Third-Party Technology Verification of the Hydropath Technology at the Robert W. Hite Treatment Facility, Denver, Colorado

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Scope and Purpose

The primary objective of this independent, third-party technology verification is to validate the effectiveness of the *Hydro*FLOW I Range product with respect to controlling struvite scaling at selected test sites. The verification is based on a review of sampling data, visual observations, and discussion with plant staff, and focuses on identifying changes to struvite scaling before and after installing *Hydro*FLOW units. During the testing period, no effort was made to investigate the mechanism that allows *Hydro*FLOW units to prevent scale accumulation. *Hydro*FLOW USA intends to examine the mechanism in 2018.

This technical memorandum specifically discusses the verification testing completed at the Robert W. Hite Treatment Facility (RWHTF) in Denver, Colorado, and the observed outcome.

Technology Description

The *Hydro*FLOW I Range uses Hydropath technology. When properly installed on a pipe (see Figure 1), it induces a 150 kilohertz, oscillating sine wave, alternating current (AC) signal. The electric induction is performed by a special transducer connected to a ring of ferrites. The pipe and the flowing fluid act as a conduit, which allows the signal to propagate. The induced AC signal is believed to cause the mineral ions that make up struvite (magnesium, ammonium, and phosphate) to form loosely held together clusters. When certain conditions are created (e.g., pressure change, temperature change, and turbulence) the clusters precipitate out of solution and form stable crystals of struvite that remain in suspension and are not able to adhere to surfaces as hard scale; the crystals are carried away with the flow. Because hard scale no longer accumulates, the shear forces created by the flowing liquid erode and soften existing scale deposits over time. It is important to note that constant liquid flow is required to remove hard scale deposits from a system.

Figure 1. Typical *Hydro*FLOW Unit Installation

Robert W. Hite Treatment Facility Description

The RWHTF (see Figure 2), is owned and operated by the Metro Wastewater Reclamation District in Denver, Colorado. The RWHTF was constructed in 1966, is rated at 220 million gallons per day (mgd) and is the largest facility in the Rocky Mountain West region. The RWHTF treats, on average, 135 mgd for a service population of more than 1.8 million people.

Figure 2. The Robert W. Hite Treatment Facility

The RWHTF has two liquid stream train plants (north and south) each consisting of screening, grit removal, primary clarification, activated sludge basins configured to achieve nutrient removal, secondary clarification, and disinfection. The primary sludge and waste-activated sludge (WAS) from the two plants are combined and processed in a single solids stream that includes gravity thickening for primary sludge, dissolved air floatation thickening for WAS, two-stage anaerobic digestion, centrifuge dewatering, and land application of Class B biosolids.

Scale accumulation that is believed to be a combination of struvite and other amorphous mineral deposits occurs at certain locations, especially in the centrate and digester piping.

Test Details

The Metro Wastewater Reclamation District (MWRD) and *Hydro*FLOW USA signed a memorandum of understanding to participate in a 60-day product evaluation test at the RWHTF to determine the effectiveness of the Hydropath technology in mitigating scale formation.

In addition, a site-specific test protocol was jointly developed by CH2M, MWRD, and *Hydro*FLOW USA that outlines details of the tests. The test protocol provided a consistent framework and guidance for testing so that the results could be used for the third-party technology verification by CH2M. Seminal information from the protocol is presented in the following sections.

Test Period

The test period was agreed to be for 60 days, with a provision to negotiate an extension, if desired by the RWHTF. Testing began 1 March 2017.

*Hydro*FLOW Unit Installation

As shown on Figure 3, the plant's centrate conveyance system consists of the following components:

- Centrate piping (8-inch, glass-lined, ductile iron)
- Foam tank
- Transfer pump
- Centrate holding tank

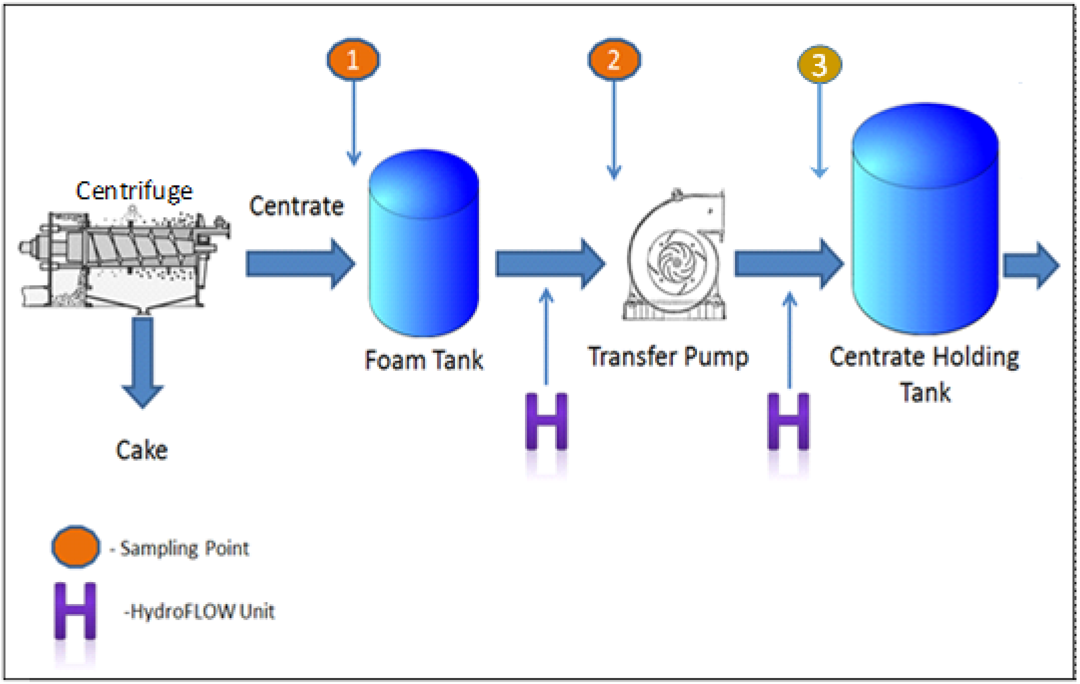


Figure 3. *Hydro*FLOW Unit Locations and Sampling Points

From the operating centrifuges, centrate flows to the foam tank before being pumped to the centrate holding tank. There are two centrate transfer pumps (one duty pump and one stand-by pump). The duty transfer pump was used to determine the impact of the *Hydro*FLOW units. Centrate is transferred continuously, 24 hours per day, everyday.

*Hydro*FLOW units were installed at two locations (see Figure 3).

- *Hydro*FLOW Unit 1: Suction side of the transfer pump
- *Hydro*FLOW Unit 2: Discharge side of the transfer pump, between *Hydro*FLOW Unit 2 and the centrate holding tank

Sampling Locations

According to RWHTF staff, three primary sampling locations have been identified (see Figure 3):

1. Sampling Point 1: Upstream from the foam tank
2. Sampling Point 2: Suction side of the transfer pump
3. Sampling Point 3: Upstream from the centrate holding tank

Baseline Condition

Before activating the *Hydro*FLOW units, baseline information was gathered at the transfer pump and the pump discharge pipe at a location upstream of the second *Hydro*FLOW unit. The baseline information characterized the extent of scaling and included thickness and other visual observations, photographs of the scaled surfaces, and samples of the scale. To observe scale accumulation trends, a portion of the scaled surface was cleaned before energizing the *Hydro*FLOW units.

To fully assess the effectiveness of the Hydropath technology, the addition of dilution water to the foam tank was discontinued during testing.

Sampling and Analysis

Weekly samples were collected from the three sampling locations and analyzed for the following parameters:

- Soluble ions (magnesium, potassium, sodium, calcium, and iron)
- Total ions (magnesium, potassium, sodium, calcium, and iron)
- Ortho-phosphate
- Total phosphorus
- pH
- Ammonium
- Conductivity

In addition, visual observations were noted and photographs taken of the transfer pump and pump discharge pipe surfaces, as shown in Table 1. This was done three times at the transfer pump, but only twice at the pump discharge pipe, because of the inability to isolate the centrate pipe.

Table 1. Visual Observation of Scale Accumulation

Action	Pump Suction	Pump Discharge Pipe[a]
When Performed	Start (baseline), Middle, and End of Testing	Start (baseline) and End of Testing
Visual Observation	X	X
Scale Thickness Measurement	X	X
Photographs	X	X

[a] Upstream from *Hydro*FLOW Unit 2

Results

Review of Sampling Data

A good indication of struvite formation is the change in soluble concentrations of its key constituents: magnesium, ammonium, and phosphate (ortho-phosphate). As shown on Figures 4, 5, and 6, these parameters did not exhibit any appreciable change between Sampling Points 1 and 3 during the sampling period (1 March through 26 April 2017), which implies there was no struvite formation or scaling.

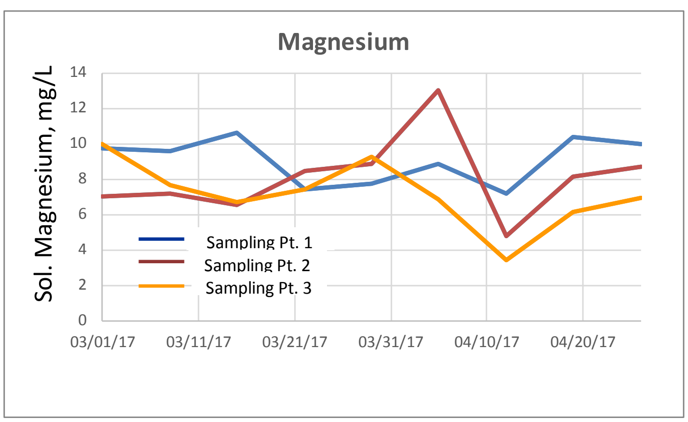


Figure 4. Soluble Magnesium Concentration Profile

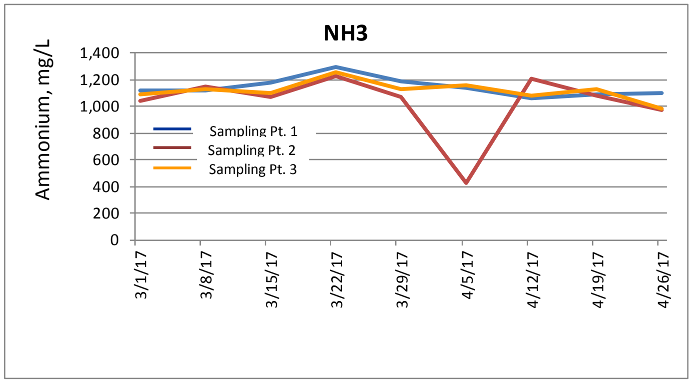


Figure 5. Ammonium Concentration Profile

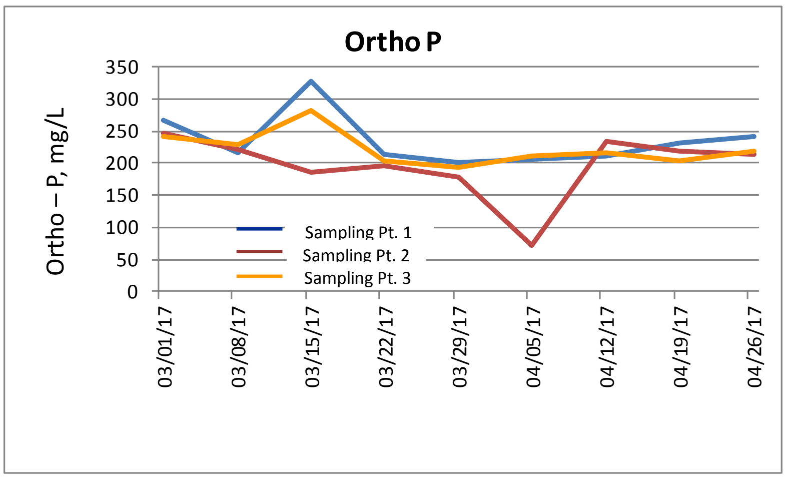


Figure 6. Ortho-phosphate Concentration Profile

The variation in data is due to systematic and random errors. Systemic errors may be due to an imperfectly made instrument or to the personal technique and bias of the observer. Random errors are due to unknown causes and usually follow the laws of chance. Averaging the data will resolve some of the errors.

A review of the average values over the sampling period (see Table 3) shows that although concentrations and pH were favorable for struvite formation, this did not occur and the concentration profiles of the three soluble components remained relatively flat at the three sampling points. If struvite formation had occurred in the test segment, soluble concentrations would have declined between Sampling Points 1 and 3.

Table 3. Average Concentrations of Struvite Constituents and pH Values

Parameter	Upstream from Foam Tank (Sampling Point 1)	Pump Suction (Sampling Point 2)	Upstream from Holding Tank (Sampling Point 3)
Soluble magnesium, mg/L	9.05	8.08	7.15
Ammonium, mg/L	1,143	1,028	1,117
Ortho-phosphate, mg/L	235	196	222
pH	8.1	8.0	8.0

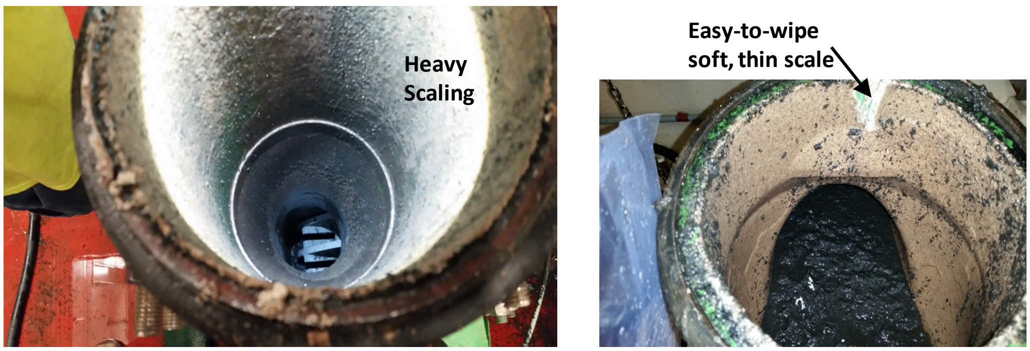
Note:
mg/L = milligrams per liter

The full dataset provided in Attachment 1 shows that the concentration profiles of other measured constituents also remained relatively flat.

Visual Observations

The RWHTF staff made visual observations and took photographs of the scale formation before activating and after energizing the *Hydro*FLOW units. The "before" observations represent the baseline condition and provide a basis for making a qualitative determination of the effectiveness of the *Hydro*FLOW units. Two locations that typically experience nuisance scaling were targeted for this comparison: (1) the transfer pump and (2) the pump discharge pipe.

The baseline condition for the transfer pump (photograph dated 27 Sept 2016 in Figure 7), shows heavy struvite encrustation, which typically causes plant operators to take the unit offline for acid cleaning twice a year. The photograph dated 27 April 2017 shows softer and thinner scale that can be easily wiped off.



27 Sept. 2016 — Before

27 April 2017 — After

Figure 7. Before and After Photographs of the Transfer Pump

The before and after photographs of the pump discharge pipe between the transfer pump and second *Hydro*FLOW unit are shown on Figure 8. The "before" photograph dated 27 Sept 2016 shows heavy scaling and reduced pipe inside diameter. The photograph dated 1 March 2017, before the test, shows the section of hard struvite that was cleaned to exposed the green, glass-lined pipe. The "after" photograph, dated 27 April 2017 shows the following:

- The clean section of the pipe remained clean, with no new struvite deposition.
- Some of the hard struvite had been gradually removed to further expose the pipe.
- The remaining struvite scale had become softer and thinner.

27 Sept. 2016 | 1 March 2017 | 27 April 2017

Figure 8. Before and After Photographs of the Transfer Pump Discharge Pipe

In general, RWHTF staff reported the following observations at the transfer pump and discharge pipe locations:

- Before the test, the scale was thick (approximately 1/8 inch), hard, and greyish in color. It was possible to collect large pieces of hard scale.
- Sixty days into the test, the scale was softer and thinner, with some areas of the surface becoming visible. The scale samples broke into smaller pieces.
- At the end of the test, the scale was significantly thinner, making it impossible to collect a scale sample. An increasing amount of surface was exposed.

Conclusion

The centrate conveyance system at the RWHTF, particularly the transfer pump and pipe, experience scaling, which requires that the system to be periodically taken offline for cleaning. Two units of the *Hydro*FLOW I Range were installed on the centrate line to evaluate their effectiveness in controlling scaling. Targeted sampling during the 60-day test period included sample collection and analysis and observations of scale characteristics before and after the *Hydro*FLOW units. Based on the review of the data and discussion with RWHTF staff, the use of *Hydro*FLOW I Range on the centrate line was effective in softening the existing scale and preventing the formation of new scale. Softening of the existing scale allowed a substantial portion of the original hard scale to be removed during the 60-day test period, because of the shearing action of the flowing liquid.

This technical memorandum verifies that the use of *Hydro*FLOW I Range units at the RWHTF prevented scale formation in the centrate transfer pump and pipe. The *Hydro*FLOW units also caused changes in the characteristics of the existing scale, making it easy to be removed by the flowing liquid. It should be noted that following the test, RWHTF purchased and installed four *Hydro*FLOW units on the centrate and digested sludge lines.

Disclaimer

This technical memorandum is not a global validation of *Hydro*FLOW I Range and provides no assurance that it will be successful in mitigating scaling at other water resource recovery facilities.
CH2M recommends that other facilities interested in using *Hydro*FLOW units to mitigate scale formation, conduct onsite testing to validate its effectiveness under plant-septic conditions. Such tests are valuable in demonstrating technical and financial feasibility of implementing *Hydro*FLOW. CH2M understands that *Hydro*FLOW USA has a limited number of rental units that it uses for trials. The availability of the rental equipment should be discussed directly with *Hydro*FLOW USA.

Acknowledgment

This technology verification was made possible through the assistance of Edyta Stec-Uddin/RWHTF and Jim McQuarrie/RWHTF, who were involved in data collection and overall coordination. Heat Waves Water Management LLC (the regional *Hydro*FLOW USA representative) provided and installed the test units. This study was funded by *Hydro*FLOW USA and Hydropath Technology, Ltd.

Attachment 1
Summary Data

Attachment 1. Summary Data

Date (d/m/y)	Upstream from Foam Tank pH	Pump Suction pH	Upstream from Holding Tank pH	Upstream from Foam Tank Conductivity	Pump Suction Conductivity	Upstream from Holding Tank Conductivity	Upstream from Foam Tank Ammonia	Pump Suction Ammonia	Upstream from Holding Tank Ammonia	Upstream from Foam Tank Ortho-phosphate	Pump Suction Ortho-phosphate	Upstream from Holding Tank Ortho-phosphate	Upstream from Foam Tank Total Phosphorus	Pump Suction Total Phosphorus	Upstream from Holding Tank Total Phosphorus	Upstream from Foam Tank Dissolved Calcium	Pump Suction Dissolved Calcium	Upstream from Holding Tank Dissolved Calcium	Upstream from Foam Tank Dissolved Iron	Pump Suction Dissolved Iron	Upstream from Holding Tank Dissolved Iron	Upstream from Foam Tank Dissolved Potassium	Pump Suction Dissolved Potassium	Upstream from Holding Tank Dissolved Potassium
3/1/17	8	7.9	8.1	9020	8220	8420	1120	1040	1090	266	246	241	275	267	271	40.7	27.5	27.3	0.153	0.133	0.136	273	258	259
3/8/17	8.2	8	8.1	8240	8940	9080	1120	1150	1130	215	220	229				37.4	31.9	30.3	0.118	0.124	0.136	254	261	262
3/15/17	7.9	7.9	7.9	9090	8500	8700	1180	1070	1100	327	185	283		230		38.1	27.7	27.7	0.215	0.162	0.196	269	237	240
3/22/17	8	7.9	7.9	8680	8460	8870	1290	1230	1250	213	195	203	227	232	227	38.6	33.7	32.3	0.169	0.14	0.155	267	243	250
3/29/17							1190	1070	1130	201	177	193	201	189		40	34.2	35.4	0.133	0.125	0.123	242	223	229
4/5/17	8.2	7.8	8.1	8770	3710	9000	1140	430	1160	205	71.7	210	219	72.7		42.3	34.4	36.9	0.158	0.133	0.145	246	95.5	245
4/12/17	8	8	8	8610	9240	9010	1060	1210	1080	212	233	215	212	262		35.3	27.6	26.5	0.126	0.157	0.189	246	279	258
4/19/17	8.2	8.1	8	8430	6550	8490	1090	1080	1130	232	219	204	241	234	242	42.5	39	36.7	0.184	0.154	0.166	260	272	280
4/26/17	8	8	8	8920	8000	8120	1100	973	985	242	213	218	251	230	230	40	34.7	34.9	0.167	0.109	0.114	285	247	253
Average	8.1	8.0	8.0	8720	7703	8711	1143	1028	1117	235	196	222	232	215	243	39	32	32	0.158	0.137	0.151	260	235	253

Date (d/m/y)	Upstream from Foam Tank Dissolved Magnesium	Pump Suction Dissolved Magnesium	Upstream from Holding Tank Dissolved Magnesium	Upstream from Foam Tank Dissolved Sodium	Pump Suction Dissolved Sodium	Upstream from Holding Tank Dissolved Sodium	Upstream from Foam Tank Total Calcium	Pump Suction Total Calcium	Upstream from Holding Tank Total Calcium	Upstream from Foam Tank Total Iron	Pump Suction Total Iron	Upstream from Holding Tank Total Iron	Upstream from Foam Tank Total Potassium	Pump Suction Total Potassium	Upstream from Holding Tank Total Potassium	Upstream from Foam Tank Total Magnesium	Pump Suction Total Magnesium	Upstream from Holding Tank Total Magnesium	Upstream from Foam Tank Total Sodium	Pump Suction Total Sodium	Upstream from Holding Tank Total Sodium
3/1/17	9.76	7	10	106	102	106	38.3	49.4	37.9	0.81	11.7	6.55	264	238	250	11	11.1	11.3	106	100	103
3/8/17	9.58	7.15	7.69	109	109	109	43.7	55.2	152	4.38	7.07	33.3	258	270	284	15.7	13	11.4	118	117	121
3/15/17	10.6	6.54	6.67	107	105	106	45.8	100	117	4.24	38	46.9	261	247	255	13	17.5	19	112	115	115
3/22/17	7.43	8.49	7.41	108	108	107	46.4	49.2	93.9	5.35	8.89	24.4	250	237	247	11.2	11.4	18.7	103	105	105
3/29/17	7.77	8.87	9.27	104	106	104	54.1	56.1	34.9	4.64	8.46	0.679	239	226	216	19.8	16.2	13.4	105	108	101
4/5/17	8.84	13	6.85	103	100	106	43.3	34.6	41.5	0.891	0.249	0.951	244	95.7	240	11.9	13.6	11.9	107	99	107
4/12/17	7.16	4.82	3.44	107	109	109	53.9	99	200	6.98	34.7	81.5	237	271	269	12.9	16.2	28.7	102	104	108
4/19/17	10.4	8.16	6.14	105	105	107		40.2	53.3		3.2	5.76		258	267		11.2	15.3		103	104
4/26/17	9.95	8.68	6.91	111	107	110	38.1	42.9	35.8	0.678	2.67	1.06	274	239	243	10.7	11.7	10.1	106	104	105
Average	9.05	8.08	7.15	107	106	107	45	59	85	3.50	12.77	22.34	253	231	252	13	14	16	107	106	108