Assessing ‘HydroFLOW’ Technology and Side-Stream Filtration in High Silica Concentration Groundwater for Prospective Operational Benefits

Authors:

Stephen M. Trujillo, C-CDE

Robert M. Wingo, MET-1

Chemical Diagnostics and Engineering Group (C-CDE)

Los Alamos National Laboratory

Report Date: December 2015

1. INTRODUCTION

The HydroFLOW Model S38 water conditioner is designed to provide a chemical-free alternative to the effects of lime scale, corrosion, bacteria, and algae growth in residential and small commercial applications (up to 5000 ft^2). It is estimated that HydroFLOW has the ability to significantly reduce blow-down in cooling tower operations offering a 50% to 95% water savings through increasing cycles-of-concentration (COC) and reduce Total Suspended Solids (TSS) through the use of side-stream filtration. Although observed anecdotal evidence of the product's effectiveness exists, no publishable independent scientific testing is available; therefore, significant skepticism exists regarding HydroFLOW's effectiveness.

As part of New Water Innovations (NWI) request for assistance through the New Mexico Small Business Assistance (NMSBA) and Los Alamos National Laboratory (LANL), LANL will assist NWI by evaluating the HydroFLOW Model S38 Chemical-Free Water Conditioner. LANL staff will simulate cooling towers through the use of evaporative coolers. Simulated cooling towers will be operated using identical 'make-up' water in 4 different configurations 1) without treatment-control; 2) with side-stream filtration only; 3) with the transponder only; and 4) with the transponder and side-stream filtration.

Los Alamos National Laboratory has the ability to evaluate water chemistry for Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) including the size and nature of the TSS. This capability may provide relevant data for HydroFLOW and side-stream filtration relevant to efficacy for achieving water savings and reduction in chemical consumption.

During operation, samples were collected and analyzed for TSS, TDS, conductivity, reactive silica, total silicon, and scale build up was analyzed via scanning electron microscopy (SEM). The premise of the proposed configurations and analytical targets are to determine the effectiveness of each treatment option.

2. EXPERIMENTAL

2.1. Equipment List

- Port-A-Cool Cyclone 3200 Portable Evaporative Cooling Unit
- Beckett 250 GPH Submersible Fountain Pump M# M250HD (for recirculation of basin water)
- Life Gard Adjustable Aquarium Heater 150W (Bi-metal)
- HydroFLOW transponders (provided by NWI)
- 50 Micron Filter(s) (provided by NWI)
- Orbit Water Flow Meter M# 52212
- Defiant In-line GFCI(s) (electrical safety requirement)
- 12 gauge outdoor extension cord(s)
- 5/8" Garden Hose
- Misc. tubing
- OWON Oscilloscope (provided by NWI)
- Corning Checkmate II Conductivity Probe

2.2. Definitions / Acronyms

Term	Description
LANL	Los Alamos National Laboratory
NMSBA	New Mexico Small Business Assistance
NWI	New Water Innovations
Unit #1	Control Unit
Unit #2	Side-Stream Only (SS)
Unit #3	HydroFLOW Only (HF)
Unit #4	Side-Stream Filter and HydroFLOW transponder (SS/HF)
Blank-Hydrant	Make-up water
COC	Cycles of Concentration
GPH	Gallons per Hour
W	Watts
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
LAC	Los Alamos County
SEM	Scanning Electron Microscopy
NPDES	National Pollutant Discharge Elimination System
ASTM	American Society for Testing and Materials
TA	Technical Area
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
SWWS	Sanitary Wastewater System
lb, lbs	Pound, pounds
ROI	Return on Investment

2.3. Test Set-up

Four identical Port-A-Cool Cyclone 3200 Portable Evaporative Cooling Units (Figure1) were procured and slightly modified to the following configurations for the assessment:

1) Control - without treatment

2) Side-stream filtration only

3) HydroFLOW transponder only

4) Side-stream filtration and the HydroFLOW transponder


Figures 1&2. (1-Left) Four identical Port-A-Cool units for assessment. (2-Right) Port-A-Cool Cyclone 3200 (as received).

Unit #1 – Control Unit

A Beckett 250 GPH Submersible Fountain Pump was placed in the right front corner of the basin for recirculation of the basin water. The 150W Life Gard Adjustable Aquarium Heater was placed in the manual fill opening in the center of the basin, just above the red drain plug seen in Figures 2 & 3.

Unit #2 – Side-Stream Filtration Only

In addition to the submersible pump and the heater placed in the control unit, a side-stream filtering unit was mounted to the upper right side of the Port-A-Cool unit as seen in Figure 3. The Beckett submersible pump was then connected to the side stream filter in this apparatus for testing.

Unit #3 – HydroFLOW transponder

As in the control (Unit #1), a Beckett 250 GPH Submersible Fountain Pump was placed in the right front corner of the basin for recirculation of the basin water along with the Heater in the center of the basin.

The HydroFLOW S38 unit was placed on the interior of the unit, just above the brass valve on the left side of the unit between the wall of the unit and the fan housing.

Figure 3. Unit #2 with Side-Stream Filtering Apparatus (50 micron filter)

Unit #4 - Side-stream filtration and the HydroFLOW transponder

Assembly of Unit #4 was a combination of Units #2 and #3. The submersible pump was connected to the side-stream filter (50 micron filter), with the heater being placed in the center of the basin, and the HydroFLOW S38 unit placed above the brass flow control valve.

The tubing used for the recirculation of basin water was cut to the total length of the tubing used for the plumbing of the side stream filters used in Units #2 and #4 to keep the four units identical in configuration during the evaluation process. Recirculation pumps were fully open to allow maximum recirculation of the basin water. Orbit water flow meters were placed on the inlets of each unit to track the water consumption during testing.

Following modifications and 90% assembly, a NWI representative was brought onsite to inspect and evaluate the proposed design and set-up/placement of each unit prior to final assembly. NWI personnel agreed that the design was suitable to create a proper air gap for proper function of HydroFLOW Model S38, and to ensure no signal interference. Additionally, the four units were all placed at Technical Area 46. Units #1 & #2 were placed in one location, while Units #3 & #4 were placed in an alternative location approximately 525 feet (0.1 mile) southeast of Units #1 & #2. All four units were facing eastward approximately five feet from the building with the intake (pads) facing westward to the buildings. All units received equivalent amounts of direct sun light throughout the day until ~1:30-2:00 pm.

2.4. Test Monitoring / Observations

Testing of the systems commenced on May 18, 2015. The systems were set in their respective locations on Friday, May 15th, connected to the water source, filled, and the basin heaters were turned on to allow the basin temperature to equilibrate over the weekend. Once the basin temperature had equilibrated to ~80^{o}F, units were all powered up and the fans were set at the low setting (1) while pump flow was at maximum capacity for the unit. All units were visually inspected on a daily basis, Monday thru Friday.

Throughout the testing of these systems, the conductivity, TDS, and salinity were monitored at frequent intervals to trend the functionality of each unit using a Corning Checkmate conductivity probe. Due to the low flow that was required for make-up water to each unit, the flow meters used were not able to totalize the overall water consumption as expected, except for occasional periods of water outages where the water levels dropped significantly, and ~ 5 gallons was needed to bring the basins up to a normal operating level.

Figure 4, provides the daily conductivity readings that were taken throughout the testing period. It is evident that the “make-up” (Blank-Hydrant) water remains consistent throughout the fourteen weeks. Conductivity results for Units 1, 2, 3, and 4 (control, SS, HF, SS/HF) remain consistent during the first 3 weeks of testing. At approximately 1 month of testing, the SS/HF unit begins to separate from the group with slightly lower conductivities for approximately a three week period. At this time both the HF and SS/HF units show similar stable performance, while the control and SS units continue to show increases in conductivity over the final six weeks of testing. Data in early to mid-August indicates a reduction in conductivity for the control, however, a similar trend is observed for the SS only unit later in August, nearing the conclusion of testing and earlier for HF and SS/HF units, although not as extreme, from late mid-July through early August.

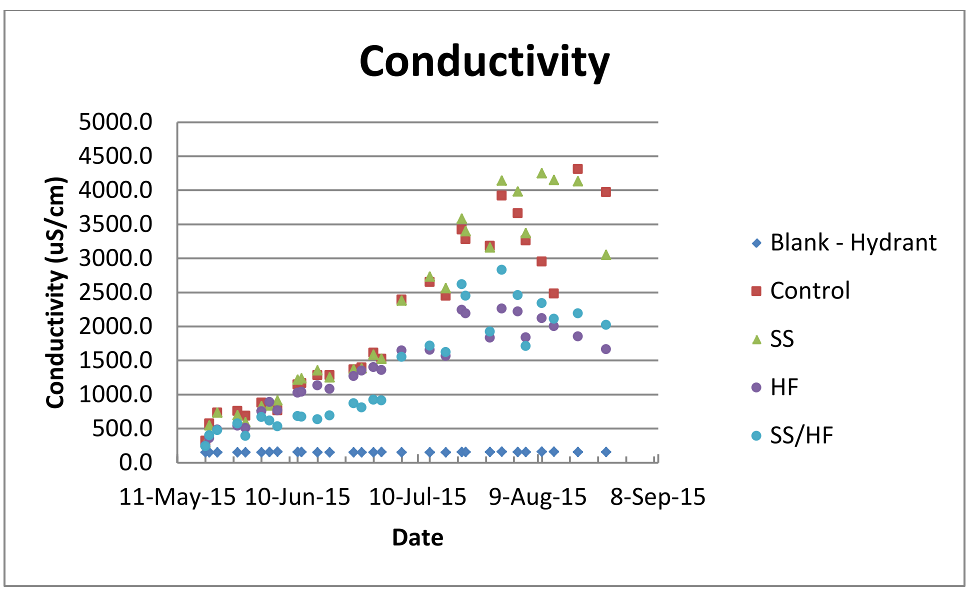


Figure 4. Conductivity Readings (Corning Checkmate II Conductivity Probe)

Figure 5 shows the daily trending of TDS for the four systems being assessed. The trends for both the conductivity and the TDS are the same as the probe measurement for TDS uses the Electrical Conductivity multiplied by a constant (which compensates for different metals, minerals and salts) to estimate TDS. For this specific probe the constant used was ~0.51 which is typical for KCl or NaCl, which might not always be representative of the chemistry of the water.

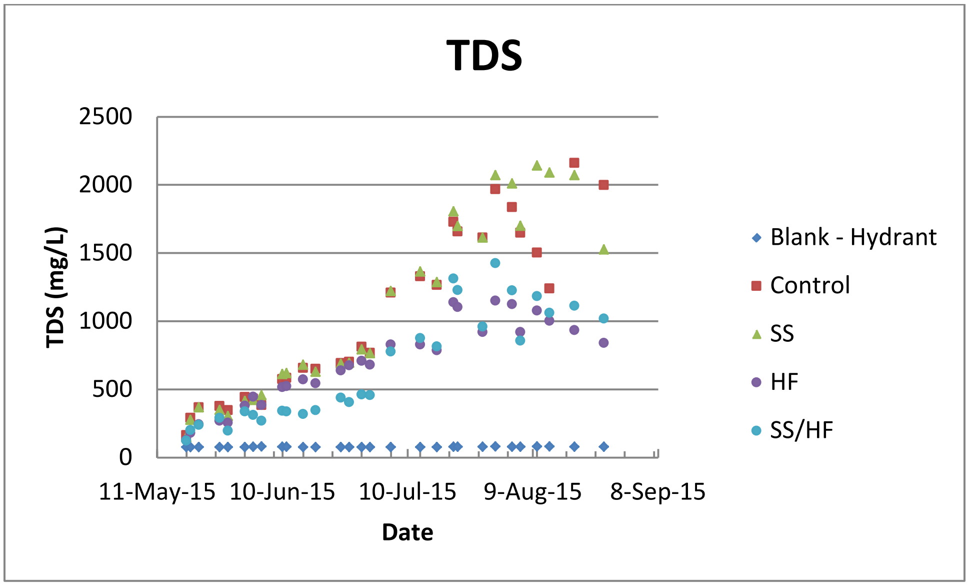


Figure 5. TDS Readings (Corning Checkmate II Conductivity Probe)

The gravimetric TSS and TDS measurements were performed using ASTM standard test methods for filterable and non-filterable matter. ASTM Methods for TSS/TDS provide results more suitable for analysis than probe and probe-corrected approaches.

Within the first week of testing (late May 2015), scaling was visible on the exterior pad screen and pads on all four units, as shown in Figure 6. Visual observations in early June indicated that the control and side stream units seemed to have less scale build up than the two units with the HydroFLOW transponder. The SS/HF combination was observed to have slightly less scale build up than that of the HF system. Both systems (HF, HF/SS) had milky recirculating basin water unlike the control and side stream units. However, visual observations later in June revealed similar milky recirculating basin water on the control and side stream units. On this date it was estimated that the systems were consuming approximately 18-25 gallons of water per day.

Figure 6. Scale build up on each unit being tested on May 26th and 27th. (top left) Unit #1 control, (top right) Unit #2 side-stream filtration only, (bottom left) Unit #3 HydroFLOW only, and (bottom right) Unit #4 side-stream and HydroFLOW.

On June 15th, during the daily check, it was observed that the indicator light on Unit #3 (HF) was not operational. All units were shut down until the HydroFLOW unit could be checked with an oscilloscope for a signal, and NWI personnel were contacted of the potential failure. On June 16th testing was resumed until June 19th when NWI personnel performed a site visit to inspect the unit in question (Unit #3). At this time it was determined that the HydroFLOW unit was not functioning properly and was immediately replaced. Dip slides were taken at this time by NWI personnel on all four units. On June 19th it was observed that the side-steam filter on Unit #2 was plugged and the flow was fully obstructed. The filter was replaced at this time. Per NWI request, all units were shut down over the weekend until a solution could be determined to protect the HydroFLOW units from any potential water damage.

On the 23rd of June, NWI personnel returned to weather proof the HydroFLOW units as there was concern that the fans were drawing water in during seasonal rainstorms. To be certain that the

HydroFLOW transponders were providing a signal at all times, a wire was placed through the transponder and the ends were placed on the exterior of the testing apparatus. NWI provided an oscilloscope at this time to perform daily checks of the transponders. At this time, the SS/HF unit was observed to have a significantly reduced flow through the side stream filter. By the end of June, the flow was significantly reduced and had no flow by July 6th. A second round of dip slides were taken on June 29th and provided to NWI. By July 22nd the control (Unit# 1) had major scale build up on the main pump, as shown in Figure 7. The pump was removed and the filter was cleaned and replaced as shown in Figure 8.

Figure 7. Debris and scale build-up on Unit #1 (control) pump filter July 22nd pre-cleaning.

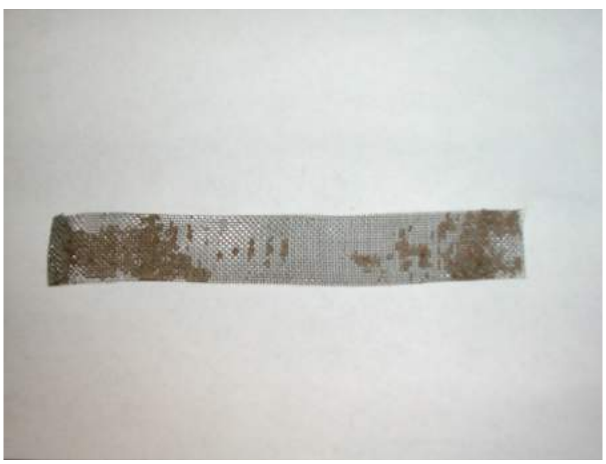


Figure 8. Scale build-up on pump filter to Unit #1 (post cleaning).

The side stream of Unit #2 had no flow through the filter and had to be replaced as well. NWI personnel acquired dip slides at this time. On July 31st the HydroFLOW transponder on Unit #3 was not putting out a signal, and subsequently had to be replaced. It was determined that the failures of the HydroFLOW transponders were due to water getting through a plug on the top of the units directly above the placement of the transponders. Therefore, NWI personnel provided a cover for the transponders to avoid future complications / failures.

On August 13th, an observation was made that the pads on Unit #1, the control, were significantly drier than that of the other three units. The pump feeding the spray bar of the unit had a significant amount of scale build up for a second time during the testing period. This was cleaned and replaced for the remainder of the test. On August 26th, Unit #3, the HydroFLOW only system, also had little to no flow to the spray bar. The pump was removed; the filter was cleaned and replaced as in the previous unit. At this time the general maintenance was not enough to get the unit fully operational and testing was immediately terminated.

Figure 9 shows the condition of the four units tested during this assessment. From a visual perspective, the HF only unit (second from the right) had the least appealing result followed by the combination SS/HF, the SS only, and the control. Upon closer inspection, it was evident that the side stream only (Unit #2) produced a 'flakey' build up shown in Figure 10, unlike the sandy sediment that was observed in the other three units. SEM imaging was performed on both interior and exterior scale specimens of which will be discussed later in this report. Additional images of the equipment (post-test) can be viewed in Appendix B at the end of this report.

Figure 9. Post-test condition of evaporative coolers (L-R: Control, SS, HF, SS/HF).

Figure 10. Close up image of scale flaking in Unit #2 basin (Side Stream Filter Only)

Analyses Performed by C-CDE

Within C-CDE, samples were analyzed using the analytical techniques listed below.

- Total Suspended Solids (TSS) (ASTM D5907-10)
- Total Dissolved Solids (TDS) (ASTM D5907-10)
- Conductivity
- Reactive Silica (Silicomolybdate Method 8185)
- pH
- Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)
- Microtox® (ASTM D5660)
- Scanning Electron Microscopy (SEM) (performed by MST-6 due to instrument failure)

Samples analyzed by C-CDE were obtained at time=0, 1, 2, 3, 6, 8, 12, and 14.5 weeks. Testing apparatus were monitored on a daily basis at start-up and spread out to 2-3 times a week as testing progressed and more data points became available.

3. RESULTS & DISCUSSION

3.1 TSS and TDS Analysis

ASTM D5907-10 method was used to determine TSS and TDS in simulated cooling tower water. Samples were filtered through a weighed glass fiber filter and dried at 105°C, cooled in a desiccator for 1 hour and weighed again to determine the total suspended solids (non-filterable matter). The filtrate collected from each sample was then evaporated at 180°C and dried in an oven at 180°C, cooled in a desiccator for 1 hour and weighed to determine the total dissolved solids (filterable matter). Five hundred milliliters (500mL) of sample were used to obtain the TSS and TDS results.

TSS results in Table 1 show that suspended solids were present in low concentrations in Units #1-#3 throughout the testing with only slight fluctuations in the concentrations on the control and side-stream units. Unit #3 maintained slightly higher TSS concentrations more consistently through the 15 week period in comparison to Units #1 and #2. Make-up water did not contain any measureable quantities except for on two occasions at 2 and 8 weeks, which were less than 0.5mg/L. Unit #4, the side-stream filter and HydroFLOW combination, showed the much higher TSS concentrations starting 1 week into the testing. The values continued to increase with time, until the 8 week measurement that a significant drop occurred to 2.27 mg/L. This may be attributed to the fact that the side-stream filter had no flow on July 6th (week 7) and was replaced at that time. Within the 7 weeks to the end of testing, TSS concentrations reached 119.53 mg/L, which is consistent with the initial 6 weeks of testing where the TSS concentration was measured to be 117.40 mg/L.

Table 1. Total Suspended Solids Results

		Blank - Hydrant	Control	SS	HF	SS/HF
Date	Week	mg/L	mg/L	mg/L	mg/L	mg/L
18-May	0	0.00	2.27	0.93	1.27	1.47
26-May	1	0.00	4.33	1.53	5.60	61.47
1-Jun	2	0.47	2.00	1.80	3.40	233.33
15-Jun	3	0.00	1.93	2.20	3.47	181.40
29-Jun	6	0.00	3.27	2.00	9.33	117.40
13-Jul	8	0.40	17.87	1.87	1.67	2.27
10-Aug	12	0.00	1.87	2.73	5.07	0.40
26-Aug	14.5	0.00	4.87	3.47	1.67	119.53

TDS results show a gradual increase in TDS concentrations as a function of time for all test units. In comparison to the blank (make-up) water concentrations, all units are significantly higher in TDS through the testing period. Based on the results provided in Table 2, the systems with the HydroFLOW transponders were able to maintain lower TDS concentrations throughout testing in comparison to the control and side-stream filter units. The control and side stream only units experienced increasing concentrations throughout the testing; SS/HF and HF only units appear to peak in concentration at 8 and 12 weeks respectively. These two units utilizing side stream filtration and HydroFLOW technology show a total reduction in TDS of approximately 75% for the SS/HF combination and 56% for the HF unit.

Table 2. Total Dissolved Solids Results

		Blank - Hydrant	Control	SS	HF	SS/HF
Date	Week	mg/L	mg/L	mg/L	mg/L	mg/L
18-May	0	162.80	253.07	266.40	222.73	232.80
26-May	1	159.67	658.40	598.53	484.07	253.87
1-Jun	2	156.33	666.27	840.20	657.87	251.07
15-Jun	3	166.67	980.53	1047.47	835.60	283.13
29-Jun	6	214.33	1183.20	1163.47	1055.00	235.47
13-Jul	8	152.07	1781.07	1625.87	1079.40	1192.53
10-Aug	12	141.00	1895.73	2737.53	1500.87	972.60
26-Aug	14.5	155.73	2685.87	2683.20	1208.60	666.47

Conductivity results shown in Figure 11, and listed in Table 3, indicate trends similar to TDS. Make-up water provided by Los Alamos County (LAC) was fairly consistent in the range of 150 uS/cm. While the control unit showed a constant increase in conductivity with time, the three remaining units showed a maximum conductivity value being reached at twelve weeks. The SS only unit shows a more pronounced trend in comparison to the HF only and SS/HF combination as it reached a value of 4250 uS/cm. At the conclusion of testing, in comparison to the control, the side stream filtering system had conductivity values reduced by 25%, the HF only system by ~58%, and the SS/HF combination by 50%.

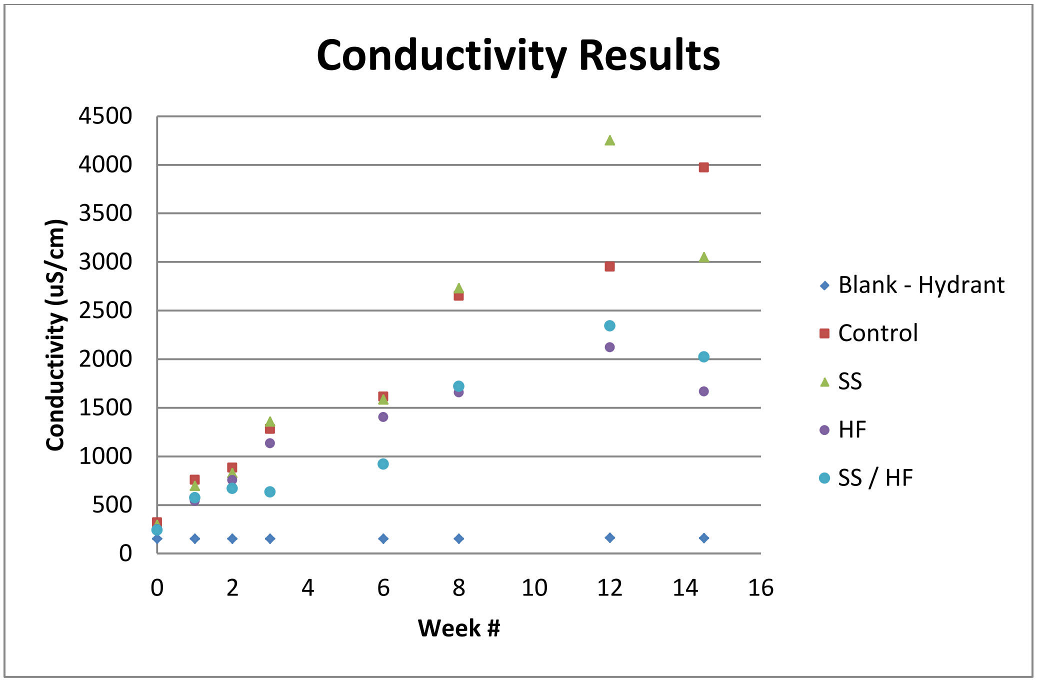


Figure 11. Conductivity Results

Table 3. Conductivity values for make-up water and test units.

		Blank - Hydrant	Control	SS	HF	SS/HF
Date	Week	uS/cm	uS/cm	uS/cm	uS/cm	uS/cm
18-May	0	152.00	318.00	292.00	251.00	240.00
26-May	1	151.30	756.00	696.00	539.00	574.00
1-Jun	2	152.30	881.00	826.00	754.00	668.00
15-Jun	3	151.40	1282.00	1355.00	1133.00	633.00
29-Jun	6	151.10	1614.00	1585.00	1403.00	919.00
13-Jul	8	151.70	2650.00	2730.00	1656.00	1717.00
10-Aug	12	160.00	2950.00	4250.00	2120.00	2340.00
26-Aug	14.5	156.90	3970.00	3050.00	1666.00	2020.00

3.2 Reactive Silica

Reactive Silica is an individual Silica/silicic acid (H_2SiO4^{2-}) moiety available for complexation with a molybdate ion, or a terminal Silica moiety in a polymerizing Silica chain available for complexation with the molybdate ion. The resultant colored complex can be measured using UV/Vis spectrometers. The magnitude of color is loosely related to the concentration of silicomolybdate in solution and, therein, related to the concentration of silica. It is a semi-quantitative method for estimating silica concentrations; however, it is not quantitative for elemental silicon. The polymerization of Silica is a complex reaction, mediated by pH and the presence of other elements (notably transition metals). See: C.H. van der Weijden, 'Cahiers of Geochemistry Silica I: Silicon Analytical, Physical, Terrestrial Geochemistry',Utrecht University, The Netherlands, 2/22/07.

See: https://en.wikipedia.org/wiki/Molybdenum_blue

High Range Silica determination in water was tested using the Silicomolybdate Method 8185 powder pillows ranging from 1 to 100 mg/L SiO_2 on the DR 3900 Benchtop Spectrophotometer. A standard solution of 50 mg/L SiO_2 was used before each test to validate the test procedure, reagents and the instrument. Samples were analyzed in duplicate and corrected for the dilution factors used for sample preparation and analysis. Samples values were averaged and reported in Table 4.

Table 4. Reactive silica results for make-up water and test units.

Date	Week	Blank - Hydrant (mg/L)	Control (mg/L)	SS (mg/L)	HF (mg/L)	SS/HF (mg/L)
18-May	0	91.95	114.50	120.00	113.00	114.50
26-May	1	82.50	146.50	153.50	160.50	169.50
1-Jun	2	83.80	162.00	167.00	171.00	164.00
15-Jun	3	83.60	183.00	196.00	196.00	172.00
29-Jun	6	84.80	128.00	128.50	134.50	135.50
13-Jul	8	83.90	133.00	137.50	134.00	140.50
10-Aug	12	84.40	188.00	220.00	205.00	205.00
26-Aug	14.5	81.00	176.50	207.50	187.50	196.50

3.3 pH Measurements

pH was tracked for the duration of the test and plotted in Figure 12. All samples taken from the coolers show a slight increase over time. Values ranged from 7.47 to 8.36 for clean make-up water, and 8.21 to 9.52 for process waters. As time progressed in testing, the gap in pH gradually widens starting between 6 and 8 weeks. At the conclusion of testing, the gap between the SS only and the HF only ranged from 9.52 to 9.28, with the pH of the HydroFLOW unit being the lowest of all the systems tested. From a LANL perspective, NPDES discharge limits for major cooling towers in the general vicinity of TA-3, have a pH requirements for discharge to outfalls from 6.6-6.8, which is slightly more stringent than those outside of the tech area that can range from 6.0-9.0.

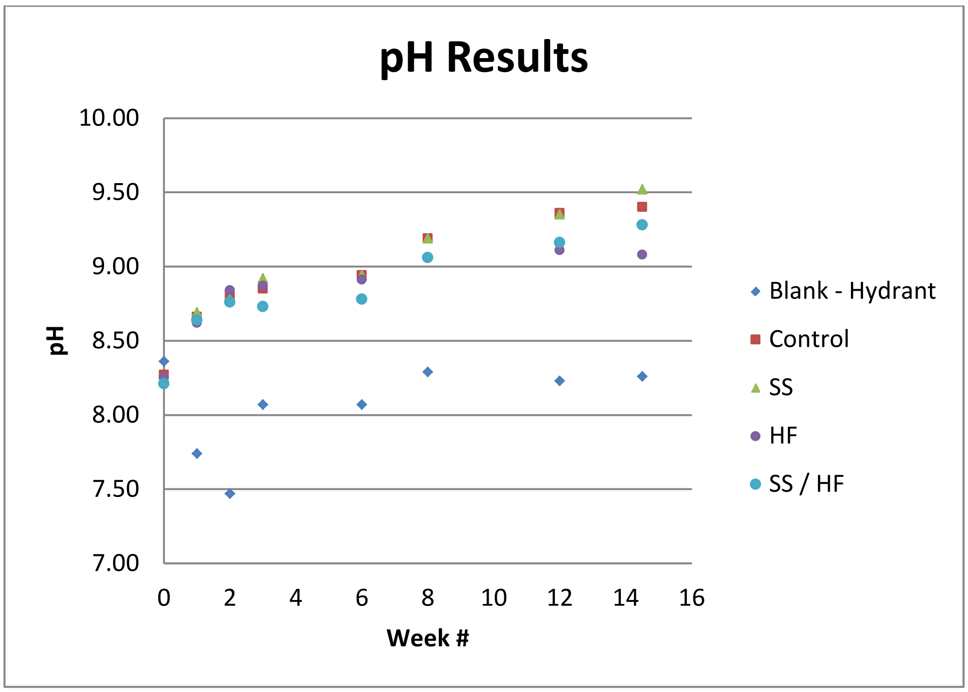


Figure 12. pH Results of evaporative cooler basin water.

3.4 Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)

ICP analysis for 'Total' silicon was performed on samples taken throughout the fifteen week testing period. Samples were not preserved, but held in a refrigerator until analysis. At the time of analysis all samples were acidified with nitric acid and trace hydrofluoric acid. Samples that were taken from the side-stream filter canisters held particulates that were filtered out prior analysis using a 0.7 um filter. *It is possible that the removal of these particulates by filtration impacted correlation of Reactive Silica to Total Silicon.* The material removed via filtration in these samples may impact values for total Silicon, such that reported values for Total Silicon are lower. All other samples were colorless with no particulates. The instrument was calibrated using multiple NIST-traceable standards, including an independent calibration verification standard. Samples were diluted as necessary to bring concentration within the calibration range of the standards. Samples were not digested because there was no particulate. Table 5 summarizes ICP-OES for make-up water, cooling basin water, and residual water taken from the side-stream filter canisters. Make-up water results were stable and averaged 38 mg/L throughout the course of the fifteen weeks. Results show gradual increases in concentration over the initial three weeks of testing for the control, SS and HF units. The combination SS/HF unit does not reach a maximum concentration until approximately week 8. At the termination of testing final concentrations were lower for both units with the HydroFLOW transponder. Finally, there was no difference in concentrations of the residual water removed from the side stream filter canister. Both samples were measured at 64 mg/L.

Table 5. ICP-OES Results.

Date	Week	Blank - Hydrant (mg/L)	Control (mg/L)	SS (mg/L)	HF (mg/L)	SS / HF (mg/L)	DI Water Blank (mg/L)	SS Filter 1 (SS) (mg/L)	SS Filter 2 (SS/HF) (mg/L)
18-May	0	38.00	50.00	52.00	44.00	47.00	<0.1		
26-May	1	38.00	100.00	82.00	75.00	74.00	<0.1		
1-Jun	2	38.00	100.00	95.00	88.00	85.00	<0.1		
15-Jun	3	37.00	104.00	118.00	123.00	69.00	<0.1		
29-Jun	6	38.00	98.00	102.00	91.00	79.00	<0.1		
13-Jul	8	37.00	97.00	105.00	85.00	92.00	<0.1		
10-Aug	12	38.00	91.00	121.00	80.00	80.00	<0.1		
26-Aug	14.5	37.00	119.00	93.00	78.00	77.00	<0.1	64	64

3.5 Microtox® Analysis - Toxicity Screening

Microtox® rapid toxicity detection is a qualitative in vitro test system that uses bioluminescent bacteria for the detection of toxicity in water and is used as a screening system to detect the relative toxicity of a sample. Microtox Screening testing were performed on liquid samples using Strategic Diagnostics Inc's (SDIX) Microtox® M500 to determine the percent effect, or relative acute toxicity of the water in the simulated cooling tower basins. The higher the percent effect, the more toxic the sample is. Per LANL's NPDES permit, samples with a percent effect >50 are not acceptable into the Sanitary Waste Water

System (SWWS). Results from the Microtox screening are compiled in Table 6. Make-up water (Blank-Hydrant) results are consistent throughout the testing period, with the exception of a value of 14.14% on June 1st. The control and side-stream units performed similar throughout the study as indicated by the screening results. With no treatment, the percent effects of Units #1 and #2 were significantly higher than that of Units #3 and #4 treated with the HydroFLOW and the combination of the HydroFLOW and side-stream filter. Early on in testing, the values for the HydroFLOW only system were closer in proximity to the control and side-stream only systems while the combination side-stream filter and HydroFLOW maintained a consistent pattern showing little to no effect until late August.

Table 7. Microtox Screening Results

		Blank - Hydrant	Control	SS	HF	SS / HF
Date	Week	% Effect	% Effect	% Effect	% Effect	% Effect
18-May	0	-6.84	15.22	19.40	2.77	1.32
26-May	1	-1.33	13.85	18.77	10.69	9.26
1-Jun	2	14.14	3.62	4.12	14.59	-0.37
15-Jun	3	-9.01	9.56	5.66	6.86	-2.18
29-Jun	6	-0.07	8.28	12.92	11.51	-3.85
13-Jul	8	-8.40	24.96	22.19	8.51	7.50
10-Aug	12	-3.58	23.63	30.39	6.12	9.55
26-Aug	14.5	1.71	44.37	55.15	15.83	25.01

3.6 Scanning Electron Microscopy (SEM)

Micrographs of scale build up were taken using a FEI Inspect F scanning electron microscope. Samples were taken from the surface of the evaporative cooler pads (Figure 13 a and b) of the unit in addition to the dried sediment within the basins of each unit as seen in Figure 14.

Figure 13 a and b. Post-test images of scale build up on the evaporative cooler pads. a) left - Side-stream filter only Unit #2 and b) right - Control Unit #1

Figure 14. Post-test images of scale and sediment in Unit #4 (SS/HF)

SEM analysis revealed that the surface morphology is consistent amongst all the samples. Units #1-#3 do not show any major difference in the overall structure of the scale/sediment taken from the units. Unit #4, the combination of side stream filtration and HydroFLOW, may show a closer resemblance to the scale build up taken from the hydrant of the clean make-up water supplying the evaporative coolers. SEM micrographs can be seen in Appendix C of this report.

3.7 Weight Gain Analysis

During the assembly and modification of the evaporative coolers, weights were taken of various components of the systems. Table A in Appendix A, provided the pre- and post-test weights for the components as well as a final total weight for each unit. It was found that Unit #4 (SS/HF) had the largest weight gain when totaling the masses of the dry components with a total of 2.8 lb increase, followed by Units #2 (SS) and #3 (HF) which had a total increase of 2.6 lbs, followed by the Unit #1 (control) at 2.5 lbs. The largest areas of weight gain were on the evaporative cooler pads as they have the most surface area available for scale build up. The center pad in particular had more build-up, mainly due to the fact that it is larger than the outer 2 filters. Total assembled unit weights show Units #1 and #2 with the largest total weight gains of 3.4 and 3.3 lbs which, can be attributed to residual water that remained in some of the tubing during the drying process.

Filters from the side-stream filtering apparatus's were removed and allowed to dry. Unit #2 had a total of 3 filters that were used that had mass increases of 30.6, 25.7, and 17.2 grams while Unit #4 had two filters that had mass increases of 45.1 and 37.5 grams. The combination of the side-stream filter with the HydroFLOW transponder was able to filter out 11% more solids with one less filter. Images of the dried filters can be viewed in Appendix B, Figures L-N.

4. CONCLUSIONS

Total suspended solids measurements represented the most noticeable difference amongst the 4 units that were tested in this assessment. The combination of side-stream filtering and the HydroFLOW unit indicates that there is a measurable effect on TSS concentration. Although this was predominant in Unit #4, Unit #3, the HydroFLOW only, did not show any significant difference in overall effect on TSS in comparison to the control and side-stream only units. Total dissolved solids analysis also showed that Unit #4 had the lowest concentration throughout the fifteen weeks of testing. It was determined that in comparison to the control, the side stream filtering system had conductivity values reduced by 25%, the HF only system by ~58%, and the SS/HF combination by 50%. Conductivity results revealed a constant increase in conductivity with time in the control unit, the three remaining units showed a maximum conductivity value being reached at twelve weeks. Final data indicates that the side stream filtering system had conductivity values reduced by 25%, the HF only system by ~58%, and the SS/HF combination by 50% in comparison to the control unit. This observation is important as maintaining lower conductivities in cooling towers allows operation with less frequent blow down cycles, therefor increasing the overall cycles of concentration that a cooling tower can be operated at.

Reactive silica was measured throughout the fifteen week testing period. While test results did not provide any conclusive trend amongst the units being tested, it was observed that all units maintained silica levels within 5-15% at any given time during the fifteen week period.

pH values ranged from 8.21 to 9.52 for process waters during the testing period. At 6 to 8 weeks it was observed that the spread in pH gradually widens between the units. At the conclusion of testing, the spread between the SS only and the HF only ranged from 9.52 to 9.28, with the pH of the HydroFLOW unit being the lowest of all the systems tested. Given LANL's current NPDES discharge limits for pH to outfalls, all units are outside of the broadest allowable range of 6.0-9.0.

Microtox analysis indicated no concerns with the relative toxicity of discharges of circulating water from the testing units. Additionally, SEM analysis revealed no major differences in the scale build up between the units over the fifteen week testing period, although a more "flakey" build up was observed in the side-stream only unit, in comparison to a sand-like sediment.

Finally, this assessment was performed as agreed upon with NWI. No chemical treatment was performed on the control system as would be done on a typical cooling tower. It must be said that Los Alamos ground water is different in the sense that it is naturally high in silica content which poses many issues in the operation and maintenance of cooling towers and blow down lines. In addition, every cooling tower is different and there are various considerations that need to be made when treating cooling towers. Cost analysis considerations for the rate of Return on Investment (ROI), cost of filters, frequency of changing filters, man hours associated with replacement, disposal costs, waste classification, permitting effects and consequences of failure are other issues that strongly need to be considered.

ACKNOWLEDGEMENTS

The Chemical Diagnostics and Engineering Group (C-CDE) would like to acknowledge April Longhair and Adam Pacheco of C-CDE along with Eric Tegtmeier (MST-6) for their contributions to the project.

APPENDIX A

Table A1. Equipment Weights (Pre and Post-Test)

	Unit #1 Control		**Unit #2 Side Stream Only**		**Unit #3 HydroFlow Only**		**Unit #4 Side Stream + HydroFlow**	
Equipment ID	Pre-Test Wt (lbs)	Post-Test Wt (lbs)	Pre-Test Wt (lbs)	Post-Test Wt (lbs)	Pre-Test Wt (lbs)	Post-Test Wt (lbs)	Pre-Test Wt (lbs)	Post-Test Wt (lbs)
Screen	1.5	1.5	1.5	1.5	1.5	1.6	1.5	1.6
Left Filter	1.1	1.7	1.0	1.7	1.0	1.7	1.1	1.8
Center Filter	1.7	2.8	1.7	2.8	1.7	2.8	1.9	3
Right Filter	1.1	1.7	1.0	1.7	1.0	1.6	1.0	1.8
Mounting Bracket (2)	N/A	N/A	1.9	1.9	N/A	N/A	1.9	1.9
SS Filter Housing	N/A	N/A	5.3	5.3	N/A	N/A	5.3	5.3
SS Filter	N/A	N/A	0.8	0.8	N/A	N/A	0.8	0.9
SS Filter (Extra) -2	N/A	N/A	0.8	0.8	N/A	N/A	0.8	0.8
SS Filter (Extra) -3	N/A	N/A	0.8	0.8	N/A	N/A	N/A	N/A
SS Filter (Extra) -4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SS Pump	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
SS Tubing	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Feed Pump	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
HydroFlow Unit	N/A	N/A	N/A	N/A	0.5	0.5	0.5	0.5
Flow Meter	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Heater	0.4	0.5	0.4	0.5	0.4	0.5	0.4	0.5
Sum of All Equipment	8.9	11.4	16.7	19.3	9.2	11.8	17.5	20.3
Total Assembled Unit (Dry)	88.3	91.7	99.4	102.7	89.2	91.8	100.2	103.5

50' Black Hose	12.2	12.2					12.0	12			
6' Leader Hose	1.0	1.0					1.0	1.0			

Table A2. Filter Weights (Pre and Post-Test)

	Unit #1 Control			**Unit #2 Side Stream Only**			**Unit #3 HydroFlow Only**			**Unit #4 Side Stream + HydroFlow**	
Equipment ID	Pre-Test Wt (g)	Post-Test Wt (g)		Pre-Test Wt (g)	Post-Test Wt (g)		Pre-Test Wt (g)	Post-Test Wt (g)		Pre-Test Wt (g)	Post-Test Wt (g)
SS Filter -1	N/A	N/A		341.3	371.9		N/A	N/A		341.2	386.3
SS Filter (Extra) -2	N/A	N/A		340.2	365.9		N/A	N/A		340.2	377.7
SS Filter (Extra) -3	N/A	N/A		342.5	359.7		N/A	N/A		N/A	N/A

APPENDIX B

Post-Test Images of Equipment

Post-test image of evaporative coolers (L-R: SS/HF, SS only, HF only, Control)

Post-test image of Unit #1 basin

Post-test image of scale / sediment in Unit #1 basin

Post-test image of Unit #2 basin

Post-test image of scale flaking in Unit #2 basin

Post-test image of scale / sediment in Unit #3 basin

Post-test image of scale in Unit #3 basin

Post-test image of scale / sediment in Unit #4 basin

Post-test image of scale in Unit #4 basin

Post-test image of scale build up on recirculation pumps

Post-test image of scale build up on recirculation pumps

Post-test image of filters from Unit #2 (Side Stream Only)

Post-test image of filters from Unit #4 (Side Stream w/ HydroFLOW)

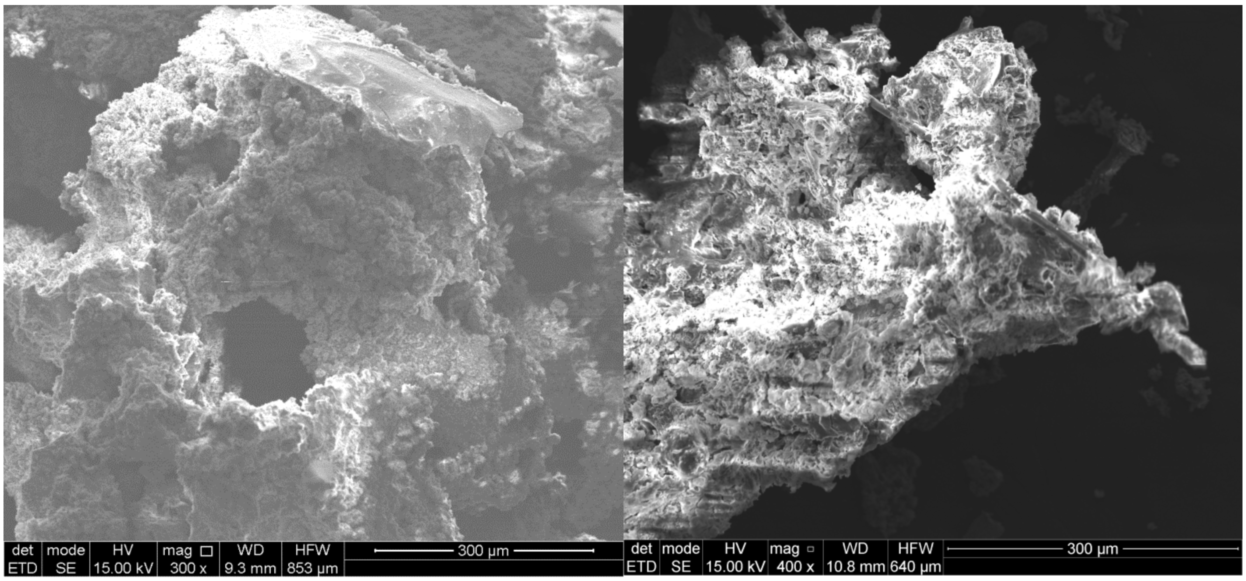
Side-by-side comparison of filters from Unit #2 and Unit #4

Side-by-side comparisons of scale build up on heaters (L-R: New, Control, SS, HF, and SS/HF)

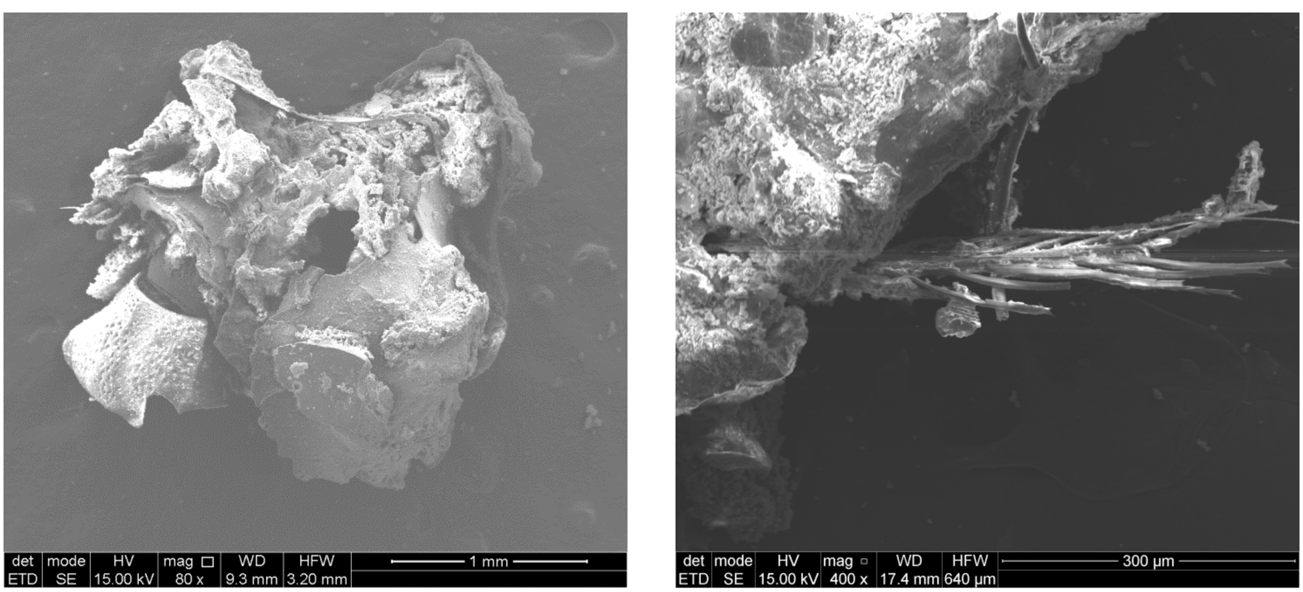
APPENDIX C

SEM Micrographs of Scale Build-Up

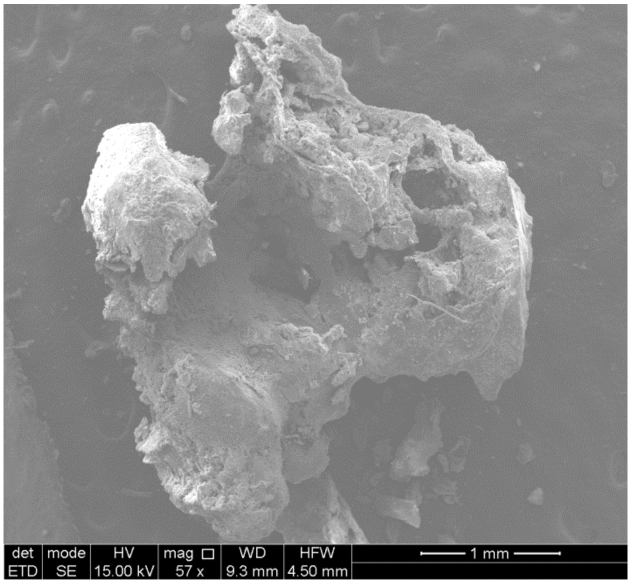
Unit #1 – Control (Left) Exterior scale build-up (Right) Scale residue from basin.

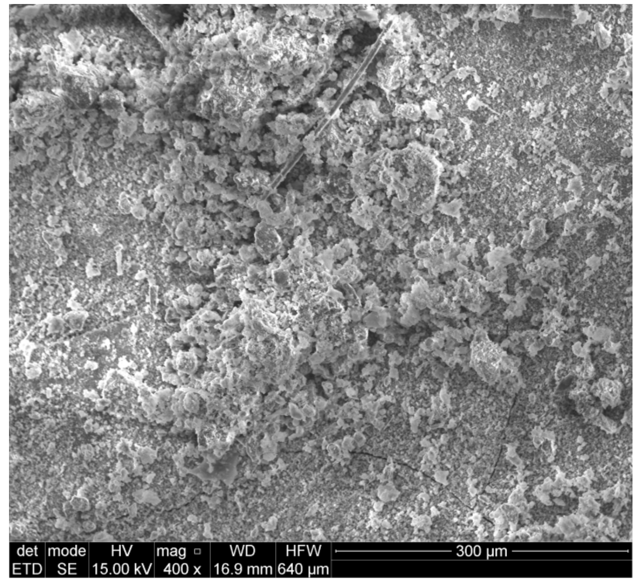


Unit #2 – Side Stream Only (Left) Exterior scale build-up (Right) Scale residue from basin.

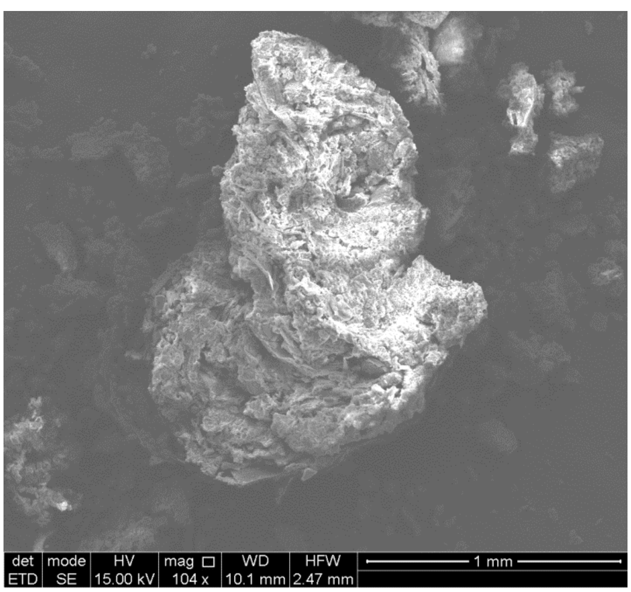


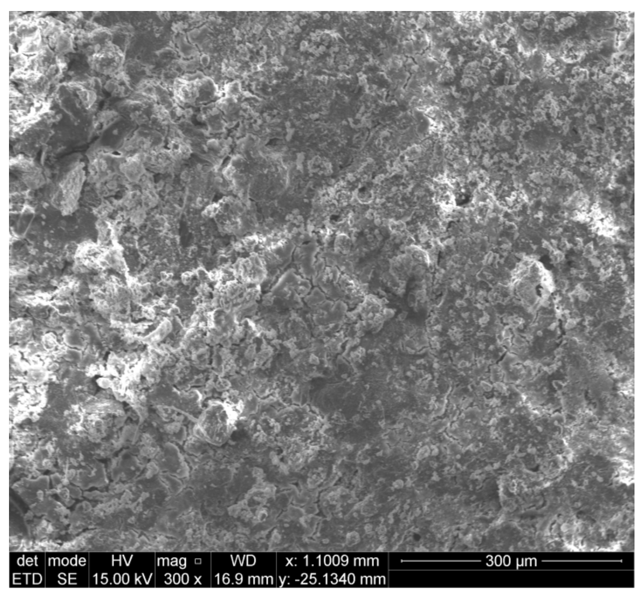
Unit #3 – HydroFLOW Only (Left) Exterior scale build-up (Right) Scale residue from basin.





Unit #4 – Side Stream and HydroFLOW (Left) Exterior scale build-up (Right) Scale residue from basin.





Scale build up taken from make-up water hydrant.