APPENDIX G

Hydrologic Data Quality Assurance Memorandum

Herrera Environmental Consultants, Inc.

Memorandum

To Project file 10-04715-003

From Kristen Matsumura and Dylan Ahearn, Herrera Environmental Consultants

Date September 12, 2013

Subject Hydrologic Data Validation Review for the Filterra® test system monitoring at Hayward Drive in Bellingham, Washington from January 2013 to July 2013

This memorandum presents the results from a quality assurance review of hydrologic data collected at monitoring stations for the Filterra test system monitoring in Bellingham, Washington, from January 2013 through July 2013. Included in this review are water level and associated discharge data from the outlet and bypass monitoring stations at the test system. Also included in this review are precipitation data from an adjacent project rain gauge. Detailed descriptions of each of these stations and their associated monitoring equipment are provided in the Quality Assurance Project Plan Addendum (Herrera 2012) for the project.

Hydrologic monitoring consisted of measurements of water level (for estimating discharge) and precipitation depth. MQOs for these measurements are expressed in terms of precision, bias, representativeness, completeness, and comparability. Data quality for each of these categories is described in the sections that follow.

Table G-1 presents a list of the equipment, which was tested as part of this evaluation.

Table G-1. Project hydrological measurement instrument characteristics.

Instrument	Make/model	Serial number	Station	Deployment
Bubble Level Gauge	OTT CS-471	297506	FB-BP	November 1, 2012, to July 23, 2013
Area-Velocity Meter	Hach Flo-Tote 3	111000000803	FB-OUT	November 1, 2012, to July 23, 2013
Rain Gauge	Texas Electronics 525	50983-412	FB-RG	November 1, 2012, to July 23, 2013

Precision

Prior to monitoring, rain gauge precision was evaluated on August 8, 2012, by repeatedly releasing 950 mL of water into the rain gauge's tipping bucket mechanism with a burette and recording the number of tips associated with the volume. The variation among the repeated tests was then compared to assess gauge precision. This procedure was repeated after the monitoring period (July 31, 2013) to assure that the gauge precision was consistent through the project.

The MQO for rain gauge precision was 5 percent. Results from the precision test indicated that the coefficient of variation (CV) before the monitoring period was 0.87 percent (Table G-2) and the CV after the monitoring period was 0.51 percent (Table G-3); both meet the MQO of 5 percent.

Table G-2. Pre-Monitoring Precipitation Precision and Bias Testing.

Water Volume Applied (mL)	Theoretical Number of Tips	Actual Number of Tips	Percent Error
950	115.3	114	-1.12
950	115.3	113	-1.99
950	115.3	115	-.26
Total Bias			-1.12
Total Precision			**0.87**

mL = milliliters

Table G-3. Post-Monitoring Precipitation Precision and Bias Testing.

Water Volume Applied (mL)	Theoretical Number of Tips	Actual Number of Tips	Percent Error
950	115.3	112	-2.86
950	115.3	112	-2.86
950	115.3	111	-3.73
Total Bias			-3.15
Total Precision			**0.51**

mL = milliliters

In order to test the precision of the pressure sensors, both the FB-OUT and FB-BP water level transducers were placed in a graduated cylinder filled with water for between 17 and 20 hours. Level data were recorded on a 5-minute time step. This precision test was conducted both before and after the monitoring period for FB-OUT, but only after the monitoring period for FB-BP. Test results are presented in Figures G-1 and G-2. The CVs for the FB-OUT transducer before and after the monitoring period were 0.52 and 1.07 percent, respectively. After the monitoring period, the CV for the FB-BP transducer was 0.93 percent. All values were less than the MQO of 5 percent identified in the project QAPP.

Bias

Bias was assessed by comparing monitoring equipment readings to an independently measured "true" value. Bias in precipitation depth data collected through this study was assessed by comparing the rain gauge's actual tip volume to its theoretical tip volume, as specified by the manufacturer. Bias was estimated by pouring a known volume of water through the rain gauge in order to generate 115 tips of the gauge. The theoretical value of 115 tips was then compared with the actual number of tips to estimate the error from bias (Table G-3).

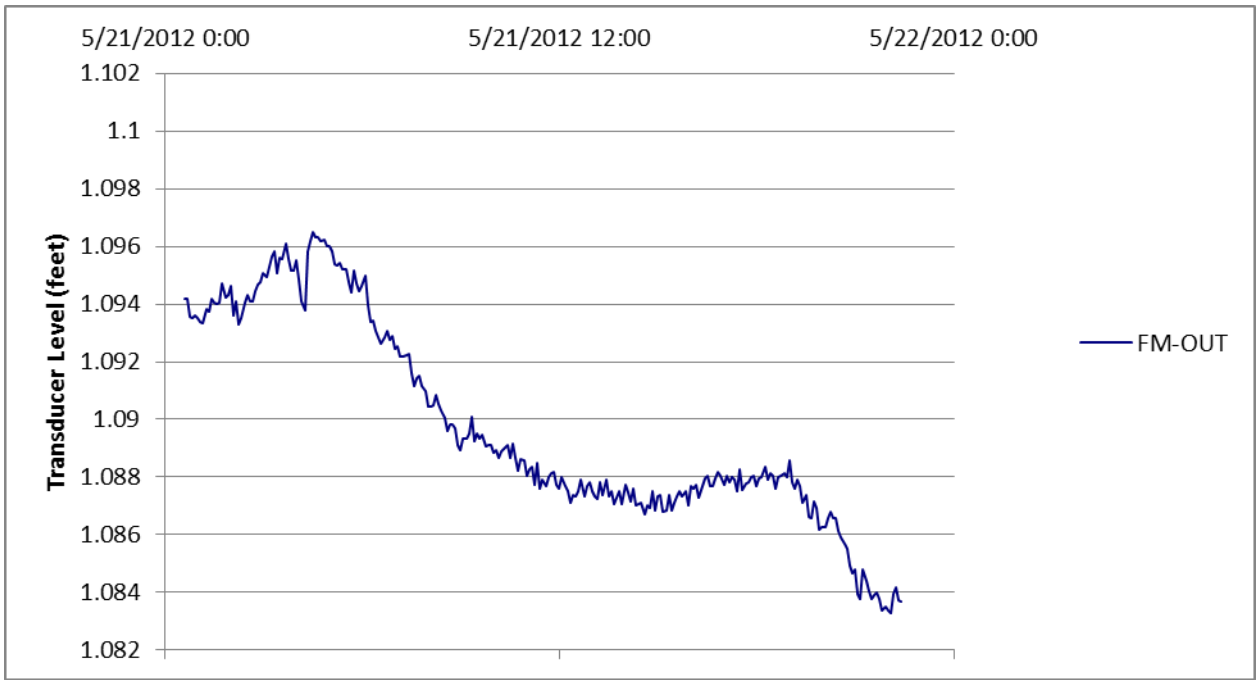

Figure G-1. Pre-Monitoring Transducer Precision Testing.

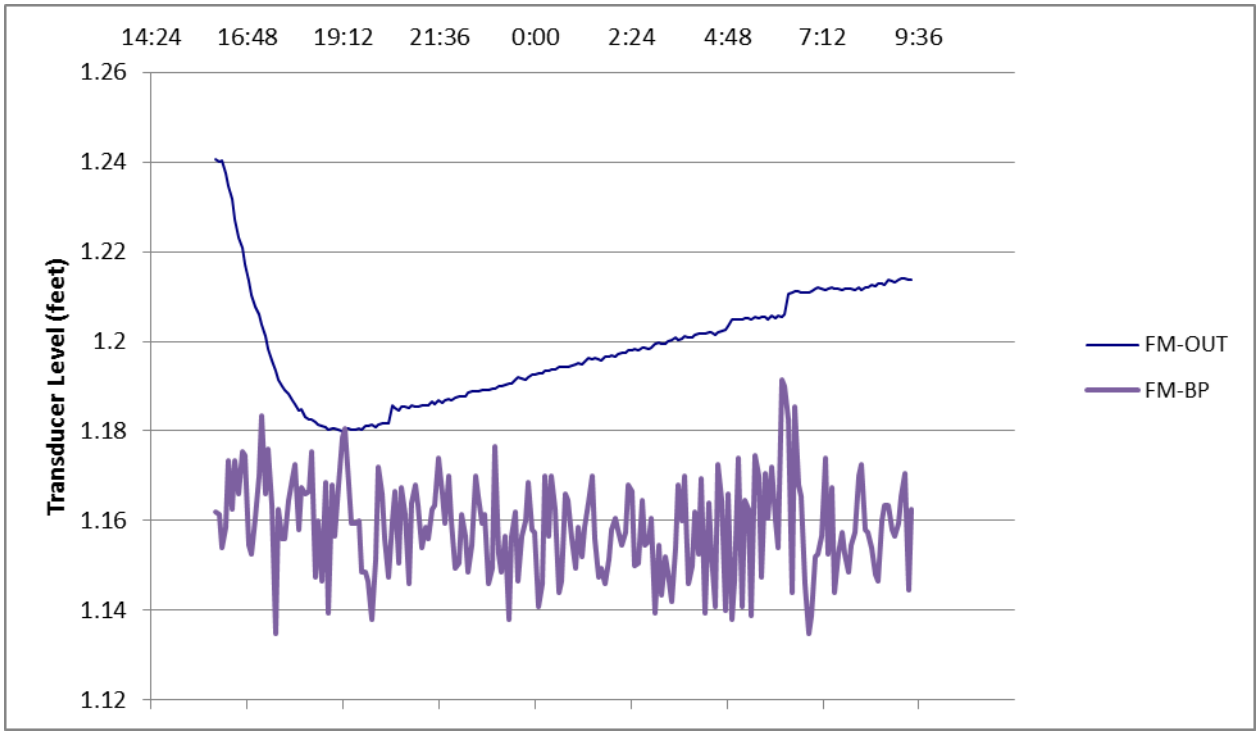

Figure G-2. Post-Monitoring Transducer Precision Testing.

Total bias before monitoring began was estimated to be -1.12 percent; total bias after the monitoring period was estimated to be -3.15 percent. The project QAPP (Herrera 2012) indicates

a bias of 5 percent or less is acceptable; consequently, the gauge was within specification through the duration of the project.

Bias in continuous level data is introduced from two primary sources: instrument design limitations and calibration or operation errors. To assess if instrument design was contributing to level gauge bias, the pressure transducers were placed in a graduated cylinder filled with water. One inch of water at a time was then added to the graduated cylinder and the pressure transducer responses were recorded. Pressure transducers depths were then compared to the measured depths to assess transducer bias. This test was conducted both before and after the monitoring period for the FB-OUT and FB-BP sensors. Results from the pressure transducer bias tests are presented in Table G-4. This table indicates that average level bias between the two sensors ranged from -5 percent to 4.8 percent. The MQO defined in the project QAPP (Herrera 2012) was 5 percent, indicating that pressure transducer bias under controlled conditions did not exceed the project MQO.

Table G-4. Results from Pressure Transducer Bias Testing at FB-OUT and FB-BP.

Date	Actual Depth (inches)	FB-OUT Transducer Depth (inches)	FB-OUT Percent Error	FB-BP Transducer Depth (inches)	FB-BP Percent Error
8/13/2012 11:00	0.4	0.37	-7	0.42	4
8/13/2012 11:05	0.5	0.49	-1.6	0.46	-8
8/13/2012 11:10	0.5	0.52	3.2	0.5	0
Total Bias			**-1.8**		**-1.3**
7/31/2013 14:04	1	0.96	-4	1.07	-6.8
7/31/2013 14:13	1	0.93	-7	0.47	53.2
7/31/2013 14:18	1	0.96	-4	1.32	-32
Total Bias			**-5**		**4.8**

Despite this result, bias can still be introduced into the level signal when the instrument is deployed and operated in the field. This bias is usually due to calibration, operation, or configuration errors. Field calibrations of the level sensors were generally conducted before each targeted sampling event. During the 8-month monitoring period, the FB-OUT transducer was calibrated 23 times, and the FB-BP pressure transducer was calibrated 25 times. Sensor drift between each calibration was corrected after the data were downloaded using Aquarius Version 3.1. Aquarius was also used to delete spikes and fill small data gaps. All edits to the continuous record from the FB-OUT transducer are presented in Table G-5; edits to the FB-BP record are presented in Table G-6.

Additional bias can result when measurement devices are incorrectly designed or installed in non-ideal conditions. In order to assess this form of bias dynamic flow testing was conducted at the monitoring site.

Table G-5. Data correction history for FB-OUT.

Station	Storm Start Date & Time	Storm Stop Date & Time	QA Issue	QA Action	Points Modified
FM	8/8/2012 10:15	9/30/2012 23:55	Delete Region	Delete Region - data collected prior to Oct 1. start date	13369
FM	10/25/2012 12:10	10/25/2012 12:55	Delete Region	Delete Region - flow testing	10
FM	10/25/2012 12:05	10/25/2012 13:00	Fill Data Gaps	Fill Data Gap - spike/drop fill	10
FM	12/1/2012 4:00	12/1/2012 4:30	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff)(2012-12-01 04:00:00 0.00000US Gal/m) (2012-12-01 04:30:00 13.41550US Gal/m)	7
FM	11/19/2012 11:15	11/19/2012 11:20	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff)(2012-11-19 11:15:00 0.00000US Gal/m) (2012-11-19 11:20:00 12.74148US Gal/m)	2
FM	11/1/2012 12:45	11/1/2012 17:05	Delete Region	Delete Region - flow testing	53
FM	11/1/2012 12:37	11/1/2012 17:14	Fill Data Gaps	Fill Data Gap - no rain during gap	53
FM	11/1/2012 12:45	11/4/2012 18:00	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	928
FM	11/4/2012 21:09	11/11/2012 18:36	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	1986
FM	11/11/2012 21:15	11/15/2012 15:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	1082
FM	11/15/2012 16:05	11/17/2012 12:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	530
FM	11/17/2012 20:00	11/19/2012 2:00	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	361
FM	11/19/2012 3:10	11/19/2012 6:55	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	46
FM	11/20/2012 1:30	11/20/2012 19:30	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	217
FM	11/20/2012 20:15	11/21/2012 13:30	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	208
FM	11/21/2012 16:55	11/23/2012 3:40	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	418
FM	11/23/2012 7:15	11/23/2012 21:55	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	177
FM	12/29/2012 7:45	1/5/2013 8:25	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	2025
FM	1/5/2013 9:00	1/5/2013 20:55	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	144
FM	1/5/2013 21:40	1/6/2013 19:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	258
FM	12/27/2012 17:30	12/29/2012 6:50	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	449
FM	12/27/2012 14:25	12/27/2012 16:30	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	26
FM	12/27/2012 2:00	12/27/2012 13:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	137

Table G-5 (continued). Data correction history for FB-OUT.

Station	Storm Start Date & Time	Storm Stop Date & Time	QA Issue	QA Action	Points Modified
FM	12/26/2012 22:00	12/27/2012 0:50	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	35
FM	12/26/2012 21:15	12/26/2012 21:35	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	5
FM	12/25/2012 14:55	12/26/2012 20:50	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	360
FM	12/24/2012 3:50	12/25/2012 12:55	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	398
FM	12/23/2012 20:55	12/24/2012 3:00	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	74
FM	12/22/2012 20:10	12/23/2012 19:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	279
FM	12/22/2012 12:50	12/22/2012 18:50	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	73
FM	12/21/2012 13:05	12/22/2012 10:25	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	257
FM	12/20/2012 15:40	12/21/2012 12:15	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	248
FM	12/20/2012 13:45	12/20/2012 13:50	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff)(2012-12-20 13:45:00 1.61627US Gal/m) (2012-12-20 13:50:00 1.40785US Gal/m)	2
FM	12/20/2012 13:05	12/20/2012 13:10	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff)(2012-12-20 13:05:00 0.00000US Gal/m) (2012-12-20 13:10:00 1.21827US Gal/m)	2
FM	12/20/2012 0:40	12/20/2012 2:55	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	28
FM	11/23/2012 22:45	11/25/2012 8:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	401
FM	11/25/2012 8:40	11/28/2012 17:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	967
FM	11/28/2012 17:45	11/30/2012 12:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	509
FM	11/30/2012 13:20	11/30/2012 18:00	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	57
FM	11/30/2012 12:20	11/30/2012 12:35	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	4
FM	11/30/2012 21:10	11/30/2012 21:55	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	10
FM	11/30/2012 23:10	12/1/2012 0:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	12
FM	12/1/2012 1:55	12/1/2012 3:00	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	14
FM	12/1/2012 7:35	12/1/2012 8:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	8
FM	12/1/2012 9:05	12/1/2012 11:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	25
FM	12/1/2012 11:20	12/1/2012 12:00	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	9

Table G-5 (continued). Data correction history for FB-OUT.

Station	Storm Start Date & Time	Storm Stop Date & Time	QA Issue	QA Action	Points Modified
FM	12/1/2012 12:15	12/1/2012 16:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	48
FM	12/1/2012 17:05	12/2/2012 3:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	122
FM	12/2/2012 5:20	12/2/2012 6:35	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	16
FM	12/2/2012 8:10	12/2/2012 10:40	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	31
FM	12/2/2012 6:45	12/2/2012 6:50	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff)(2012-12-02 06:45:00 0.00000US Gal/m) (2012-12-02 06:50:00 8.85988US Gal/m)	2
FM	12/2/2012 11:40	12/2/2012 22:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	126
FM	12/7/2012 14:55	12/11/2012 13:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	1131
FM	12/3/2012 1:50	12/3/2012 4:35	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	34
FM	12/3/2012 1:30	12/3/2012 1:40	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	3
FM	12/3/2012 0:05	12/3/2012 0:40	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	8
FM	12/3/2012 4:55	12/3/2012 5:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	6
FM	12/3/2012 6:30	12/4/2012 2:25	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	240
FM	12/4/2012 4:20	12/4/2012 17:15	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	156
FM	12/4/2012 18:10	12/4/2012 21:35	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	42
FM	12/4/2012 23:00	12/6/2012 10:50	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	431
FM	12/6/2012 15:25	12/7/2012 2:15	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	131
FM	12/7/2012 3:55	12/7/2012 7:00	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	38
FM	12/7/2012 7:15	12/7/2012 7:40	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	6
FM	12/7/2012 8:20	12/7/2012 8:45	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	6
FM	12/7/2012 8:55	12/7/2012 10:45	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	23
FM	12/7/2012 10:55	12/7/2012 13:45	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	35
FM	12/11/2012 15:35	12/11/2012 21:55	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	77
FM	12/11/2012 22:20	12/12/2012 3:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	59

Table G-5 (continued). Data correction history for FB-OUT.

Station	Storm Start Date & Time	Storm Stop Date & Time	QA Issue	QA Action	Points Modified
FM	12/12/2012 3:40	12/12/2012 6:15	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	32
FM	12/12/2012 6:45	12/12/2012 11:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	54
FM	12/12/2012 11:45	12/13/2012 2:30	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	178
FM	12/13/2012 5:40	12/14/2012 1:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	237
FM	12/14/2012 4:40	12/15/2012 7:40	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	325
FM	12/15/2012 8:30	12/15/2012 10:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	20
FM	12/15/2012 11:10	12/15/2012 20:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	109
FM	12/15/2012 20:55	12/16/2012 3:30	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	80
FM	12/16/2012 4:40	12/16/2012 6:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	21
FM	12/16/2012 7:30	12/16/2012 16:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	107
FM	12/16/2012 22:50	12/17/2012 5:05	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	76
FM	12/17/2012 9:20	12/18/2012 10:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	299
FM	12/18/2012 11:00	12/18/2012 12:35	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	20
FM	12/18/2012 13:15	12/19/2012 4:15	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	181
FM	12/19/2012 5:15	12/19/2012 9:50	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	56
FM	12/19/2012 10:45	12/19/2012 14:10	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	42
FM	12/19/2012 14:55	12/19/2012 16:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	18
FM	12/19/2012 16:55	12/19/2012 18:20	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	18
FM	12/19/2012 19:20	12/19/2012 22:30	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	39
FM	12/19/2012 18:40	12/19/2012 18:45	Amplification	Amplification Correction -- Simple with start factor of 0.00000 and end factor of 0.00000	2
FM	4/18/2013 16:20	4/18/2013 16:30	Fill Data Gaps	Fill Data Gap - short gap	2
FM	5/8/2013 12:10	5/9/2013 10:05	Delete Region	Delete Region - erroneous flow spikes with no associated rain	264
FM	5/8/2013 10:40	5/9/2013 14:00	Fill Data Gaps	Fill Data Gap - no rain during gap	264

Table G-6. Data correction history for FB-BP.

Station	Storm Start Date & Time	Storm Stop Date & Time	QA Issue	QA Action	Points Modified
BP	12/21/2012 3:55	12/21/2012 10:40	Delete Region	Delete Region - frozen water caused erroneous flow spike	82
BP	12/21/2012 3:50	12/21/2012 10:45	Fill Data Gaps	Fill Data Gap - spike/drop fill	82
BP	1/10/2013 19:15	1/11/2013 11:55	Delete Region	Delete Region - frozen water caused erroneous flow spike	201
BP	1/10/2013 19:10	1/11/2013 12:00	Fill Data Gaps	Fill Data Gap - spike/drop fill	201
BP	2/7/2013 23:40	2/8/2013 7:40	Delete Region	Delete Region - frozen water caused erroneous flow spike	97
BP	2/7/2013 23:35	2/8/2013 7:45	Fill Data Gaps	Fill Data Gap - spike/drop fill	97
BP	3/4/2013 2:35	3/4/2013 14:20	Delete Region	Delete Region - erroneous flow spikes when no rain present	142
BP	3/4/2013 2:30	3/4/2013 14:25	Fill Data Gaps	Fill Data Gap - spike/drop fill	142
BP	2/7/2013 22:55	2/8/2013 10:35	Delete Region	Delete Region - frozen water caused erroneous flow spike	141
BP	2/7/2013 22:35	2/8/2013 11:40	Fill Data Gaps	Fill Data Gap - spike/drop fill	141
BP	2/10/2013 1:05	2/10/2013 11:15	Delete Region	Delete Region - erroneous flow spikes with no associated rain	123
BP	2/10/2013 0:45	2/10/2013 11:30	Fill Data Gaps	Fill Data Gap - spike/drop fill	123
BP	2/19/2013 8:20	2/19/2013 11:10	Delete Region	Delete Region - erroneous flow spikes with no associated rain	35
BP	2/19/2013 8:15	2/19/2013 11:15	Fill Data Gaps	Fill Data Gap - spike/drop fill	35
BP	1/7/2013 14:35	1/7/2013 15:25	Delete Region	Delete Region - erroneous flow spikes with no associated rain	11
BP	1/7/2013 14:30	1/7/2013 15:30	Fill Data Gaps	Fill Data Gap - spike/drop fill	11
BP	12/21/2012 2:00	12/21/2012 12:25	Delete Region	Delete Region - frozen water caused erroneous flow spike	126
BP	12/21/2012 1:45	12/21/2012 12:35	Fill Data Gaps	Fill Data Gap - spike/drop fill	126
BP	11/26/2012 0:15	11/26/2012 11:30	Delete Region	Delete Region - erroneous flow spikes with no associated rain	136
BP	11/26/2012 0:10	11/26/2012 11:35	Fill Data Gaps	Fill Data Gap - spike/drop fill	136
BP	11/1/2012 12:35	11/1/2012 16:00	Delete Region	Delete Region - spurious data during sensor configuration	42
BP	11/1/2012 12:30	11/1/2012 16:10	Fill Data Gaps	Fill Data Gap - spike/drop fill	42
BP	10/30/2012 10:30	10/31/2012 17:05	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	368

Table G-6 (continued). Data correction history for FB-BP.

Station	Storm Start Date & Time	Storm Stop Date & Time	QA Issue	QA Action	Points Modified
BP	10/31/2012 18:15	11/4/2012 18:20	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	1154
BP	11/4/2012 20:30	11/15/2012 15:15	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	3106
BP	11/15/2012 15:45	11/17/2012 12:25	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	537
BP	11/17/2012 19:05	11/19/2012 8:20	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	448
BP	11/19/2012 20:35	11/21/2012 13:45	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	495
BP	11/21/2012 15:55	11/30/2012 18:25	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	2623
BP	11/30/2012 19:40	12/1/2012 3:15	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	92
BP	12/1/2012 6:30	12/2/2012 2:40	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	243
BP	12/2/2012 4:30	12/2/2012 6:25	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	24
BP	12/2/2012 7:50	12/6/2012 11:10	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	1193
BP	12/6/2012 13:25	12/7/2012 13:20	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	288
BP	12/7/2012 14:30	1/8/2013 22:10	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	9309
BP	1/9/2013 3:00	3/5/2013 11:15	Offset Correction	Offset Correction with value of -0.02000ft - eliminating noisy signal	15940
BP	3/9/2013 2:40	3/9/2013 3:25	Delete Region	Delete drop/spike	10
BP	3/9/2013 2:35	3/9/2013 3:30	Fill Data Gaps	Fill Data Gap - spike/drop fill	10
BP	3/5/2013 11:15	4/11/2013 12:55	Offset Correction	Offset error correction	10677
BP	4/11/2013 13:00	5/24/2013 14:25	Offset Correction	Offset Correction with value of -0.01000ft	12401
BP	4/4/2013 11:05	4/6/2013 18:50	Offset Correction	Offset Correction with value of -0.02000ft	670
BP	4/6/2013 19:55	4/7/2013 10:55	Offset Correction	Offset Correction with value of -0.01500ft	181
BP	4/7/2013 12:15	4/11/2013 15:45	Offset Correction	Offset Correction with value of -0.02000ft	1195
BP	4/12/2013 6:55	5/11/2013 23:00	Offset Correction	Offset Correction with value of -0.02000ft	8545
BP	5/12/2013 4:15	5/24/2013 14:25	Offset Correction	Offset Correction with value of -0.02000ft	3579
BP	5/24/2013 14:30	7/23/2013 9:35	Offset Correction	Offset Correction with value of -0.02000ft	17222

On November 1, 2012, field technicians conducted a dynamic flow test at the Filterra monitoring site. A fire hose was attached to a nearby fire hydrant and flows from the hydrant were assessed using a graduated bucket and timer. Known flow rates across the range of flows observed at each FB-OUT and FB-BP were produced in this manner. Pressure transducer water levels at FB-OUT and FB-BP were simultaneously recorded at each known flow rate to verify the rating curve for each station. The results from this test are presented in Table G-7 and Figures G-3 and G-4. Because FB-OUT flows were measured using a velocity sensor, it was most efficient to compare actual flow rates to sensor flow rates (Figure G-3). FB-BP was equipped with a level gauge and flume so a more traditional rating curve comparison was conducted (Figure G-4).

Table G-7. Results from the Dynamic Flow Tests at FB-OUT and FB-BP.

Date	FB-OUT Reference Discharge (gpm) [a]	FB-OUT Measured Discharge (gpm)	FB-OUT Percent Error	FB-BP Reference Discharge (gpm) [a]	FB-BP Measured Discharge (gpm)	FB-BP Percent Error
11/1/2012 13:44	3.85	4.00	-3.9	9.25	5.8	-37.3
11/1/2012 13:51	2.05	2.30	-12.2	10.1	8.3	-17.8
11/1/2012 14:00	6.50	5.70	12.3	15.3	13.5	-11.7
11/1/2012 14:10				2.5	0.72	-71.2
11/1/2012 14:15				5	4.5	-10
Total Bias			**-1.3**			**-29.6**

[a] Reference discharge measured with graduated bucket and timer.
gpm = gallons per minute

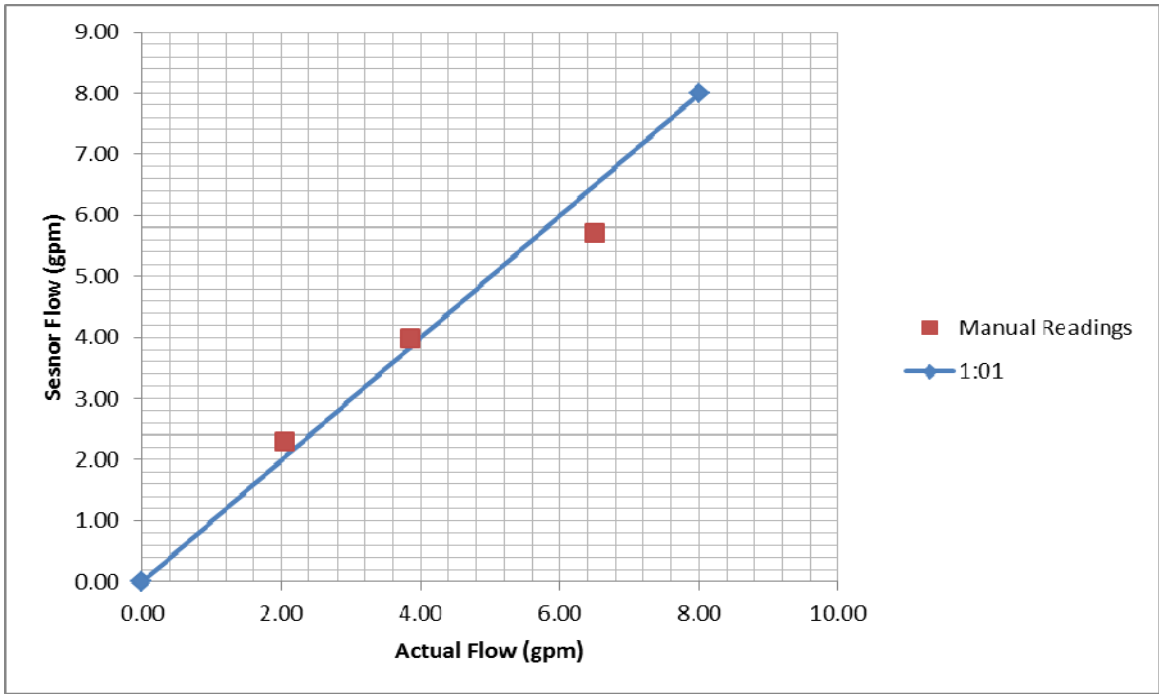

Figure G-3. Rating curve comparison from dynamic flow testing at FB-OUT.

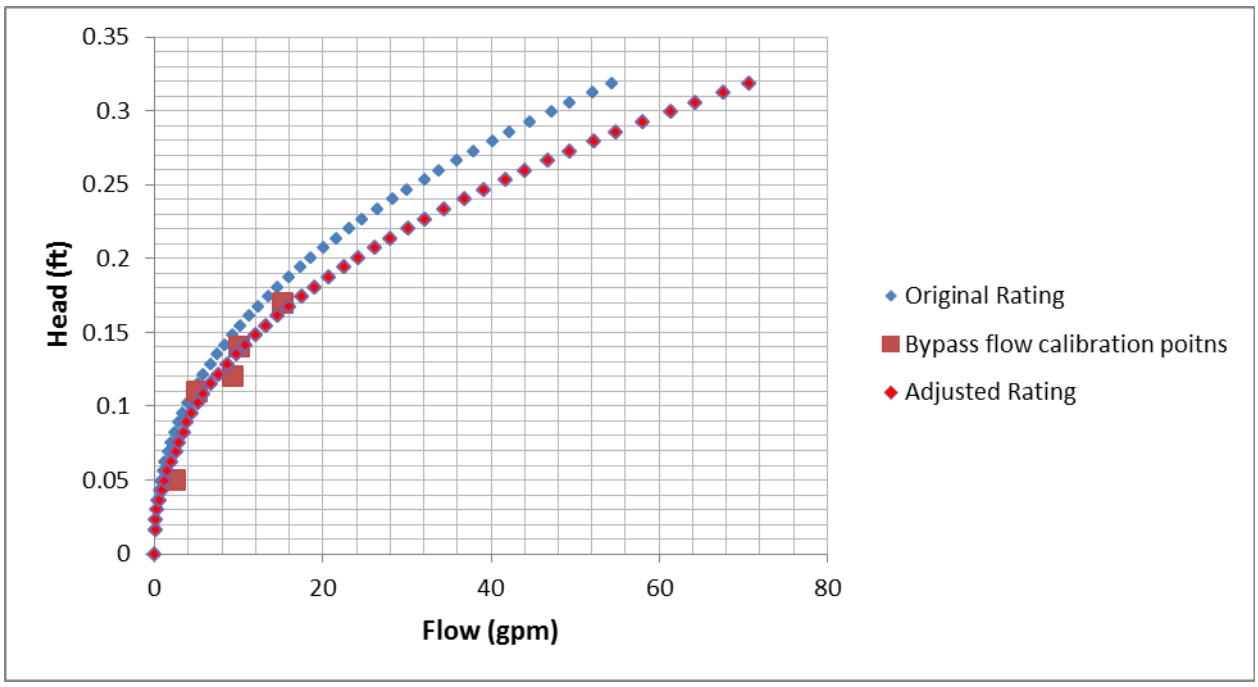

Figure G-4. Rating curve comparison from dynamic flow testing at FB-BP.

Independent flow testing indicated that the FB-BP flume and bubbler combination was underestimating flows by approximately 29.6 percent (Table G-7, Figure G-4). This error was addressed by adjusting the rating curve so that it more closely fit the dynamic flow test calibration points (Figure G-4). All flow data presented in this study are based on these adjusted rating curves.

The flow testing indicated that the FB-OUT velocity sensor was in good agreement with the independently measured flows (Table G-7, Figure G-3). The average error was only -1.13 percent. Consequently, no adjustments to the rating curve were made for this station.

Representativeness

The representativeness of the hydrologic data was ensured by properly selecting and installing all associated monitoring equipment. Rainfall patterns, stormwater conveyance features, and surrounding land uses were also considered when identifying monitoring locations and sampling frequencies, to ensure that representative data were obtained. Finally, monitoring was conducted during an average water year (Table 8, main text), thus ensuring that data were collected during representative climatic conditions for northwestern Washington.

Completeness

Completeness was assessed based on the occurrence of gaps in the data record for all hydrological data signals. The associated MQO requires that less than 10 percent of the total data record be missing due to equipment malfunction or other operational problems. During the

monitoring period there were minimal data gaps (Tables G-5 and G-6), and the majority of those gaps that did occur were sufficiently short in duration that they could be filled by interpolation. Therefore, the completeness MQO for hydrological data was met.

Comparability

Although there is no numeric MQO for this data quality indicator, standard monitoring procedures, units of measurement, and reporting conventions were used in this study to meet the quality indicator of data comparability.

Conclusions

Results from this quality assurance review indicated that data the final flow record at FB-OUT and FB-BP were of sufficient quality to be used in this TER without qualification. In addition, the rainfall data at FB-RG can be used without qualification

References

Herrera. 2012. Filterra® Bioretention System Phosphorus Treatment and Supplemental Basic and Enhanced Treatment Performance Monitoring Quality Assurance Project Plan. Prepared for Americast by Herrera Environmental Consultants, Seattle, Washington. June 2012.