Tracer Study Report
Lockheed Martin Middle River Complex
2323 Eastern Boulevard,
Middle River, Maryland

Prepared for:

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ACRONYMS AND ABBREVIATIONS

CB	catch basin
DO	dissolved oxygen
°F	degrees Fahrenheit
gph	gallon(s) per hour
gpm	gallon(s) per minute
in. Hg	inches of mercury
IW	injection well
lbs	pounds
Lockheed Martin	Lockheed Martin Corporation
mg/L	milligram(s) per liter
mL/min	milliliters per minute
MP	metering pump
MRC	Middle River Complex
NMW	new monitoring well
O&M	operations and maintenance
ORP	oxidation-reduction potential
PLC	programmable logic controller
psig	pound(s) per square inch gauge
SDS	safety data sheet
TCE	trichloroethene
Tetra Tech	Tetra Tech, Inc.
USEPA	United States Environmental Protection Agency
UST	underground storage tank

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Section 1
Background

On behalf of Lockheed Martin Corporation (Lockheed Martin), Tetra Tech, Inc. (Tetra Tech) has performed a

- determine if injected material is being transported from the injection areas via flow through utilities or utility bedding, and if such transport is occurring, determine how to prevent it from occurring during the groundwater response action

- test and confirm the full functionality of the injection system, including the process equipment, controls, and communications

This report provides the results of the tracer testing in the following two areas:

- southwestern chlorinated volatile organic compounds area (Block G)

- northern chlorinated volatile organic compounds area (Block I)

Tracer testing was performed using treated pH-adjusted potable water with added sodium-bromide tracer and the same processing equipment and controls as will be used in the enhanced anaerobic bioremediation work. Testing also included process equipment startup, communications testing, and de-bugging.

Section 2

General Approach and Methodology

Tracer testing in each area consisted of the following general components:

a) The injection equipment containers were placed in the Block G and Block I test areas as shown on Figures 2-1 and 2-2. (Tracer testing will be performed in Block E after contamination issues associated with the underground storage tanks (UST) encountered in Block E have been resolved.)

b) The underground injection lines, potable-water line, and power supply were connected to the equipment containers.

c) Baseline performance-monitoring sampling was performed, including bromide sampling.

d) Process equipment, controls, and communications were configured and tested.

e) Test injections were performed using water (with chlorine and dissolved oxygen removed), tracer, and [illegible] buffer (sodium bicarbonate). Specific test co[illegible]

2.1 LOGISTICS AND EQUIPMENT

Tracer test equipment and logistics were selected to ensure safety during field procedures, and to minimize risk while achieving the stated test objectives. The following steps summarize general logistics and equipment used for tracer testing:

1) Injection-equipment modules designed to perform full-scale injection events were used for tracer injection. Two equipment modules were used for the tracer tests.

2) Tracer tests were performed simultaneously in Blocks G and I. The equipment modules were positioned as shown on Figures 2-1 and 2-2.

3) For each tracer test, the pH adjustment tank (T-2) in the equipment module was filled with 330 gallons of treated potable water; sodium bromide tracer was then placed in tank T-2. Sodium bromide is a nontoxic tracer commonly used for groundwater studies. Refer to Appendix E of the O&M manual (Tetra Tech, 2014) for the sodium-bromide safety data sheet (SDS).

4) Sodium bicarbonate buffer was also added to [illegible]

9) Injection equipment operated automatically, with little involvement from the system operator. However, field personnel monitored injections at least three times during the first week of operation in each area, and then weekly for the remaining study period.

2.2 BROMIDE SAMPLING PROCEDURE

The results of the bromide tracer analyses will be used to estimate the effects injection has on the aquifer, and to determine if transport via site utilities is occurring. This information will be used to finalize the full-scale injection events. Collecting representative groundwater samples is therefore important for tracer analyses, so a standard low-flow sampling

Samples from utilities were collected by filling the sample bottle directly from the water flowing in the utility; field parameters were not collected for those samples.

The samples were shipped to a fixed-based laboratory (Analytical Laboratory Services, Middletown, Pennsylvania) to be analyzed for bromide using United States Environmental Protection Agency (USEPA) Method 300.0 ("Anions, Ion Chromatography"). The method detection-limit for bromide samples was 0.050 milligrams per liter (mg/L). Samples were collected in 250 milliliter (mL)-unpreserved plastic bottles, and were shipped on ice. Samples were analyzed within method-specific holding time of 28 days.

Section 3
Block G Tracer Testing

Groundwater levels in existing monitoring and injection wells near the active injection location were manually measured before tracer testing began. Groundwater levels within these wells were also measured three times during the first week of each injection event, and weekly thereafter.

3.3 INJECTION SOLUTION PREPARATION

The following procedure was used to prepare the injection solution in tank T-2 during Block G tracer testing:

1) T

1-1.5 gpm (seven wells connected). Metering pump MP-2 was activated to begin injection of tracer solution from tank T-2 into the injection manifold. Settings for metering pump MP-2 are described above in Section 3.3.

The entire full-scale design volume (6,400 gallons per well, or approximately 44,000 gallons total) was injected during the first injection event. The average flow rate was 0.19 gpm per well, over a 24-day duration. The injection event was finished on May 27, 2014. The entire volume of tank T-2 (approximately 330 gallons) containing 55-lbs of sodium bromide tracer and 75-lbs of sodium bicarbonate was injected by metering pump MP-2 into the treated water stream; the average concentrations of tracer (sodium bromide) and buffer (sodium bicarbonate) were 150 mg/L and 205 mg/L, respectively. The site operator visited the site at least three times during the first week of testing, then weekly thereafter.

Injection event #2 began on June 9, 2014. Injection wells IWW-30, IWW-31, IWW-33, IWW-35, IWW-36, IWW-38, and IWW-39 were connected for this event. A similar (as compared to first injection event) injection solution (sodium bromide and sodium bicarbonate) was prepared in tank T-2. The system was re-activated, and the second injection event was performed. The average flow rate during the second injection event was 0.14 gpm per well, over a duration of 30 days. This injection event was finished on July 10, 2014.

3.5 SUMMARY OF RESULTS – INJECTION EVENT #1

This section summarizes the results of the first injection event. Injection-system process parameters (injection rates, pressures), injection wells parameters, the formation hydraulic response, and bromide tracer results follow.

3.5.1 Process Parameters for Injection Event #1

The Block G injection system operated intermittently between April 23-28, 2014, but was shut down due to problems with programmable logic controller (PLC) software. The PLC software problems were fixed, and the system resumed continuous operation on May 6, 2014 until the end of event on May 27, 2014.

System process parameters for the first injection event are summarized in Table 3-1. The parameters discussed below are presented in the flow direction starting at the upstream parameters.

The potable water pressure was stable during the entire injection event, and ranged from 73 to 76 pound(s) per square inch gauge (psig) [Table 3-1, first data column]. This pressure was in excess of the required injection pressure, and was reduced using pressure regulator PR-1.

The outlet pressure for pressure regulator PR-1 (same as GAC-1 inlet pressure) was adjusted to approximately 10 psig; it remained near this level throughout the injection event (Table 3-1, second data column). The GAC-1 outlet pressure (same as filter PF-1 inlet pressure) varied mostly from 5 to 6.5 psig, indicating that no clogging occurred across the carbon bed (Table 3-1, third data column). Outlet pressure for filter PF-1 varied between 6.5 and 8 psig, indicating that no clogging occurred across the filter (Table 3-1, fourth data column). The filter-outlet pressure was slightly higher than the upstream outlet pressure at GAC-1, because the pressure gauge was mounted lower than at the GAC-1 outlet.

The injection manifold pressure was consistently moderate (mostly between5 and 6 psig) during the injection event [Table 3-1, fifth data column]). The injection pressure was maintained as consistently as possible

Based on the reading of the mechanical flow totalizer (Table 3-1, eighth data column), a total volume of 44,765 gallons was injected during the first injection event (6,395 gallons average per injection well). This is very close to the injection volume for the full-scale groundwater treatment in Block G (6,400 gallons per injection well).

The electronic flow-meter FMT-1 indicated a slightly lower total injection volume of 41,865 gallons during the first injection event (Table 3-1, ninth data column). The volume of the tracer solution tank (330 gallons, with 55 lbs sodium bromide and 75 lbs sodium bicarbonate) was injected uniformly over the event (Table 3-1, tenth data column).

3.5.2 Injection Wells Parameters for Injection Event #1

The parameters for individual injection wells include the manifold branch injection pressure (measured downstream of the flow regulating valve), the actual wellhead pressure, and the injected volume, as measured by the flow totalizer at each injection well (Table 3-2).

The manifold branch injection pressures (measured on individual injection lines downstream of the flow-reducing regulating valve) ranged from 0-3.5 psig, and the average value for all wells was 1.8 psig. This parameter is important as it represents the actual line pressure applied to individual injection wells. The injection pressure -3.5 psig and 5u.5 0 Tdalluni (va)4e

6,045 gallons based on totalizer FT-1 reading. The full-design injection-volume per well is 6,400 gallons. Well IWW-37 received the least flow; it operated intermittently due to a plumbing problem which was fixed after the first injection event was finished.

3.5.3

the lower permeability of shallow soil, and higher horizontal conductivity of the formation (as compared to a vertical direction in the formation).

Groundwater levels in several

adjusted higher on July 1 and July 7, 2014 to compensate for decreasing pressure at the GAC-1 outlet.

Outlet pressure at GAC-1 (same as filter PF-1 inlet pressure) mostly varied from 4.5 psig at the start of the event to 3.0 psig on July 1, 2014. The pressure differential across the GAC-1 unit increased to 14 psig by the end of injection event, indicating that clogging occurred across the carbon bed (Table 3-5, third data column). The potable water source was very turbid, and likely contained suspended solids that caused GAC-1 clogging. Measures will be taken to address this issue during full-scale groundwater treatment, and will include carbon bed backwash or replacement, and possibly additional filtration at the GAC-1 inlet.

The outlet pressure at filter PF-1 varied from 5 to 7 psig during the injection event, indicating that no clogging occurred across the filter (Table 3-5, fourth data column). The outlet pressure was slightly higher than that of the (upstream) GAC-1 outlet, because the pressure gauge at filter PF-1 was mounted lower than on the gauge at the GAC-1 outlet.

The injection manifold pressure mostly ranged between 2 and 5 psig during the injection event #2 (Table 3-5, fifth data column).

The total injection rate (as measured by electronic flow-meter FMT-1) typically ranged between 0.5 and 1.1 gpm during this injection event (Table 3-5, sixth data column), with an average of approximately 0.14 gpm per injection well. This injection rate is lower than what was achieved during the first injection event due to GAC-1 clogging and correspondingly lower injection pressure.

The vacuum applied to the hollow membrane contactor MC-1 ranged from 23.5 to 24.5 in. Hg, and is sufficient to remove the bulk of dissolved oxygen from the aqueous stream (Table 3-5, seventh data column).

Based on the readings from the mechanical flow totalizer (Table 3-5, eighth data column), 41,405 gallons of fluid was injected into seven wells during the second injection event, an average of 5,915 gallons per injection well. This is slightly lower than the injection volume for full-scale groundwater treatment in Block G (6,400 gallons per injection well), and is likely due to an insufficient injection rate at well IWW-35 (see discussion in the following section).

Without well IWW-35, the average injection volume per well is 6,643 gallons which is very close to the design injection volume (6,400 gallons).

Electronic flow-meter FMT-1 indicated a slightly lower total injection volume (39,332 gallons) for the second injection event (Table 3-5, ninth data column). The entire volume of tracer solution (330 gallons, with 55 lbs sodium bromide and 75 lbs sodium bicarbonate) was injected uniformly during the event (Table 3-5, tenth data column).

3.6.2 Injection Wells Parameters for Injection Event #2

The individual injection wells parameters for the second injection event in Block G are summarized in Table 3-6.

ash1p2(he0.337o( )i)-20(

Injection pressures for the manifold branch (as measured on individual injection lines downstream of the flow-reducing regulating valve) ranged from negative to 2.0 psig t5d831.91 1A5,

3.6.3 Formation Hydraulic Response for Injection Event #2

As indicated in Section 3-2, the hydraulic response of the formation was monitored via pressure transducers placed within several injection wells, and via manual gauging of idle injection- and available monitoring- wells.

During the second injection event, transducers were installed in wells IWW-32, IWW-34, IWW-37 and SWMW-5I (Figure 2-1) approximately five to 10 feet below the static water level, and recording frequency was set to five minutes. To ensure data quality, wells containing transducers were not sampled or otherwise disturbed.

The measurements recorded by the transducers in wells IWW-32, IWW-34, IWW-37 and SWMW-5I are presented on Figures 3-5 through 3-8, respectively. The results are shown as the positive changes in hydrostatic pressure relative to the baseline (shown as a zero value) before the injection event began. System shutdowns and re-starts are also indicated on these graphs.

Similar to first injection event, transducer measurements in the second event indicated that all four wells responded very quickly to injection. For example, the hydrostatic pressure in well SWMW-5I (Figure 3-8) increased by approximately two feet after only two hours of injection. Similarly, rapid hydraulic response was observed in all wells after the system was turned off; the hydrostatic pressure in all wells decreased by several feet within several hours of the system shutdowns, and the hydrostatic pressure of the formation returned to a level close to its pre-injection level within several days after the end of injections (Figures 3-5 through 3-8). The effects of GAC-1 clogging, and subsequent system adjustment events (pressure and flow decreases, and then an increase after adjustment) can be seen on all graphs. As described earlier, these events occurred at the end of the second injection event. Similar to the first event, this rapid hydraulic response is indicative of a limited storage in the formation, and thus limited mounding of the groundwater table.

The overall magnitude of a hydraulic response in wells IWW-32, IWW-34, IWW-37 and SWMW-5I during the second injection event was similar to the first, and ranged between four and

1-3 feet). However, similar to the first event, day-lighting or preferential channeling into the low-laying areas such as the swale or low-laying spots in Block G was not observed. This is likely due to lower permeability of the overlying shallow soil acting as a vertical hydraulic barrier. I may also be due to a higher formation conductivity in the horizontal direction (as compared to a vertical direction) in the formation.

Groundwater levels in several existing monitoring and injection wells near the active injection locations (four wells) w

Bromide levels above background were not detected in the shallow surface-water

Table 3-3

Gauging in Block G Wells - Injection Event #1
Lockheed Martin Middle River Complex, Middle River, Maryland

	IWW-3	IWW-5	IWW-14	IWW-12	SWMW-2I	IWW-18	IWW-16	SWMW-3I	SWMW-4S	SWMW-4I	IWW-25	IWW-27	IWW-31	IWW-33	IWW-36	IWW-38
4/22/14	6.39	6.5	4.97	6.72	4.38	3.63										

Table 3-4
Block G Bromide Tracer Sampling Results Summary
Lockheed Martin Middle River Complex, Middle River , Maryland

	Bromide ug/L	pH		Bromide ug/L	pH	Bromide ug/L	pH	Bromide ug/L	pH			6/10/2014[2] ug/L	6/17/2014[2] ug/L	6/30/2014[2] ug/L		7/24/2014[2] ug/L
MW-12A	170	5.68		88	5.75								120	200		280
MW-12B	<81	5.34														

Table 3-5

Block G Injection-Equipment Process Parameters - Injection Event #2
Lockheed Martin Middle River Complex, Middle River, Maryland

Date	Potable water line pressure (psig)	Pressure regulator (PR-1) outlet pressure (psig)	GAC-1 outlet pressure (psig)	Filter (PF-1) outlet pressure (psig)	Injection manifold pressure (psig)	Total injection flow (gpm)	Contactor (MC-1) vacuum (in.Hg)	Total volume injected by FT-1 (gallons)	Total volume injected by FMT-1 (gallons)	Tracer solution tank (T-2) level (inches)	Comments
6/9/2014	76	10.00	4.50	5.50	4.00	1.00	-24	44,980	42,069	40.00	
6/11/2014	76	10.00	3.75	5.00	10.50	1.10	-24.5	47,601	44,708	38.50	
6/13/2014	76	10.00	3.50	5.00	2.50	0.90	-24.5	50,617	47,683	36.00	
6/16/2014	75	11.50	4.00	5.50	10.50	1.00	-24.5	54,199	51,103	33.50	
6/23/2014	75	11.50	4.00	5.00	3.00	0.90	-24	64,305	60,603	26.50	
7/1/2014	72	14.50	4.00	5.50	3.50	1.10	-24	75,277	70,466	18.50	
7/7/2014	70	19.50	5.50	7.00	4.50	1.40	-23.5	82,719	77,548	8.00	
[illegible]	--	--	--	--5--							4,0

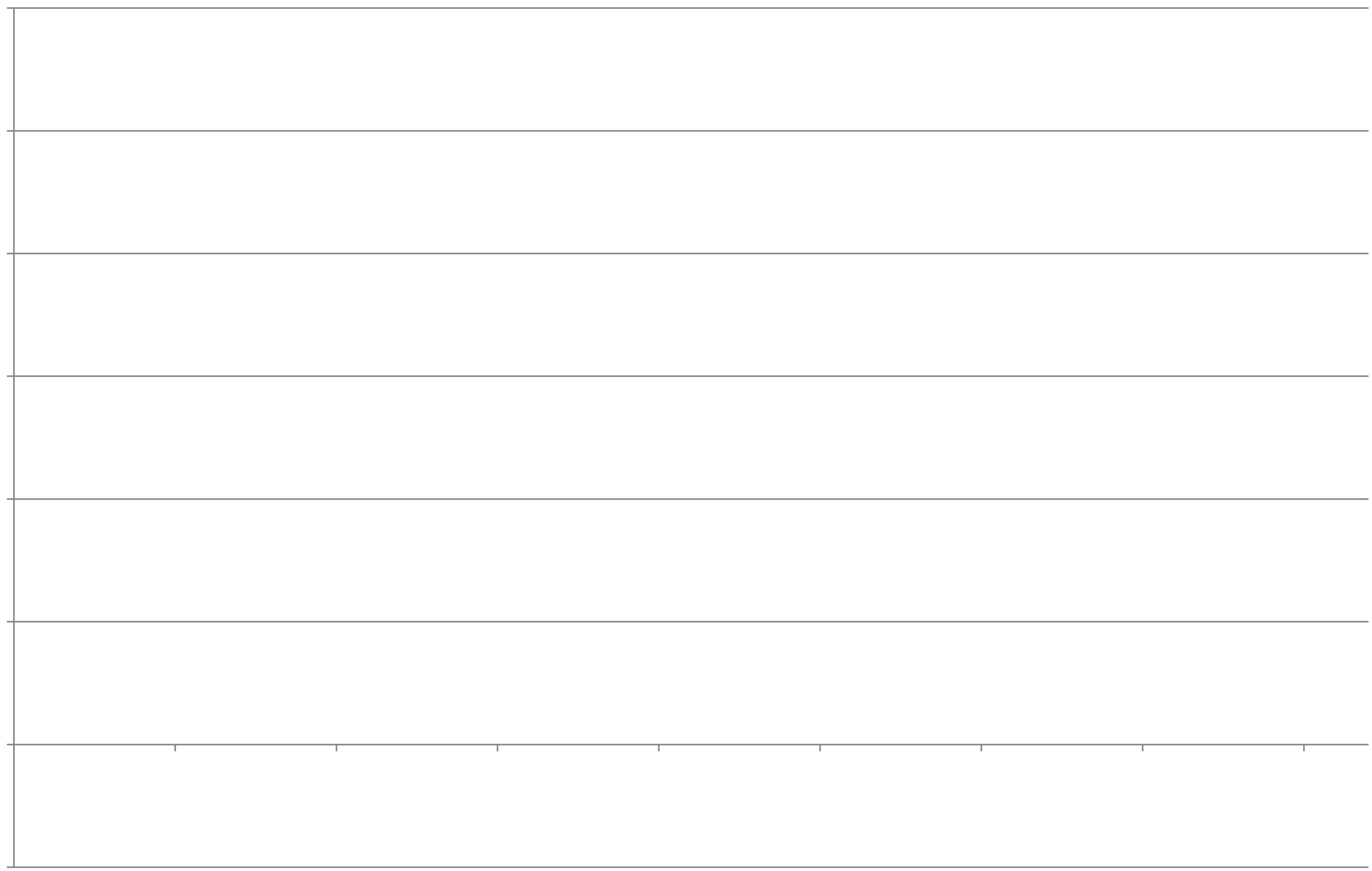
Table 3-6

Table 3-7

Gauging in Block G Wells - Injection Event #2
Lockheed Martin Middle River Complex, Middle River, Maryland

	SWMW-2I	SWMW-3I	MW-12A	MW-14B	SWMW-5I	IWW-24	IWW-27	IWW-32	IWW-34	IWW-35	IWW-37
6/2/2014	0.79	2.39	--	1.08	2.05	--	--	--	--	--	--
6/6/2014	--	--	3.32	--	2.98	1.02	0.37	pressure	pressure	1.04	1.78
6/11/2014	--	--	2.34	--	--	0.84	0.35	--	--	pressure	--
6/13/2014	--	--	1.12	--	--	pressure	pressure	--	--	pressure	--
6/16/2014	--	--	0.46	--	--	pressure	pressure	--	--	pressure	--
6/23/2014	--	--	0.32	--	--	pressure	pressure	--	--	pressure	--
7/1/2014	--	--	2.62	--	--	pressure	pressure	--	--	pressure	--
7/7/2014	--	--	1.96	--	--	pressure	pressure	--	--	pressure	--

Note:
-- : reading not recorded
pressure : Well head under pressure when monitoring took place



begin injection of bromide tracer/sodium bicarbonate solution from tank T-2 into the injection manifold, using settings described in the O&M manual.

The total volume injected was slightly above the volume for the full-scale design Approximately 45,000 gallons of tracer fluid were injected (equivalent to approximately 5,600 gallons per injection well); the injection volume for the full-scale design is 5,000 gallons per well (or 40,000 gallons total). The average flow rate during injection was 0.13 gpm per well. The injection duration was 31 days (from May 6, 2014 through June 7, 2014). The site operator visited the site at least three times during the first week of testing, then weekly thereafter.

4.5 INJECTION EVENT RESULTS SUMMARY

This section presents a summary of the results for the Block I injection event, including process parameters for the injection system (injection rates, pressures), parameters for injection wells, the hydraulic response of the underlying formation, and results of bromide tracer testing.

4.5.1 Process Parameters

System-process parameters for the entire injection event are summarized in Table 4-1. The parameters discussed below are presented in the flow direction starting at the upstream parameters.

The potable water pressure was stable during the entire injection event, and ranged from 64 to 66 pounds per square-inch gauge (psig) [Table 4-1, first data column]. Pressure was in excess of the required injection pressure, and was reduced using the pressure regulator PR-1. Outlet pressure for pressure regulator PR-1 (same as GAC-1 inlet pressure) was adjusted to approximately 8 psig; it remained close to this level for the entire injection event (Table 4-1, second data column). GAC-1 outlet pressure (same as filter PF-1 inlet pressure) was adjusted to 5 psig; it also remained relatively constant for most of the injection event. However, approximately three weeks after injection began, clogging of activated carbon in GAC-1 was indicated: the outlet pressure at GAC-1 began to decline, decreasing to 3 psig by the end of injection. The pressure differential across the GAC-1 unit increased from 3 psig to 5 psig from beginning to the end of injection, indicating clogging occurred across the carbon bed (Table 4-1, third data column). Note that the potable water source was very turbid, and likely contained suspended solids that caused GAC-1 clogging. Preventative measures that will be taken to address this issue, including carbon bed backwash or replacement, and possibly additional filtration at the inlet to GAC-1.

The

amount of sodium bicarbonate injected during the tracer test was insufficient for groundwater pH buffering. The design quantities of sodium bicarbonate to be injected during the full scale injection event will be much greater that the amounts used during the tracer tests.

4.5.2 Injection Wells Parameters

Table 4-2 summarizes parameters for individual injection wells, including the injection pressure at manifold-branch (measured downstream of the flow regulating valve), pressure of the actual wellhead, and the injected volume (measured by the flow totalizer) at each injection well. Injection-pressures at the manifold branch (measured on individual injection lines downstream of the flow-reducing regulating valve) ranged from negative to 5 psig, with a negative average value of -0.7 psig for the entire injection event.

Injection pressure at the wellhead (measured at gauges installed within injection wells manholes) ranged from negative to 5.5 psig, with an average value of 2 psig for the entire injection event. Wellhead injection pressures were slightly higher (typically 2 psig higher) than the pressures at the manifold branch because the wellheads were 4-5 feet lower than the injection manifold; therefore, corresponding hydrostatic pressure was added.

The total volume injected at each injection well varied, depending on the hydraulic conductivity of the local formation. The well in the most conductive area (IWN-6) received a volume approximately 1.7 times greater as compared to wells in the least conductive areas (IWN-5 and IWN-8). The injection volume for the rest of the wells was fairly uniform, and close to the design injection volume of 5000 gallons per well. The average injection volume per well was 4,994 gallons based on the hydrostatic pressure relative to baseline (shown as zero value) before the injection event began System shutdown and re-start events are also indicated on these graphs.

Transducers measurements indicate that all four wells responded to injection. For example, the hydrostatic pressure in well IWN (Figure 4-2) increased by approximately two feet after approximately six hours of injection. Well MPN-2S was screened in the shallow zone, and responded to the injection more slowly (Figure 4-3). After the system was turned off, the hydrostatic pressure in all wells returned close to pre-injection levels within several days (Figures 4-1 through 4-4). System shutdown events of short duration (several hours) occurred twice at the beginning of injection; these events are clearly seen on all graphs.

The hydraulic response in wells MPN-2I, IWN, MPN-2S and OW-1B ranged between four and five feet relative to the static level. Pre-injection static depths to water in these wells, and an increase in hydrostatic pressure during the injection, indicate that water levels in these wells were approximately five feet below the ground surface; therefore, potential day-lighting was limited.

Groundwater levels in five nearby existing monitoring- and injection-wells were also manually gauged before the injection started and while the injection was performed. These manual gauging results are summarized in Table 4-3. The baseline (pre-injection) measurements in these wells indicate that groundwater table was approximately 8-10 feet below the ground surface

All five wells responded when the injection began. Hydraulic response was similar to that measured by the transducers: depth to water decreased by approximately four feet by the end of injection. However, water levels in all five wells remained well under ground surface levels, thus limiting potential day-lighting. Visual observations of the ground surface and the underground structures (e.g., catch basins) did not indicate day-

Baseline bromide sampling indicated high bromide levels at one Block I location, in the shallow and intermediate depths: NMW-2S and NMW-2I, respectively (both at 18,000 micrograms per liter [μ

Based on the presence of tracer in the storm sewer system, the injection event for the full-scale bioremediation will be modified to address this. These modifications will be reflected in the updated O&M manual for the bio-remediation system.

Table 4-1

Block I Injection-Equipment Process Parameters
Lockheed Martin Middle River Complex, Middle River, Maryland

Date	Potable Water Line Pressure (psig)	Pressure Regulator PR-1 outlet Pressure (psig)	GAC-1 Outlet Pressure (psig)	Filter PF-1 Outlet Pressure (psig)	Injection Manifold Pressure (psig)	Total Injection Flow (gpm)	Contactor MC-1 Vacuum (in.Hg)	Total Injected Volume by FMT-1 (gallons)	Tracer Solution Tank (T-2) Level (inches)	Comments

Table 4-2
Block I Injection-Well Parameters
Lockheed Martin Middle River Complex, Middle River, Maryland

	Manifold Pressure (psig)	Wellhead Pressure (psig)	Injected Volume (gallons)	Manifold Pressure (psig)	Wellhead Pressure (psig)	Injected Volume (gallons)	Manifold Pressure (psig)	Wellhead Pressure (psig)	Injected Volume (gallons)
5/6/2014	4.5	1.25	163	2.5	0	86	0	0	99
5/7/2014	-2	0	286	-2	0	223	off	off	305
5/9/2014	-3	0	517	0	0.5	405	--	--	305
5/12/2014	0	0	1302	0	0	1027	--	--	--
5/16/2014	0	0.5	2299	1	3	1803	--	--	--
5/19/2014	0	0.5	3105	0	0.5	2418	-3	1.5	348
5/27/2014	0	1	4743	0	0	3605	-4	1.75	2350
6/2/2014	-4	0	5160	1	0	4789	-3	2.25	4885
Averages	**-0.6**	**0.4**		**0.3**	**0.5**		**-2.5**	**1.4**	

	Manifold Pressure (psig)	Wellhead Pressure (psig)	Injected Volume (gallons)	Manifold Pressure (psig)	Wellhead Pressure (psig)	Injected Volume (gallons)	Manifold Pressure (psig)	Wellhead Pressure (psig)	Injected Volume (gallons)
5/6/2014	3.5	1	84	5	2.5	73	0	0	86
5/7/2014	-2	1.75	364	2.5	5	168	-6	--	441
5/9/2014	-4	1.5	614	1	4.5	327	-7	0	758
5/12/2014	0	1	1433	2	4	843	0	0	1867
5/16/2014	0	1.25	2435	2	4	1473	0	0	3285
5/19/2014	0	1.5	3258	2	4	1950	-4	0	4452
5/27/2014	0	1	4945	2	3.75	2803	-5	0	6915
6/2/2014	-6	0	5073	2.5	4.5	3994	-9	0	6928
Averages	**-1.1**	**1.1**		**2.4**	**4.0**		**-3.9**	**0.0**	

	Manifold Pressure (psig)	Wellhead Pressure (psig)	Injected Volume (gallons)

Table 4-3

Gauging in Block I Wells
Lockheed Martin Middle River Complex, Middle River, Maryland

Date	Depth to Groundwater, feet from top of well casing				
	NMW-1I	NMW-2I	NMW-2S	NMW-3I	MW-81B
4/23/2014[1]	9.66	9.74	9.65	8.02	9.48
5/7/14	6.67	7.61	7.38	6.46	5.68
5/9/14	6.92	6.99	7.23	5.98	5.46
5/12/14	6.3	6.51	6.4	5.24	4.93
5/16/14	5.81	5.82	5.23	--	3.94
5/19/14	5.24	5.92	6.08	3.62	4.09
5/27/14	5.02	5.42	5.56	3.61	3.45
6/2/14	5.35	5.12	5.84	3.38	3.92

Note:
-- : reading not recorded
[1]Static conditions before injection

Table 4-4
Block I Brominde Tracer Results Sammary
Lockheed Martin Middle River Complex, Middle River, Maryland

	Baseline 2/10/2014[1]			5/16/2014[2]		5/27/2014[2]		6/04/2014[2]			6/20/2014[2]		7/24/2014[2] ug/L
	Bromide ug/L	pH		Bromide ug/L	pH	Bromide ug/L	pH	Bromide ug/L	pH		Bromide ug/L	pH	
MW-81B	360	8.51	Begin injection event on 5/6/2014. Injecting into wells IWN-1 through IWN-8	250	6.81	290	6.01	6800	5.83	End injection event on 6/7/14.	10000	6.27	
NMW-2I	18000	5.47		35000	5.5	72000	5.5	68000			36000		
NMW-3I	570	6.21		7500	5.81	77000	5.24	120000	5.38		50000	6.02	
NMW-1I	330	5.15		230	5.14	220	5.42	240	4.58		19000		
NMW-2S	18000	6.24		27000	5.47	61000	5.58	63000	5.74		28000		
OUTFALL-9	280	8.05		1400		1500		1300			1000		
MH-10	<81			9.7		110		3700			2100		3200
CB-10A	<81			200		220		4700			430		51

[1]Minimum MDL = 81 ug/L; Minimum RL = 500 ug/L

[2]Minimum MDL = 2.2 ug/L; Minimum RL = 2.5 ug/L

Injection event average injected bromide concentration:	434	mg/L
Injection event total bromide tracer injected:	165	pounds
Injection event total volume injected:	45488	gallons
Injection event volume per well:	5686	gallons
Injection event average injection rate per welll:	0.13	gallons per minute
Injection event duration:	31	days

Section 5
Summary and Conclusions

A summary of the tracer study results and conclusions follow:

1. The system design was fully validated and the injection process equipment and controls were tested under actual operating conditions similar to future full-scale operation requirements.

2. A full design injection volume was injected into each set of injection wells. Some individual injection wells received higher or lower volume, but most wells received the approximate full-design injection volume of bromide-tracer and sodium bicarbonate buffered water.

3. No day-lighting was observed during the tracer study.

4. The injected fluid entered storm drain utilities in Block I. Specific recommendations to address this issue for the full-scale Block I injection event are in the updated operations and maintenance (O&M) manual.

5. Tracer tests indicated that injection fluid may have entered the storm drain utilities in Block G. Specific recommendations to address this potential issue for the full-scale Block G injection event are in the updated operations and maintenance manual

6. The injection rates for individual wells were lower than the values achieved during the November 2011 injection test, which could increase the overall duration of the future full-scale bio-remediation injection event. Modifications to avoid an increased duration are made in the updated operations and maintenance manual, and consist of altering the number of wells used for simultaneously injecting amendment.

7. Bromide tracer was clearly detected in multiple monitoring wells in Blocks G and I. Therefore, we conclude that an adequate injected-fluid distribution was achieved, and that adequate distribution of amendments can be achieved using the design injection volumes.

8. Strong hydraulic response to injection was detected in all monitoring locations at distances up to 57 feet from the point of injection. Thus, we conclude that the existing hydraulic conditions are favorable for achieving adequate distribution of amendments using the design injection volumes.

9. Untreated potable water used for injection in Blocks G and I was very turbid and contained suspended solids. At the end of injection in both areas, suspended solids began to clog the granular carbon vessels. Measures to address this issue include replacing the activated carbon bed and additional filtration (as detailed in the updated operations and maintenance manual).

Section 6
References

1. Tetra Tech, Inc. (Tetra Tech), 2012. March.

Tetra Tech Inc. (Tetra Tech), 2014. January.

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