.97	0.000E+00	%	2.862E-08	1.00E+03	G	
			256.25	0.000E+00	%	5.112E-08	1.00E+03	G	
			329.85	0.000E+00	%	7.905E-08	1.00E+03	G	
			300.00	0.000E+00	%	2.201E-07	1.00E+03	G	
Rn-219	N	0.0000E+00							
			271.23	0.000E+00	&	3.638E-08	1.00E+03	G	
			401.81	0.000E+00	%	7.410E-08	1.00E+03	G	
Ra-224	N	4.7493E-07							
			240.99	4.749E-07	(	1.457E-07	3.14E+01	G	

(- This peak used in the nuclide activity average.

* - Peak is too wide, but only one peak in library.
! - Peak is part of a multiplet and this area went
negative during deconvolution.
? - Peak is too narrow.
@ - Peak is too wide at FW25M, but ok at FWHM.
% - Peak fails sensitivity test.
$ - Peak identified, but first peak of this nuclide
failed one or more qualification tests.
\+ - Peak activity higher than counting uncertainty range.
\- - Peak activity lower than counting uncertainty range.

ORTEC g v - i (1087) Env32 G53W4.22 07-DEC-2015 13:54:37
RSSI Spectrum name: G150589.An1

Sample description
G150589 Tonka Water, Filter Media, 696.2 g

Spectrum Filename: H:\GammaVision\User\Spectra\G150589.An1
= - Peak outside analysis energy range.
& - Calculated peak centroid is not close enough to the library energy centroid for positive identification.
P - Peakbackground subtraction
} - Peak is too close to another for the activity to be found directly.

Nuclide Codes:	Peak Codes:
T - Thermal Neutron Activation	G - Gamma Ray
F - Fast Neutron Activation	X - X-Ray
I - Fission Product	P - Positron Decay
N - Naturally Occurring Isotope	S - Single-Escape
P - Photon Reaction	D - Double-Escape
C - Charged Particle Reaction	K - Key Line
M - No MDA Calculation	A - Not in Average
R - Coincidence Corrected	C - Coincidence Peak
H - Halflife limit exceeded	

- -
This section based on library: Natural 2015-10.Lib

ORTEC g v - i (1087) Env32 G53W4.22 07-DEC-2015 13:54:37
RSSI Spectrum name: G150589.An1

Sample description
G150589 Tonka Water, Filter Media, 696.2 g

Spectrum Filename: H:\GammaVision\User\Spectra\G150589.An1

********** U N I D E N T I F I E D P E A K S U M M A R Y **********

Peak Channel	Centroid Energy	Background Counts	Net Area Counts	Intensity Cts/Sec	Uncert 1 Sigma %	FWHM keV		Suspected Nuclide
129.92	23.87	5443.	7716.	1.072	1.77	1.098	-	D
136.27	25.45	10076.	3008.	0.418	5.06	1.099	-	D
140.39	26.13	16351.	5858.	0.814	3.35	1.099	-	D
154.62	29.42	11979.	1845.	0.256	11.85	1.230	-	D
175.06	33.85	8360.	2250.	0.312	9.03	1.675	-	sM
200.24	39.30	2503.	1940.	0.269	5.41	1.104	-	M
328.18	67.00	208.	21.	0.003	97.09	0.476	-	c
365.50	75.19	801.	293.	0.041	14.86	1.112	-	D
374.56	77.16	879.	404.	0.056	11.51	1.113	-	D
878.81	186.25	706.	309.	0.043	16.23	0.390	-	s
994.61	211.22	527.	82.	0.011	40.94	1.155	-	D
1888.51	404.97	67.	29.	0.004	46.35	0.343	-	s
3232.94	696.29	65.	48.	0.007	36.07	0.632	-	s
4998.00	1078.93	20.	18.	0.002	44.68	0.377	-	s

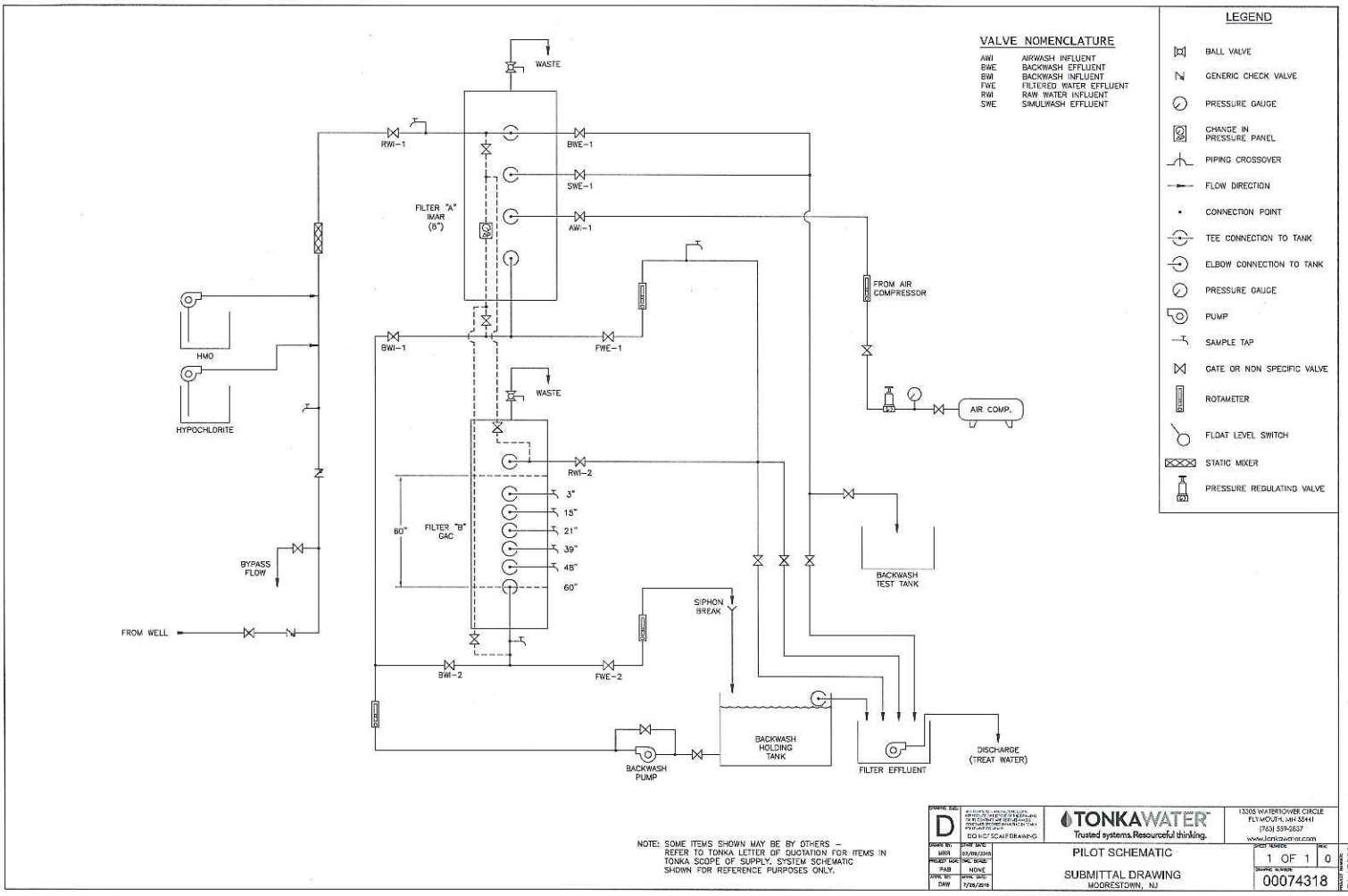
s - Peak fails shape tests.
D - Peak area deconvoluted.
L - Peak written from unknown list.
C - Area < Critical level.
M - Peak is close to a library peak.

This section based on library: Natural 2015-10.Lib

```
     ORTEC g v - i (1087) Env32  G53W4.22  07-DEC-2015 13:54:37
RSSI                              Spectrum name: G150589.An1

Sample description
     G150589 Tonka Water, Filter Media, 696.2 g

Spectrum Filename: H:\GammaVision\User\Spectra\G150589.An1
Acquisition information
       Start time:                07-Dec-2015 11:31:39
       Live time:               7200
       Real time:               7211
       Dead time:                 0.15 %
       Detector ID:                  3

Detector system
     CLTCOMP MCB 9

Calibration
       Filename:                  G150589.An1
     2015-07-08 30% GEM-30185-P Calibration

       Energy Calibration
            Created:              07-Dec-2015 13:54:05
            Zero offset:         -4.057 keV
            Gain:                 0.217 keV/channel
            Quadratic:            3.216E-08 keV/channel^2

       Efficiency Calibration
            Created:              08-Jul-2015 09:48:04
            Type:                 Polynomial
            Uncertainty:          2.535 %
            Coefficients:        -0.447741  -4.380340   0.497833
                                 -0.052519   0.001776  -0.000030

Library Files
       Main analysis library:     Natural 2015-10.Lib
       Library Match Width:       0.500
       Peak stripping:            Library based

Analysis parameters
       Analysis engine:           Env32   G53W4.22
       Start channel:            20 (     0.27keV )
       Stop channel:           8144 (  1761.45keV )
       Peak rejection level:    100.000%
       Peak search sensitivity:   3
       Sample Size:               6.9620E+02
       Activity scaling factor:   1.0000E+00/(  1.0000E+00*  6.9620E+02) =
                                  1.4364E-03
       Detection limit method:    Traditional ORTEC method
       Random error:              1.0000000E+00
       Systematic error:          1.0000000E+00
       Fraction Limit:            0.000%
       Background width:          best method (based on spectrum).
       Half lives decay limit:   12.000
       Activity range factor:     2.000
       Min. step backg. energy    0.000
       Multiplet shift channel    2.000

Corrections                         Status          Comments
       Decay correct to date:        NO
       Decay during acquisition:     NO
       Decay during collection:      NO
       True coincidence correction:  NO
       Peaked background correction: NO
       Absorption (Internal):        NO
       Geometry correction:          NO
       Random summing:               NO

total peaks alloc.     30  cutoff   20.00000     %
       Energy Calibration
            Normalized diff:      0.1117
```

APPENDIX C

Pilot Schematic



NOTE: SOME ITEMS SHOWN MAY BE BY OTHERS – REFER TO TONKA LETTER OF QUOTATION FOR ITEMS IN TONKA SCOPE OF SUPPLY. SYSTEM SCHEMATIC SHOWN FOR REFERENCE PURPOSES ONLY.

DRAWING SIZE: D — DO NOT SCALE DRAWING

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PROJECT MGR: PAB | DWG. SCALE: NONE
LEVEL OF DAW | APPR. DATE: 7/26/2018

PILOT SCHEMATIC

SUBMITTAL DRAWING
MOORESTOWN, NJ

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