APPENDIX 4-A

Processed Hydromodification Survey Data

Gunpowder Creek Watershed Plan

Prepared by the
Gunpowder Creek Watershed Initiative

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NOTE: The regression lines presented throughout this Appendix are not meant to represent exact correlations illustrating changes in cross section, profile, and bed material parameters. Such regression lines between only two data points can be misleading in that they imply more certainty than actually exists. These regression lines are meant to illustrate the variability between the two years of data and provide comparisons to regional data (Hawley *et al.,* 2013).

APPENDIX 4.A.1

BCCD Survey Sites

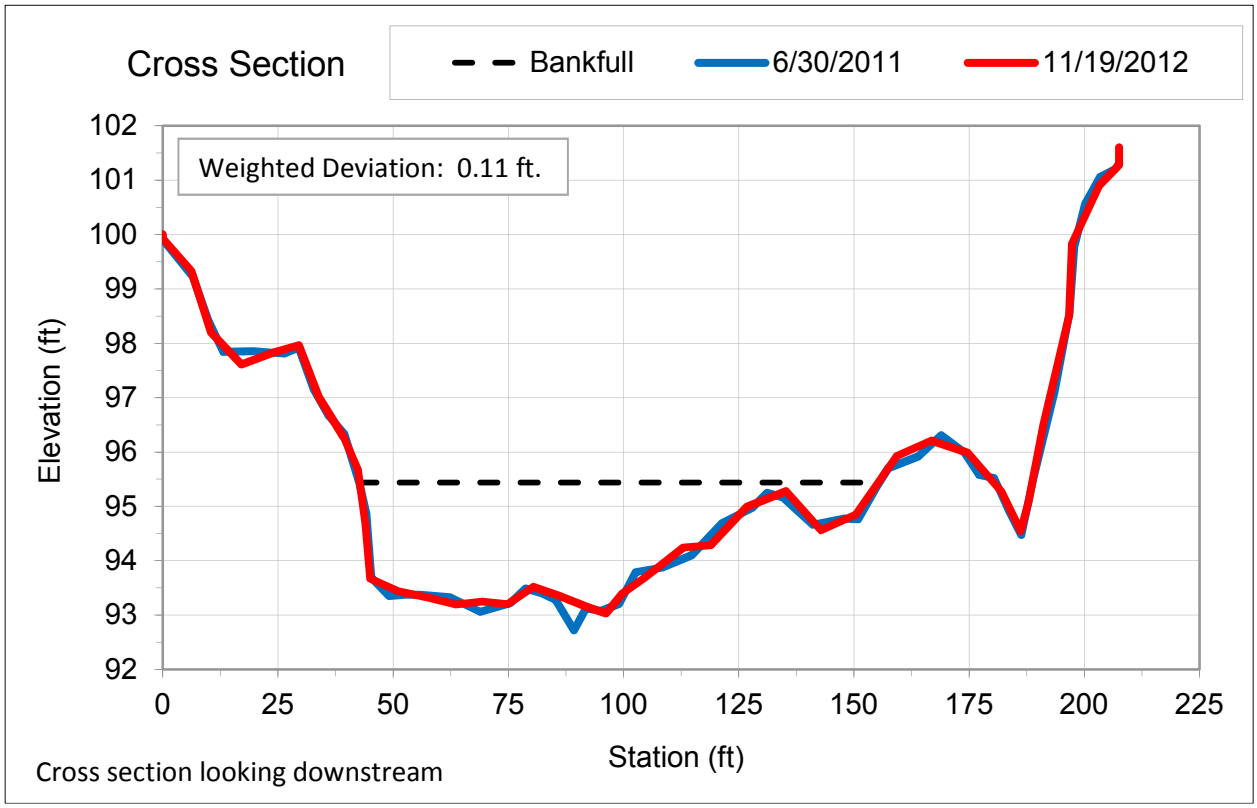
Site: GPC 7.5

Imp: 20.6% Drainage Area: 43.6 mi^2

KDOW 2011 Grade: C+ KDOW 2012 Grade: B

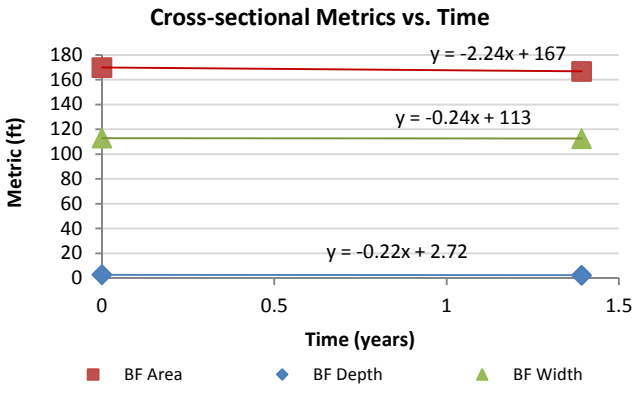
Stream Condition Index: 6.9 Stability Index: 2.9

Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
1	6/30/2011	169.71	2.72	112.88	0.0032	1.5	82.4
2	11/19/2012	166.60	2.41	112.54	0.0037	3.6	54.5

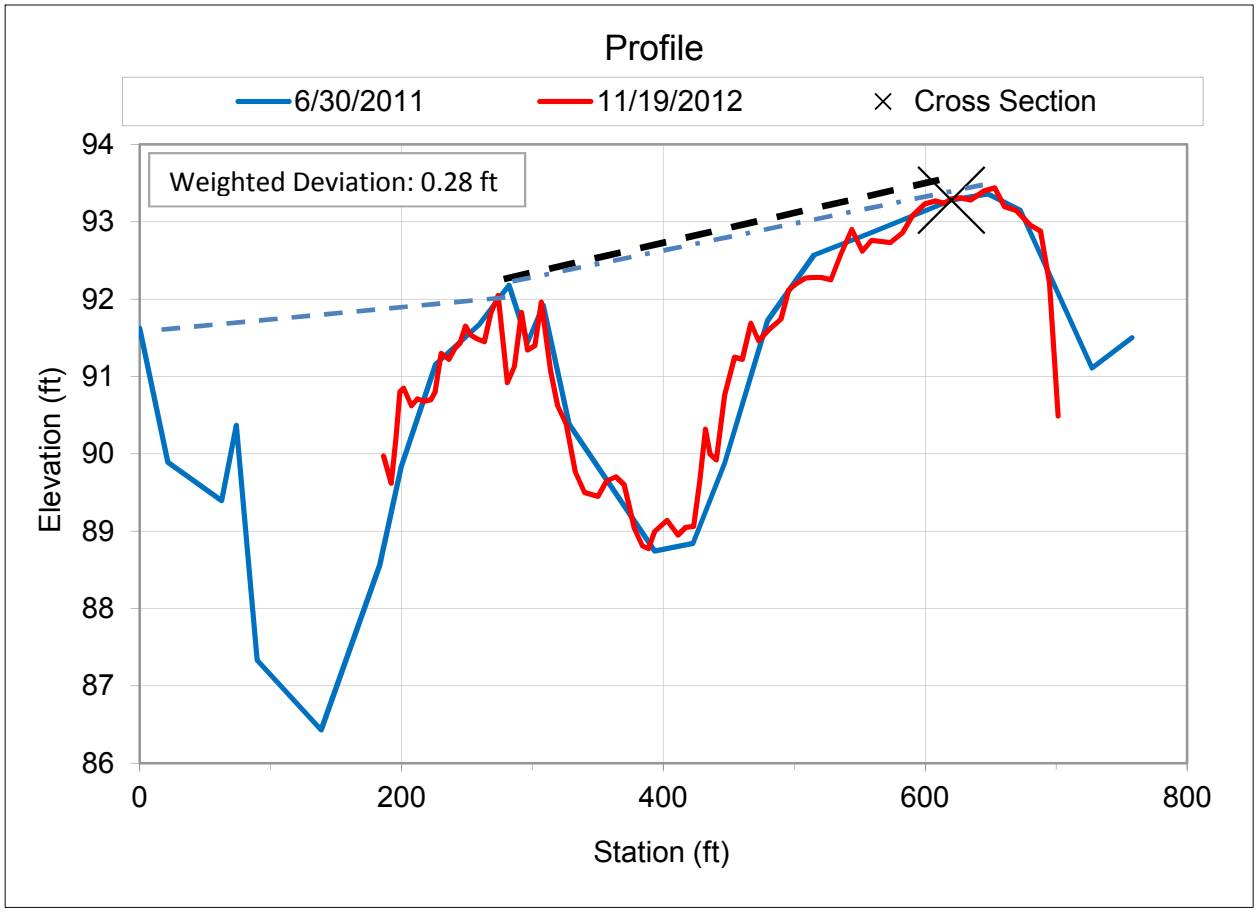


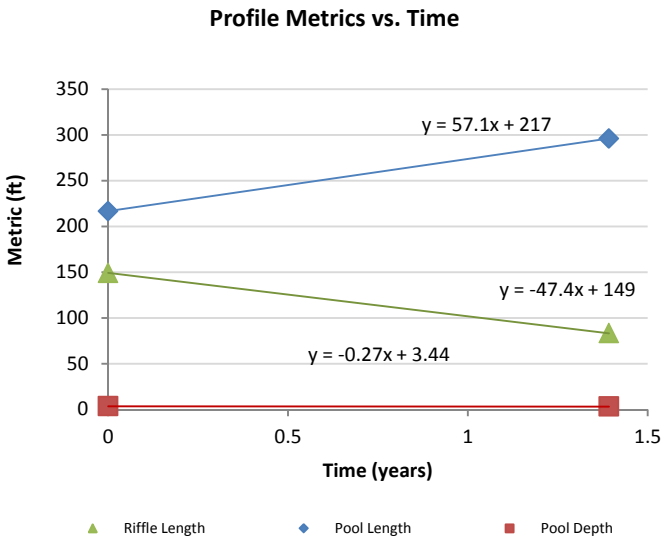
Cross section looking downstream

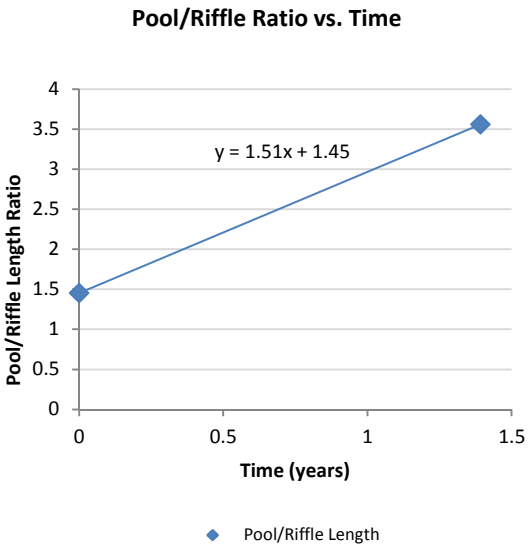
2012 photo looking upstream



Site: **GPC 7.5** (continued)







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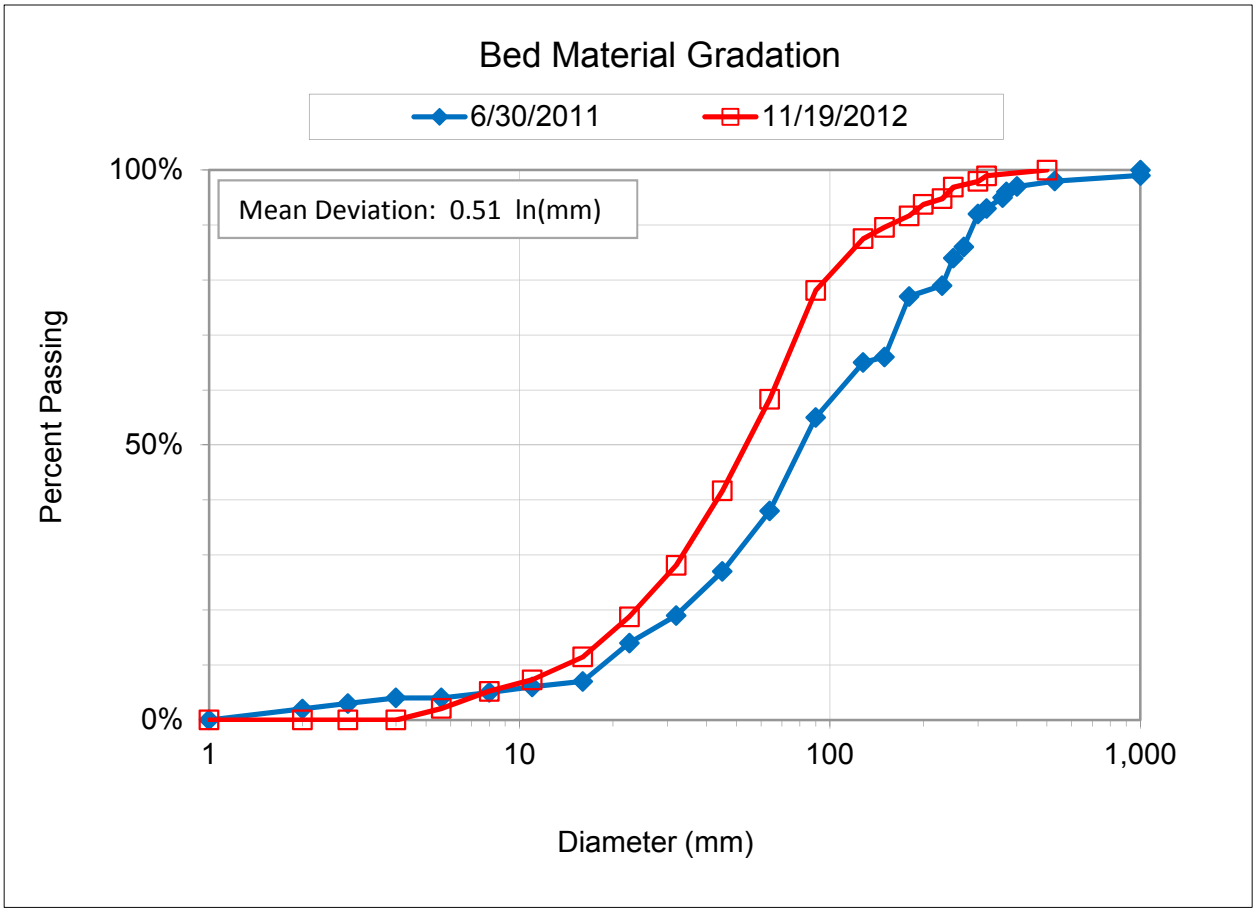
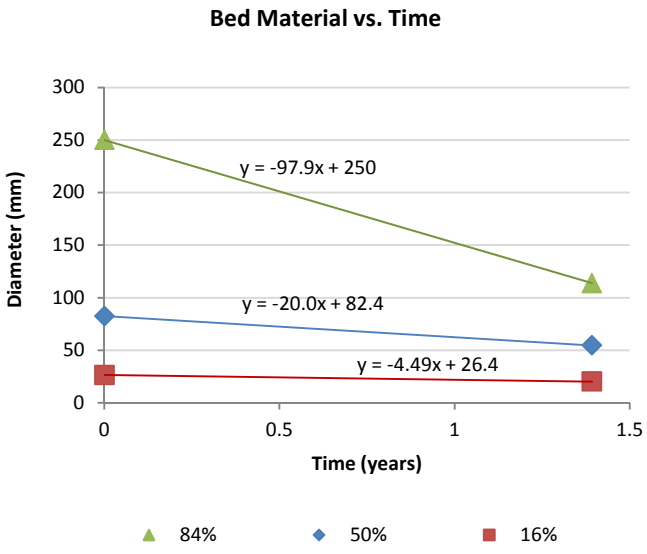




The average weighted deviation presented in the above figures was calculated sensu Baker et. al. (2012) and Hawley, et. al. (In Prep) and measures average change in survey points between 2012 and 2011.

Cross Section: measures change in the active channel bed ground surface.

Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

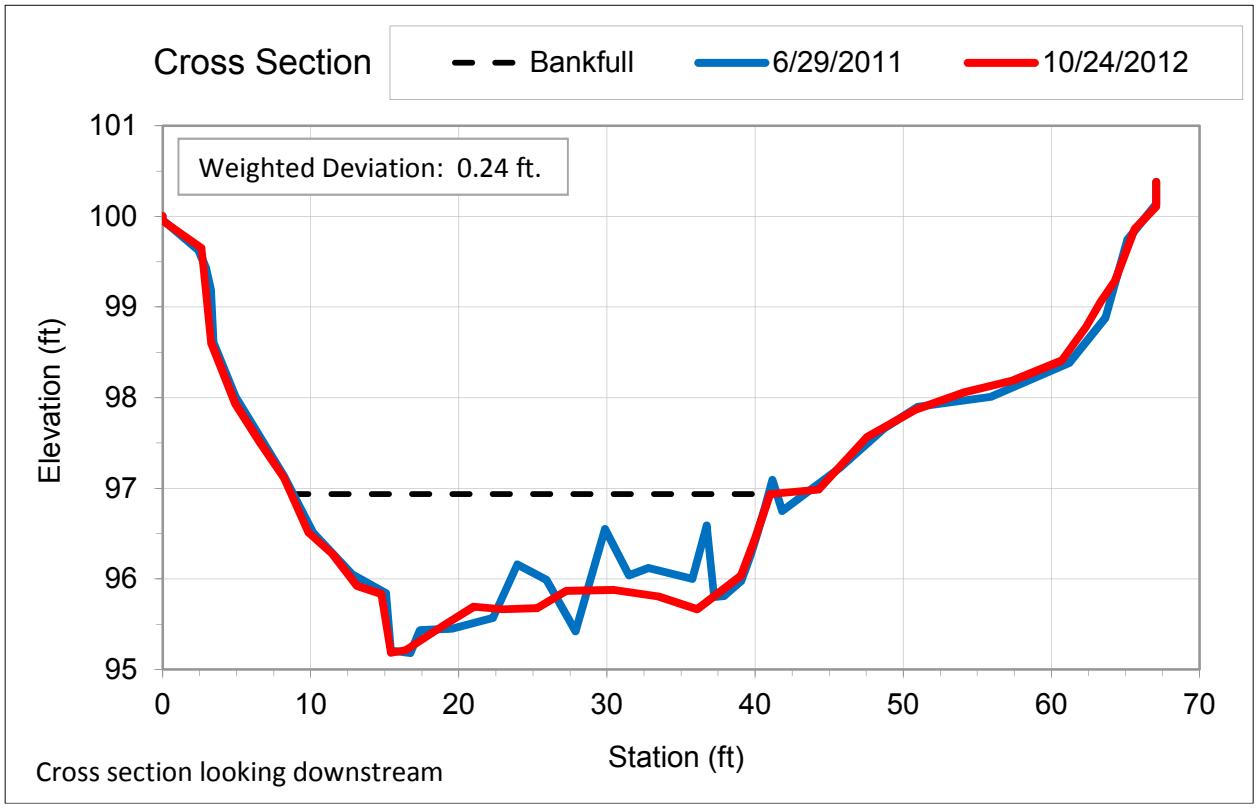
Site: FWF 0.8

Imp: 11.5% Drainage Area: 4.29 mi^2

KDOW 2011 Grade: D+ KDOW 2012 Grade: C-

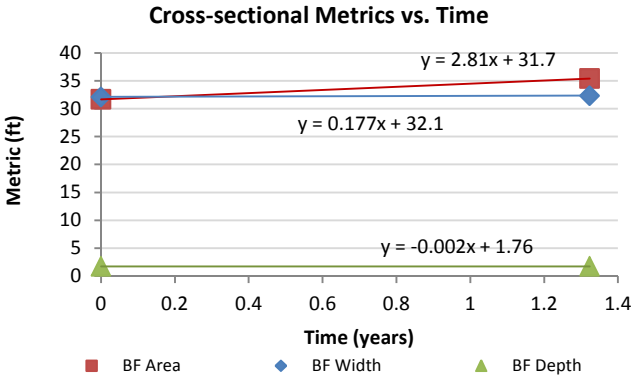
Stream Condition Index: 4.5 Stability Index: 2.9

Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
1	6/29/2011	31.68	1.76	32.10	0.0057	7.5	64.0
2	10/24/2012	35.40	1.75	32.33	0.0037	12.9	61.6



Cross section looking downstream

2012 photo looking upstream



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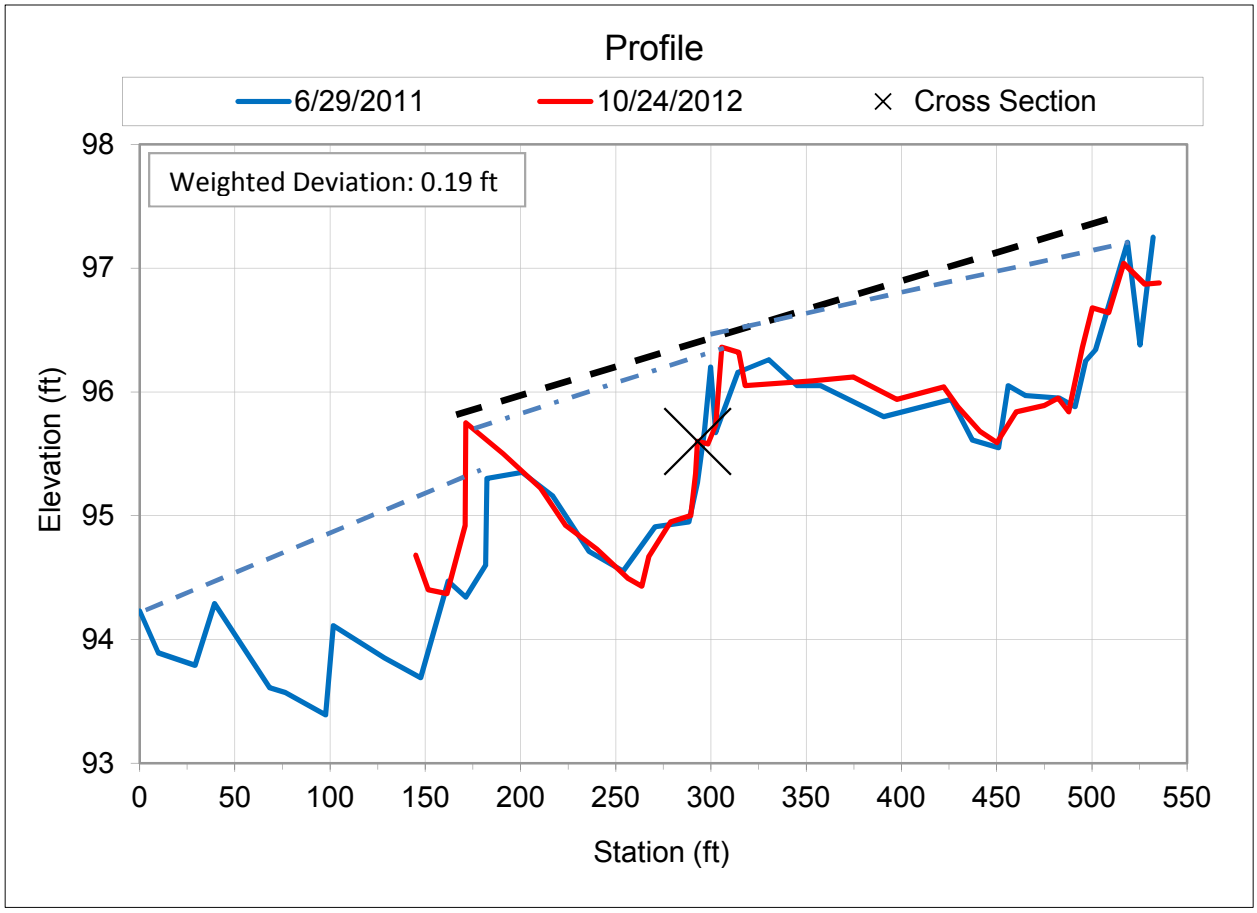
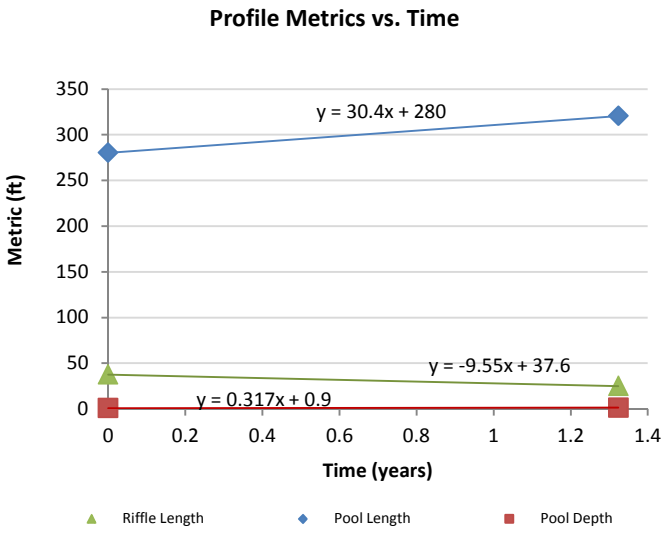
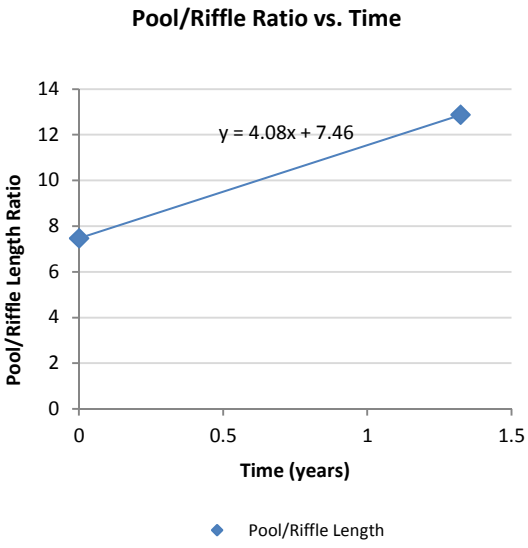
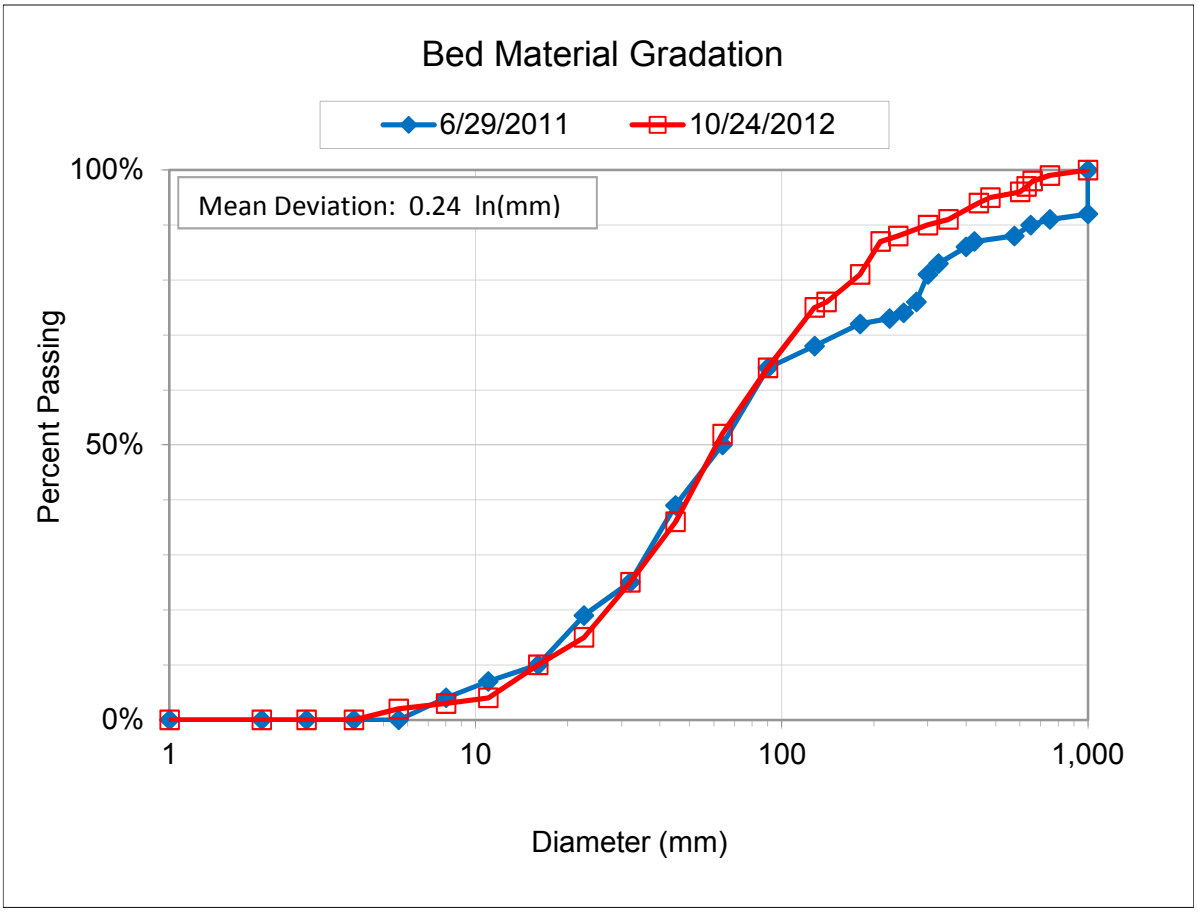
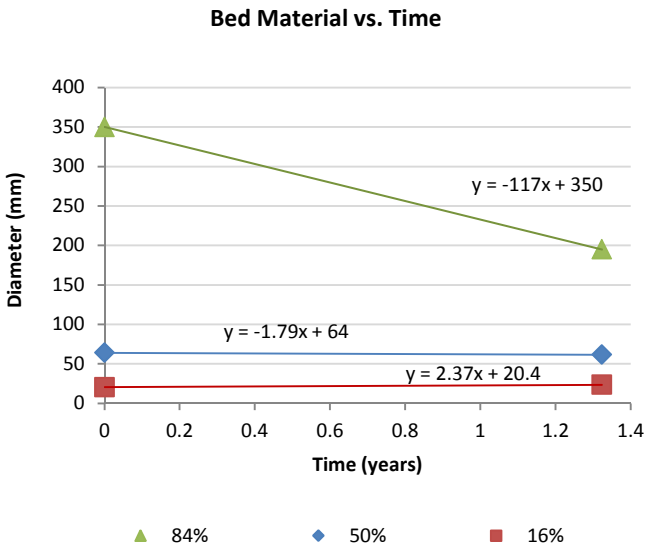






Site: **FWF 0.8** (continued)





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Cross Section: measures change in the active channel bed ground surface.

Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

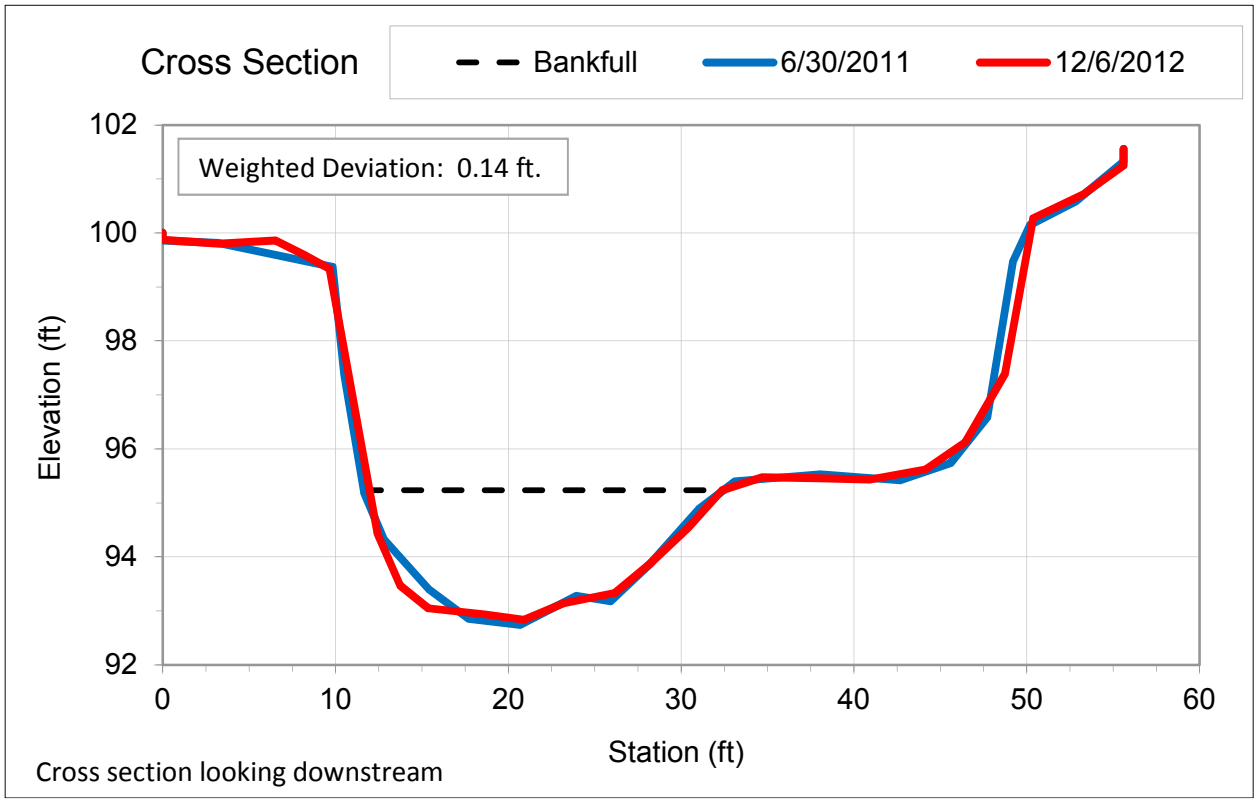
Site: RDR 1.1

Imp: 2.13% Drainage Area: 3.19 mi^2

KDOW 2011 Grade: C KDOW 2012 Grade: C

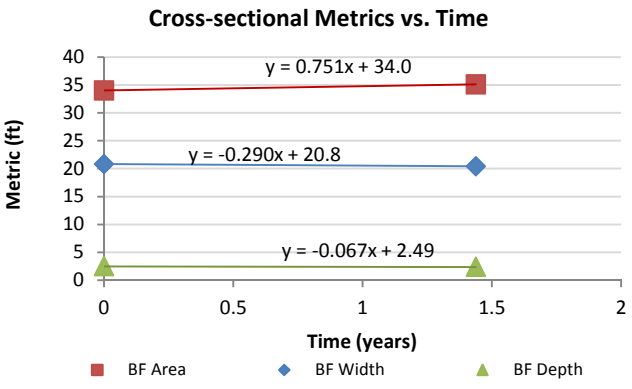
Stream Condition Index: 5.4 Stability Index: 4.9

Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
1	6/30/2011	34.0	2.49	20.83	0.009	12.7	39.0
2	12/6/2012	35.08	2.40	20.41	0.012	6.57	62.6

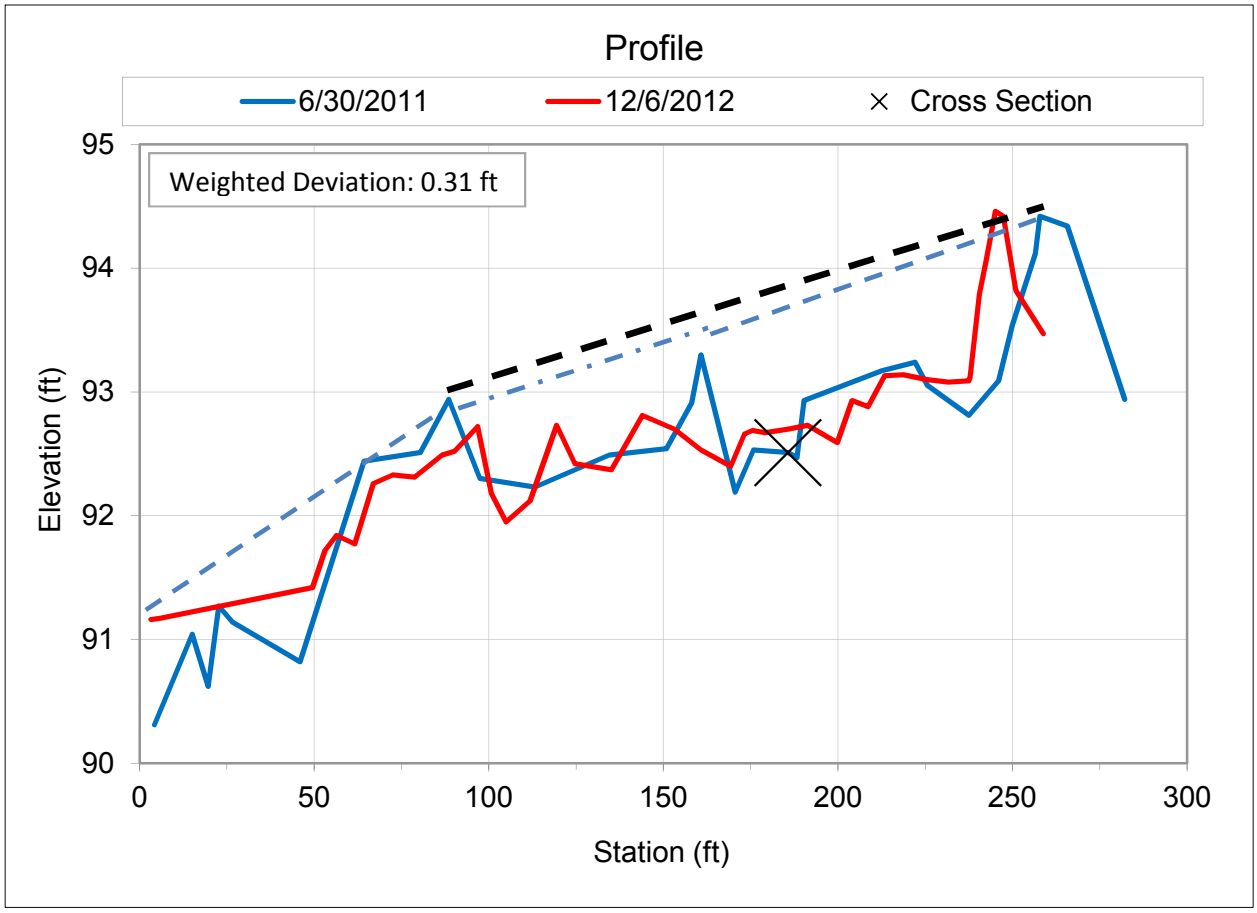


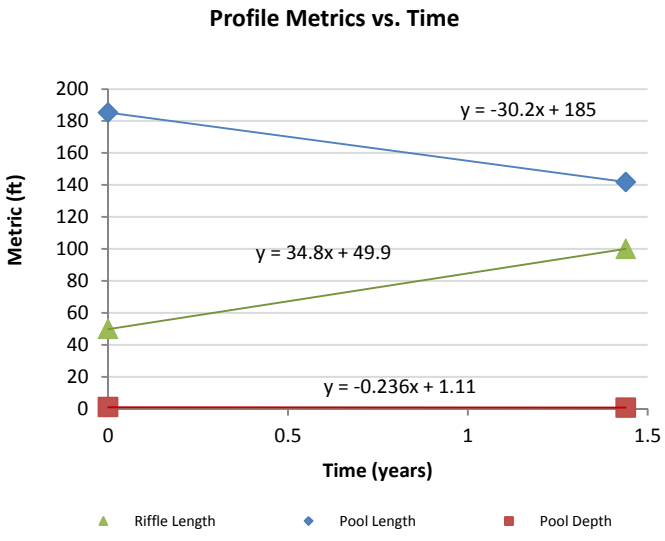
Cross section looking downstream

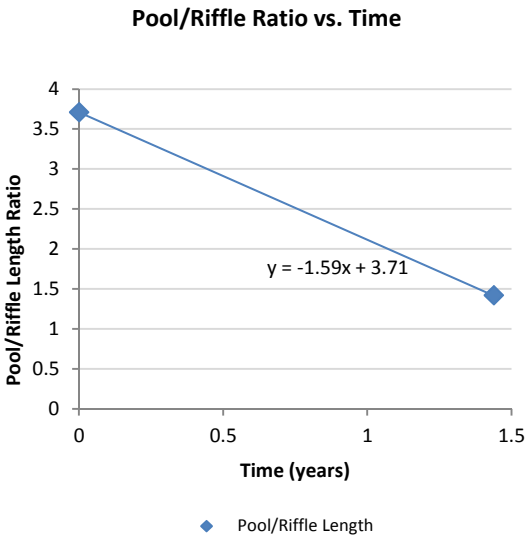
2012 photo looking upstream



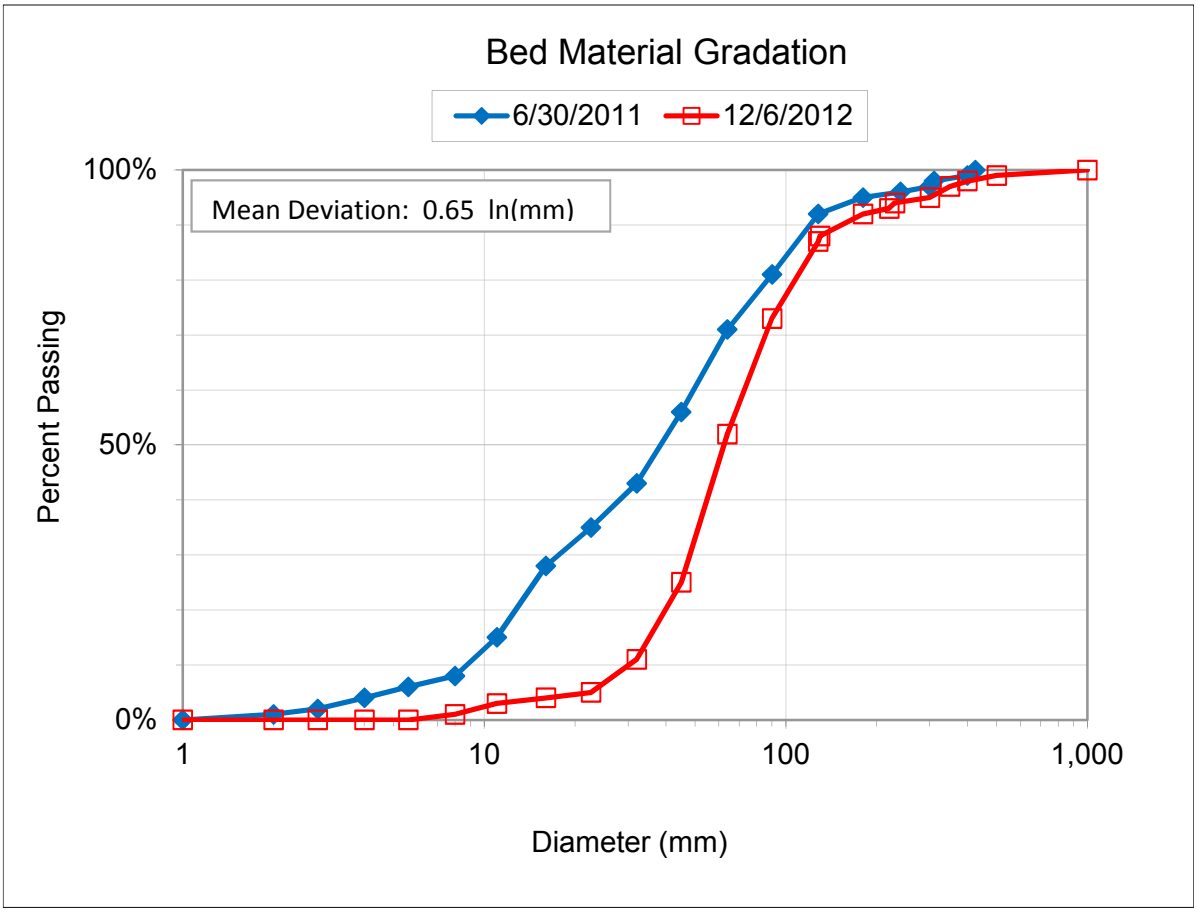
Site: **RDR 1.1** (continued)

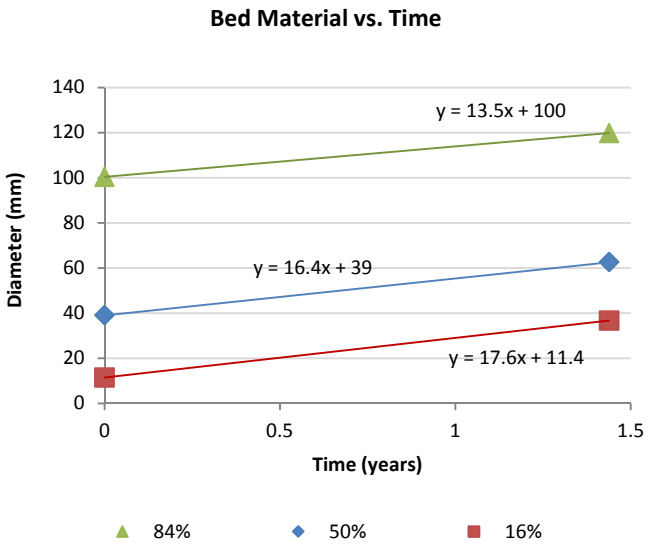






Site: **RDR 1.1** (continued)





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Cross Section: measures change in the active channel bed ground surface.

Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

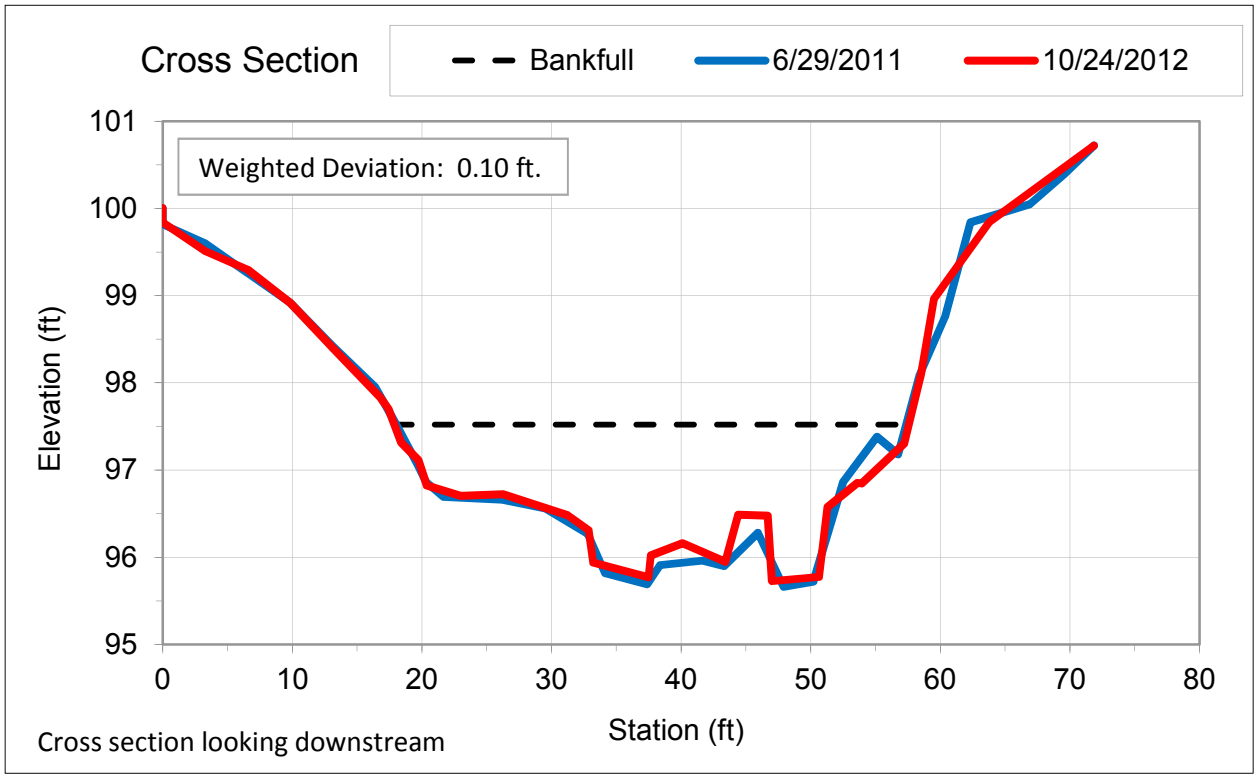
Site: LOB 0.5

Imp: 3.70% Drainage Area: 2.71 mi^2

KDOW 2011 Grade: D+ KDOW 2012 Grade: D+

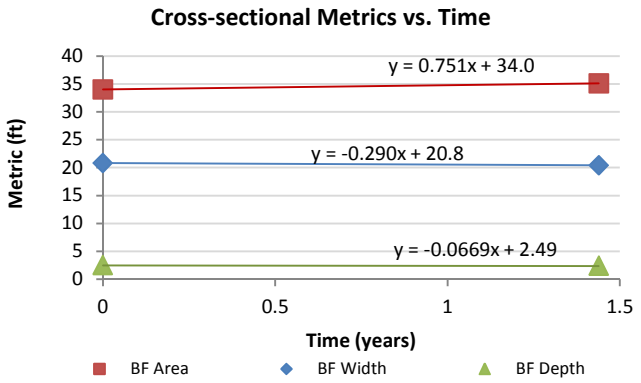
Stream Condition Index: 3.6 Stability Index: 1.6

Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
1	6/29/2011	44.8	1.86	39.3	0.0170	2.07	bedrock
2	10/24/2012	43.0	1.79	39.7	0.0165	1.28	bedrock

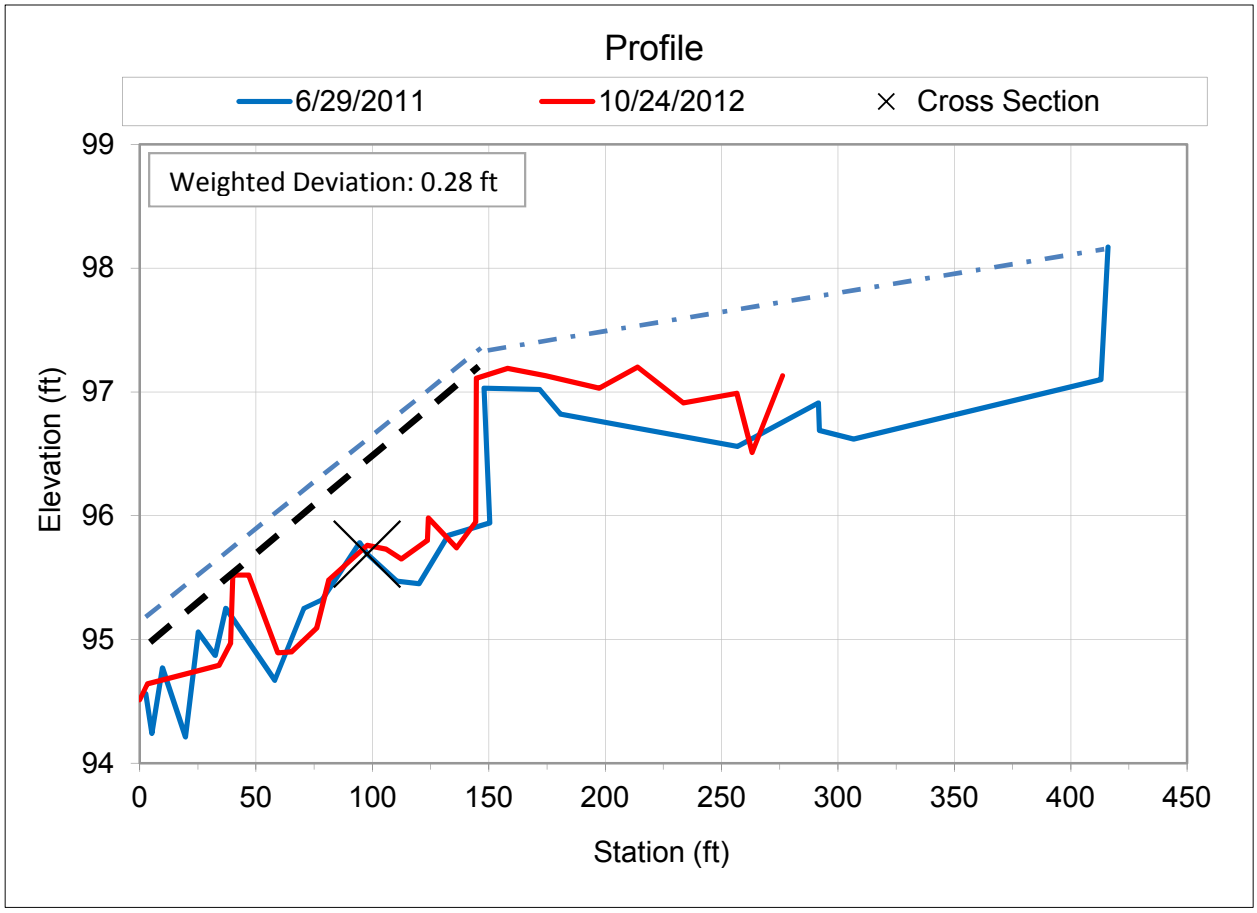


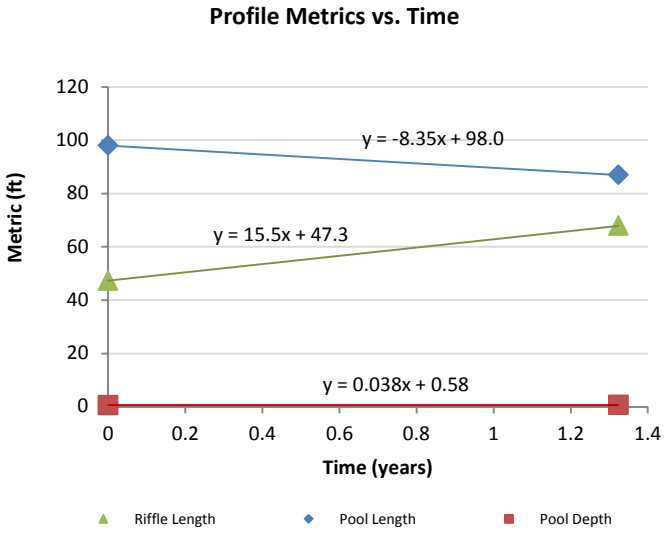
Cross section looking downstream

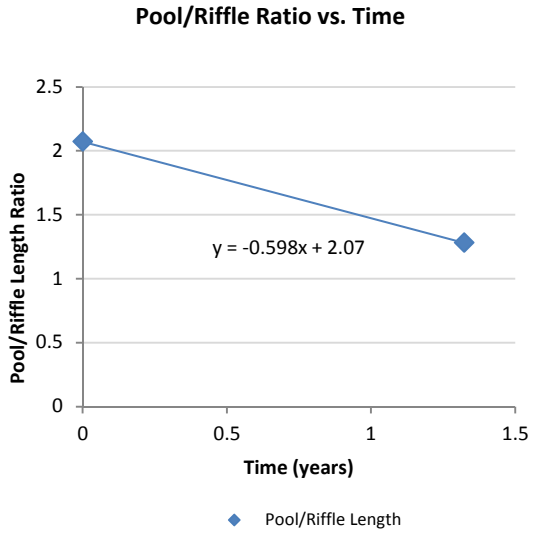
2012 photo looking upstream



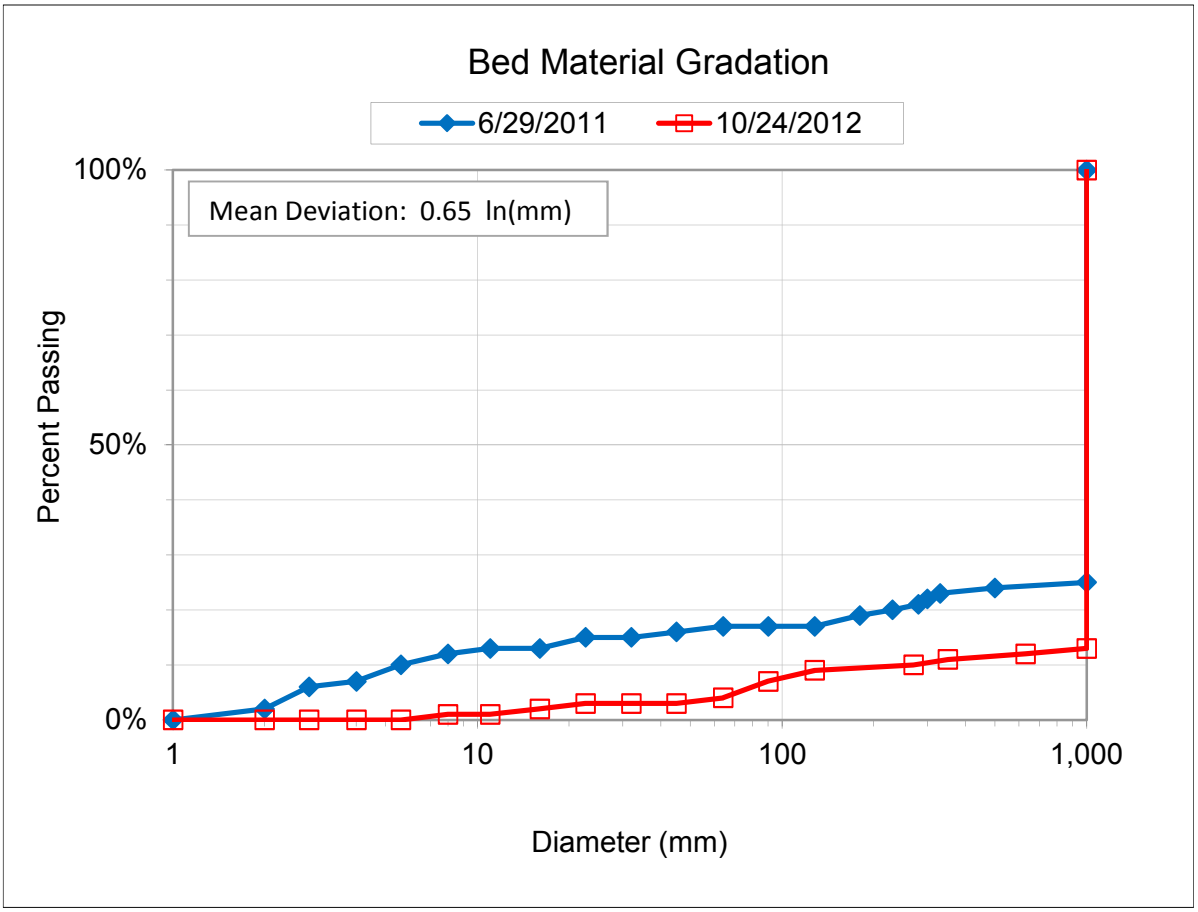
Site: **LOB 0.5** (continued)

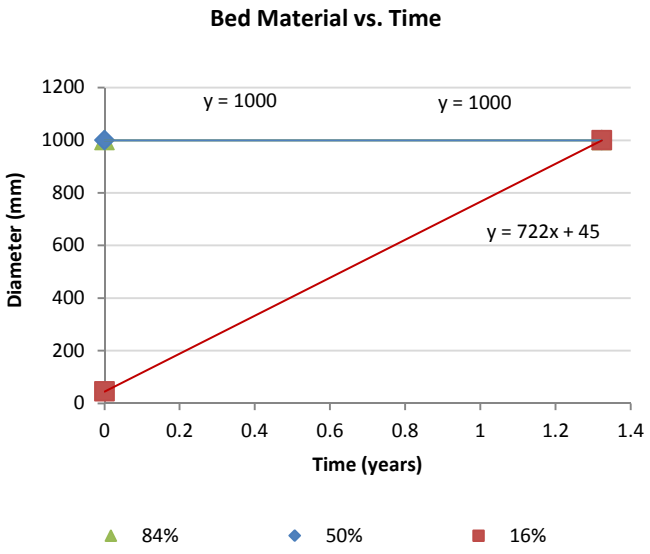






Site: **LOB 0.5** (continued)





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Cross Section: measures change in the active channel bed ground surface.

Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

APPENDIX 4.A.2

SD1 Survey Sites

NOTE: SD1 monitoring sites include 4 rounds of survey data beginning in 2008. The following Cross Section, Profile, and Bed Material Gradation figures illustrate 4 years of data for overall visual observation. However, in processing measured change as a function of time as well as the average weighted deviation, only the 2011 and 2012 data is presented for direct comparison to the BCCD data, which was only collected over the 2011 and 2012 period.

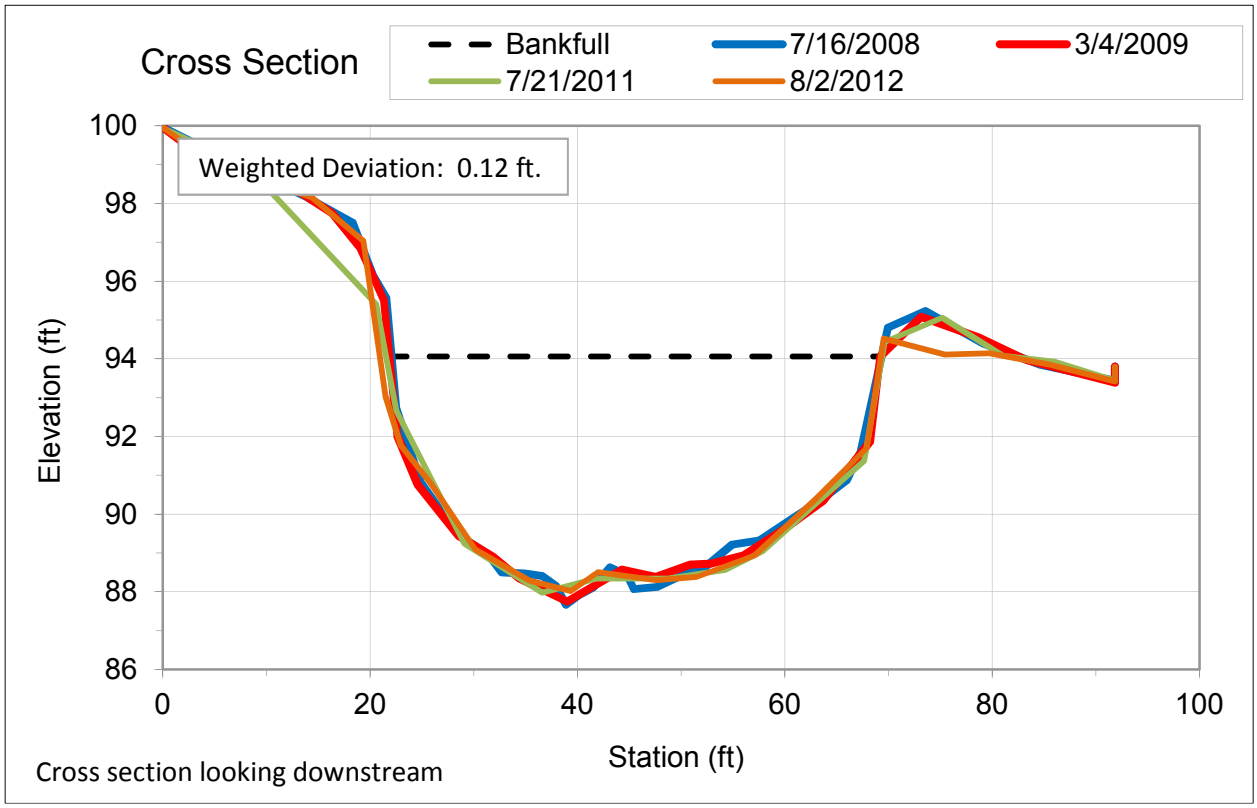
Site: GPC 17.9

Imp: 27.0% Drainage Area: 5.7 mi^2

KDOW 2011 Grade: NA KDOW 2012 Grade: NA

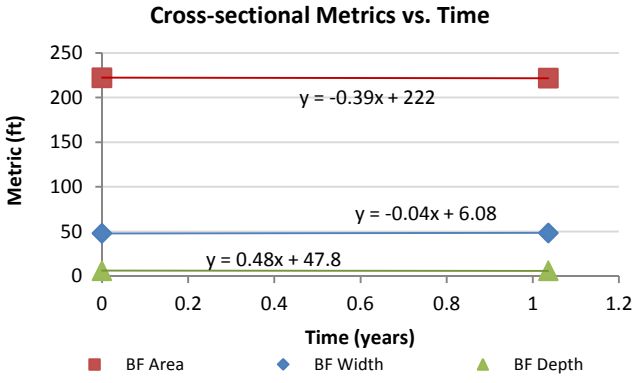
Stream Condition Index: 5.5 Stability Index: 2.0

Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
3	7/21/2011	222.1	6.08	47.8	.0028	11.79	36.3
4	8/2/2012	221.7	6.04	48.3	.0015	168.6	46.6

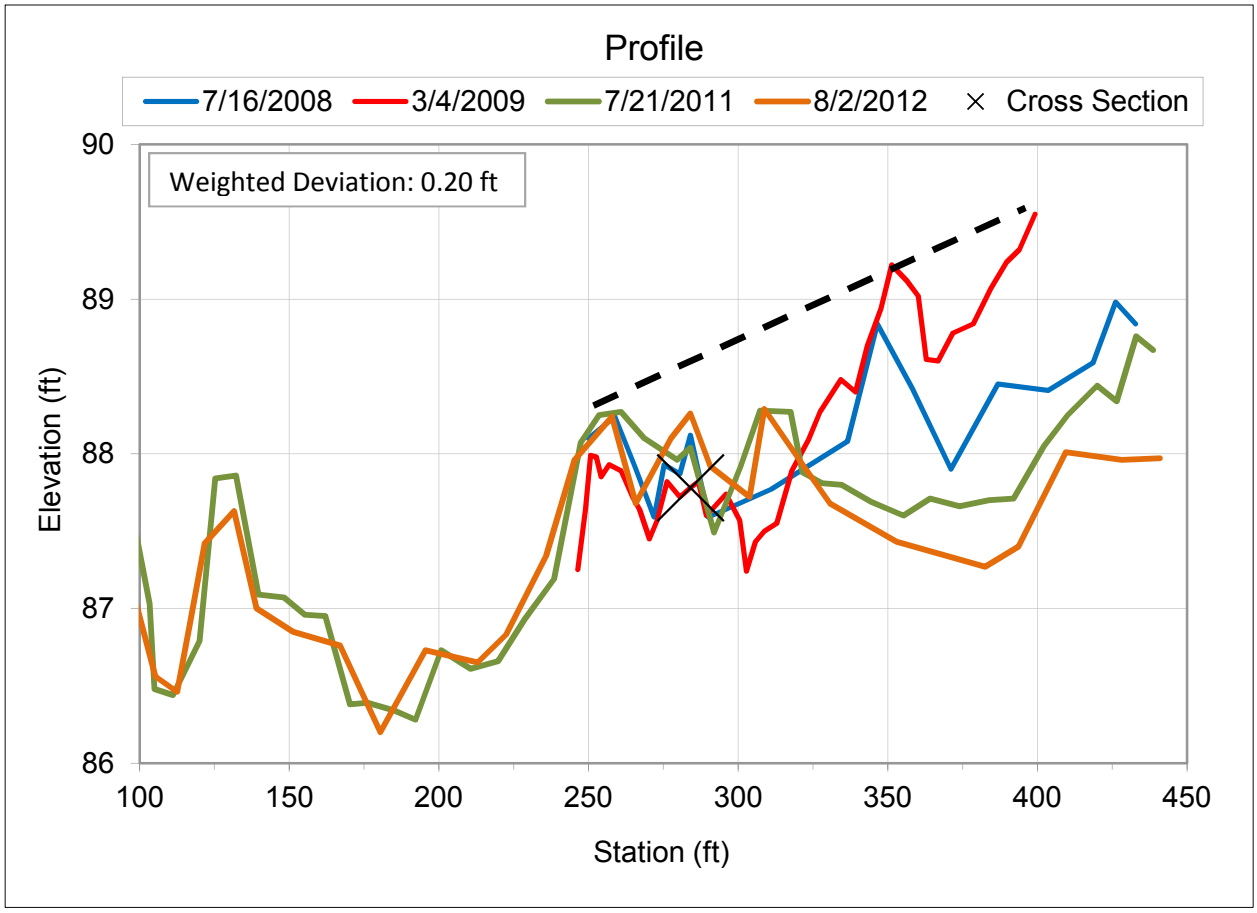


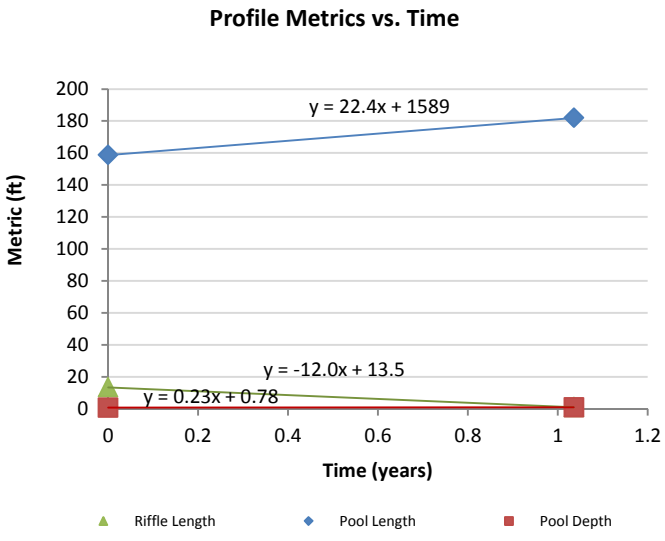
Cross section looking downstream

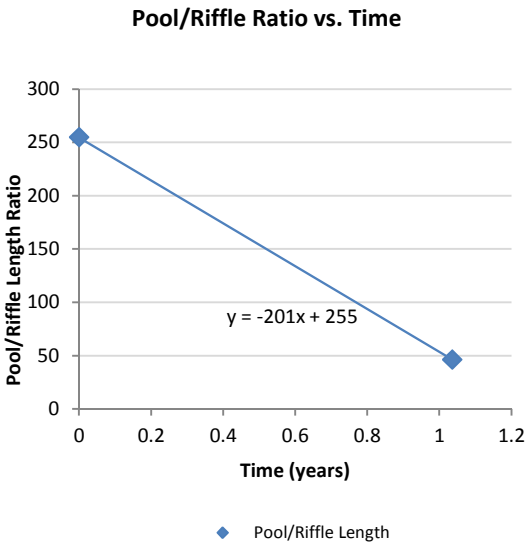
2012 photo looking upstream



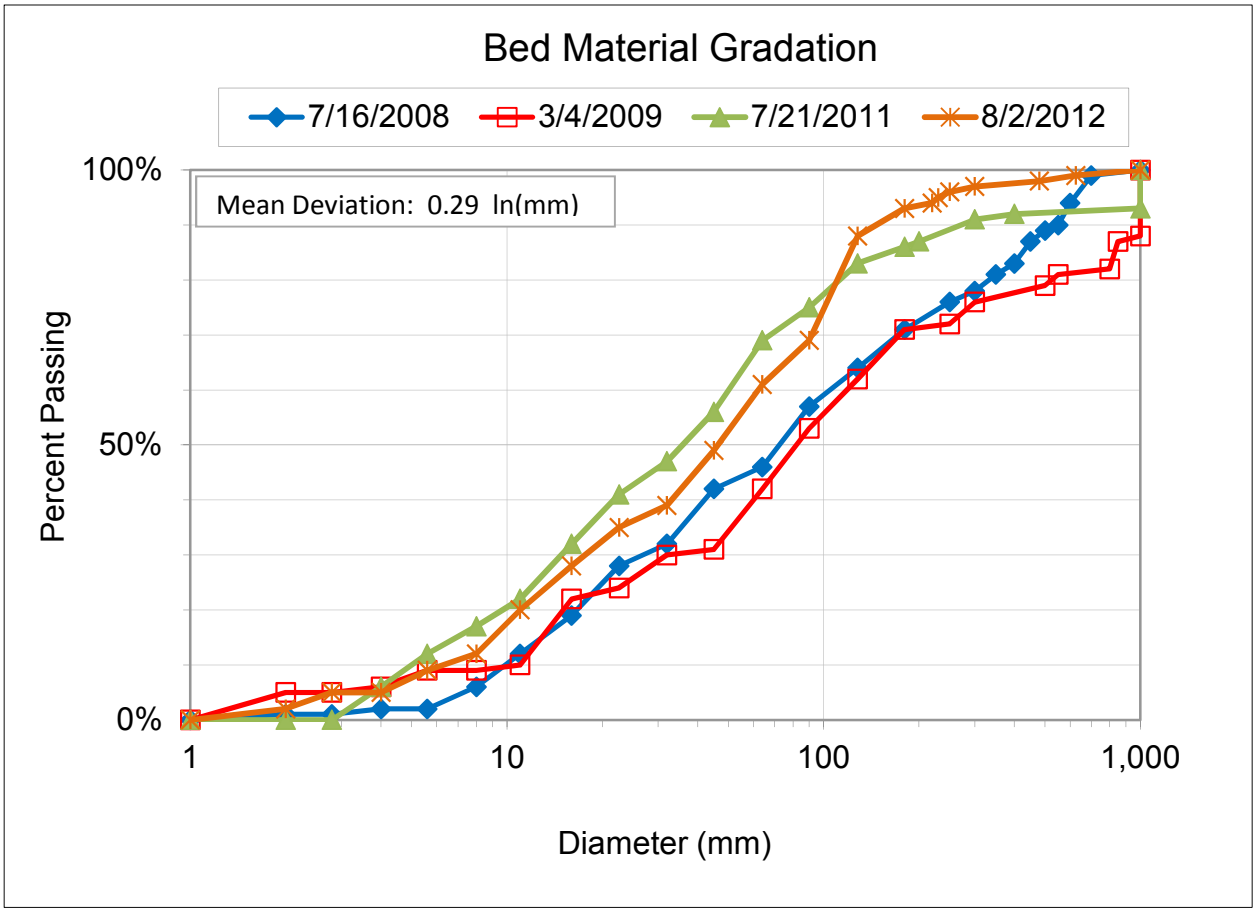
Site: **GPC 17.9** (continued)

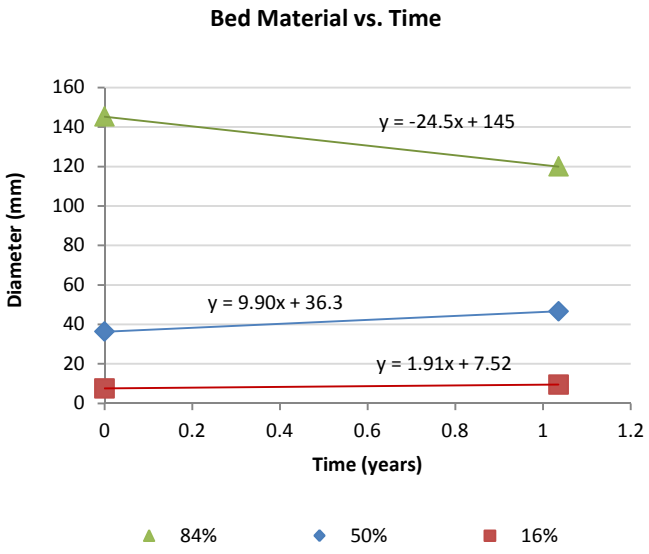






Site: **GPC 17.9** (continued)





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Cross Section: measures change in the active channel bed ground surface.

Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

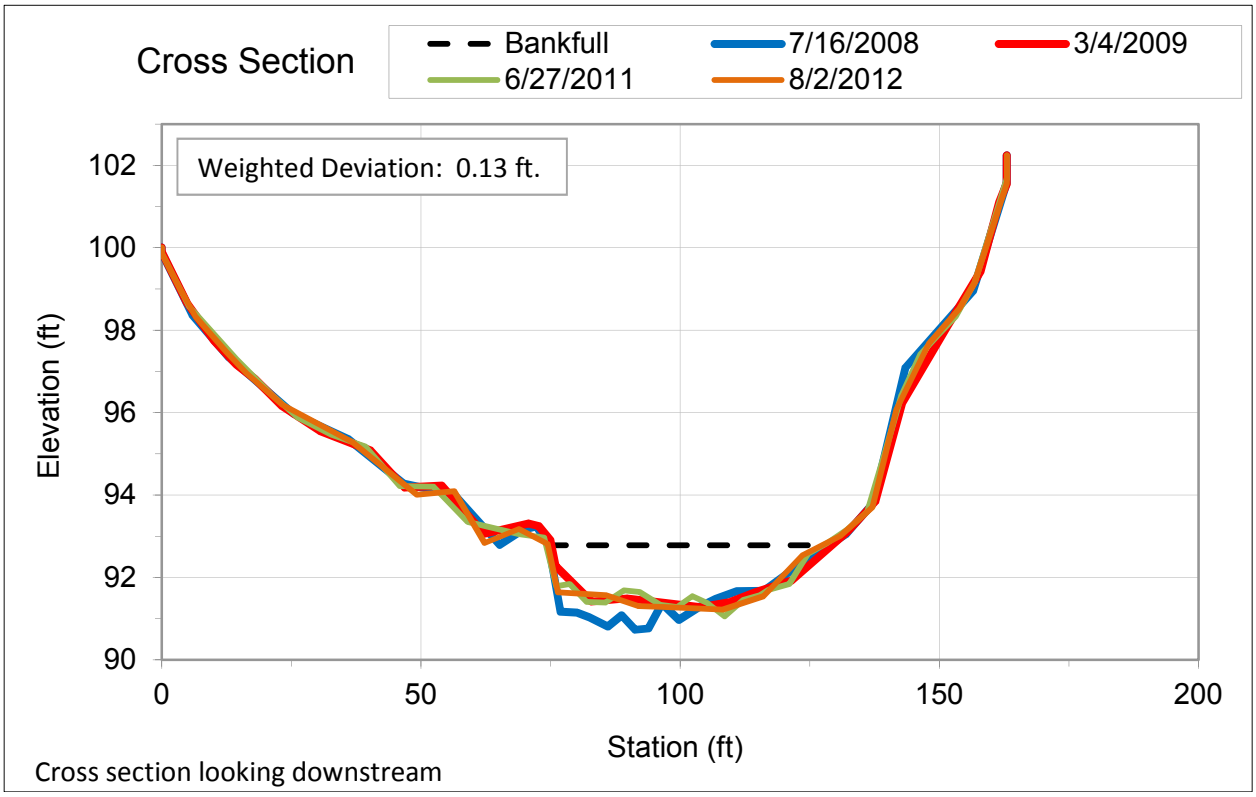
Site: GPC 17.1 – UNT 0.1

Imp: 29.0% Drainage Area: 3.84 mi^2

KDOW 2011 Grade: C KDOW 2012 Grade: C+

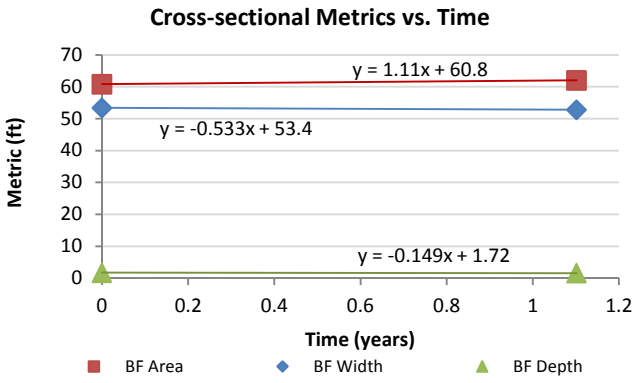
Stream Condition Index: 7.2 Stability Index: 6.8

Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
3	6/27/2011	60.80	1.72	53.39	0.0109	5.53	70.8
4	8/2/2012	62.03	1.56	52.80	0.0100	1.84	64.0

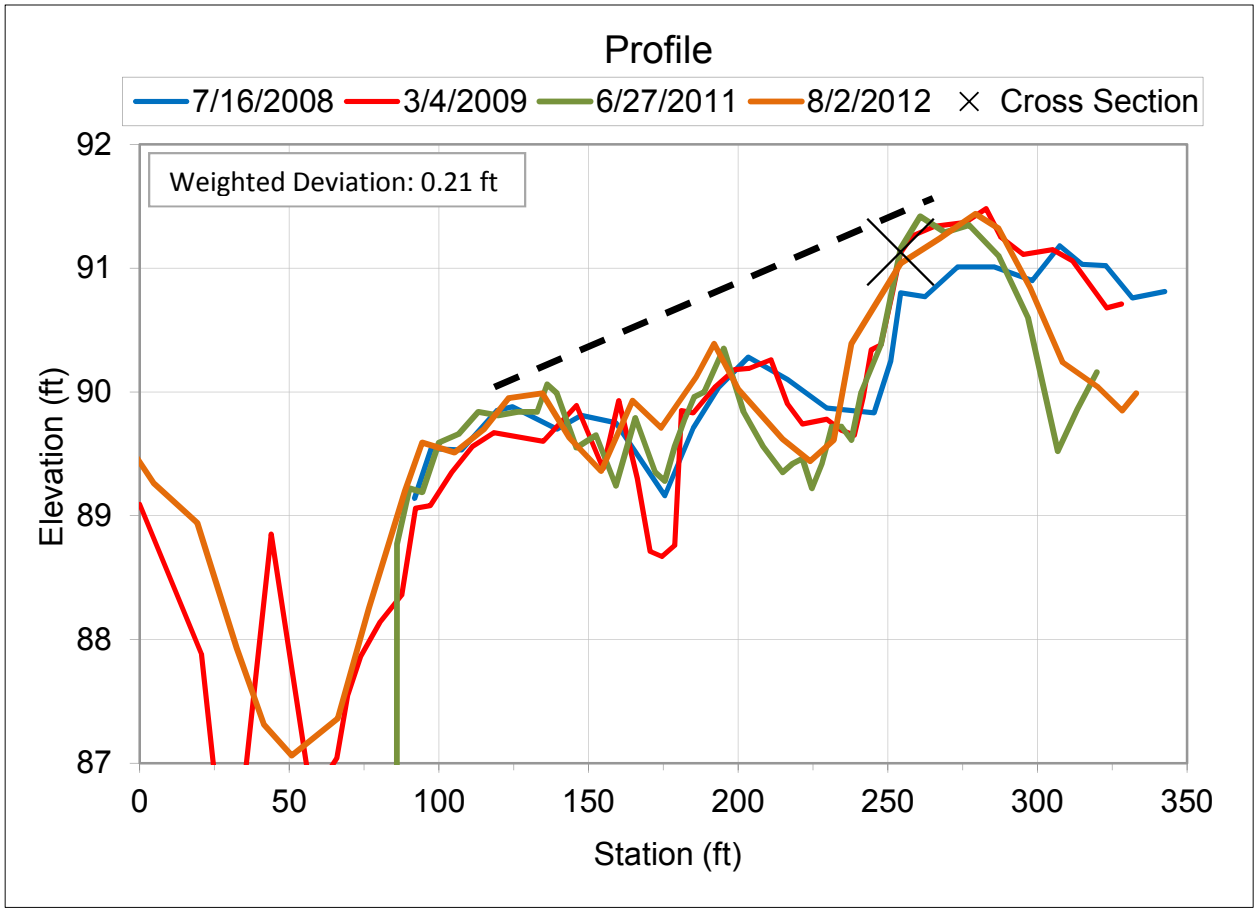


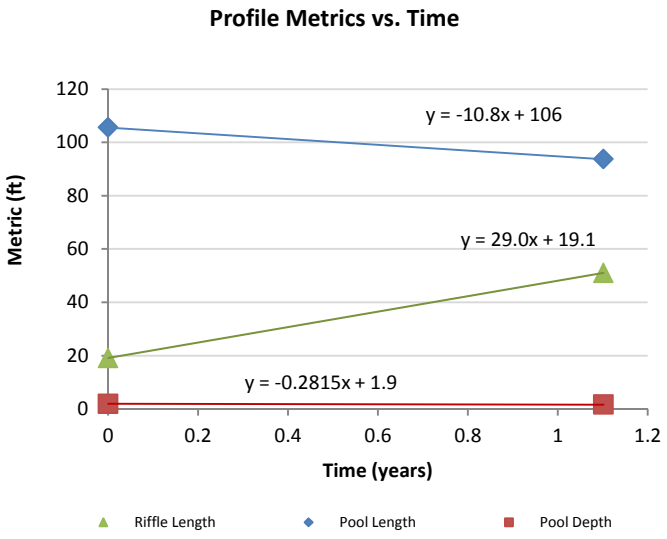
Cross section looking downstream

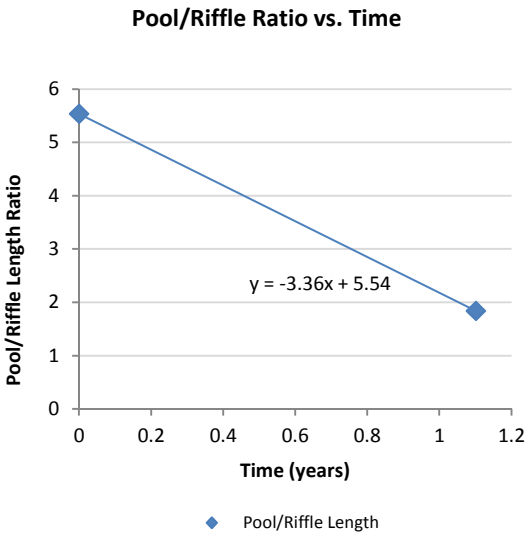
2012 photo looking upstream



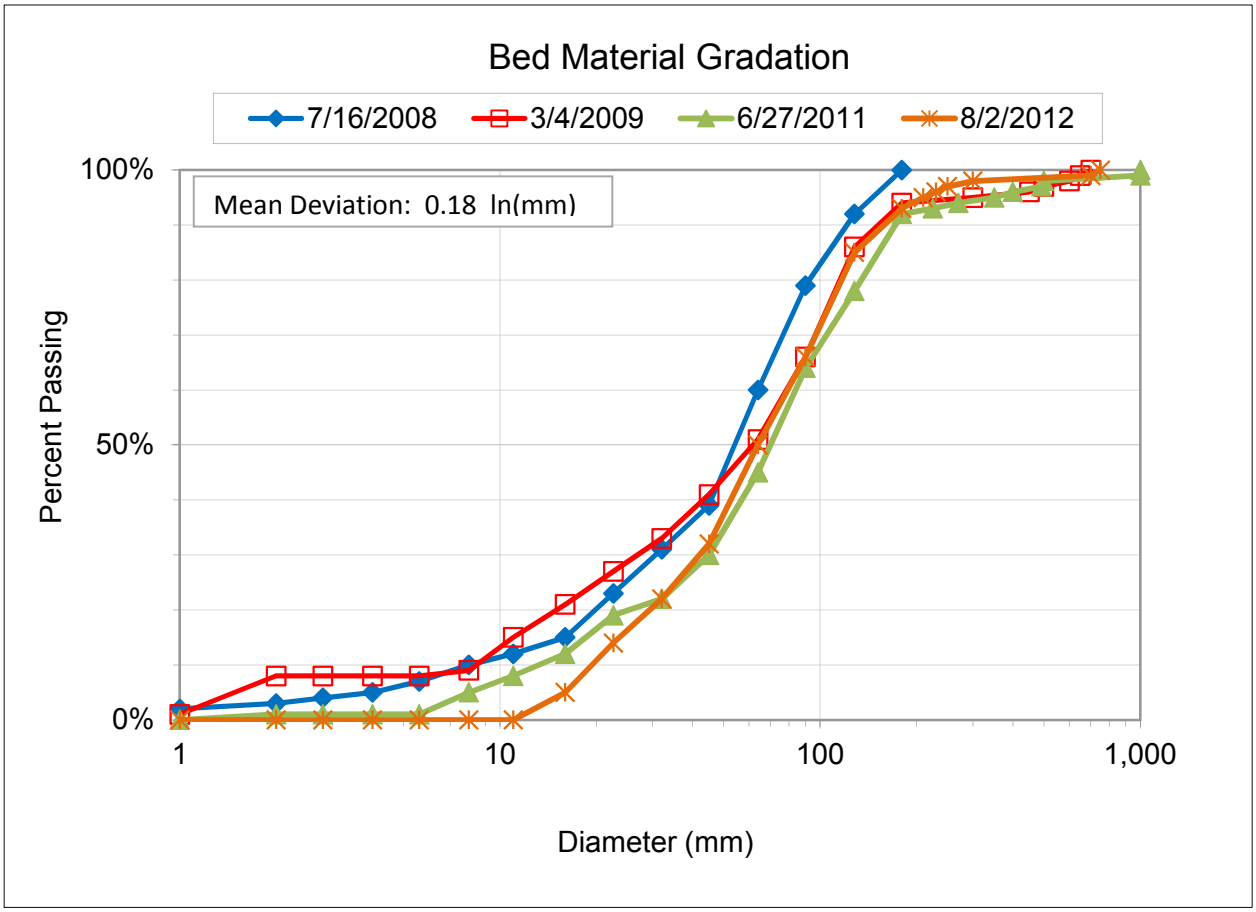
Site: **GPC 17.1 - UNT 0.1** (continued)

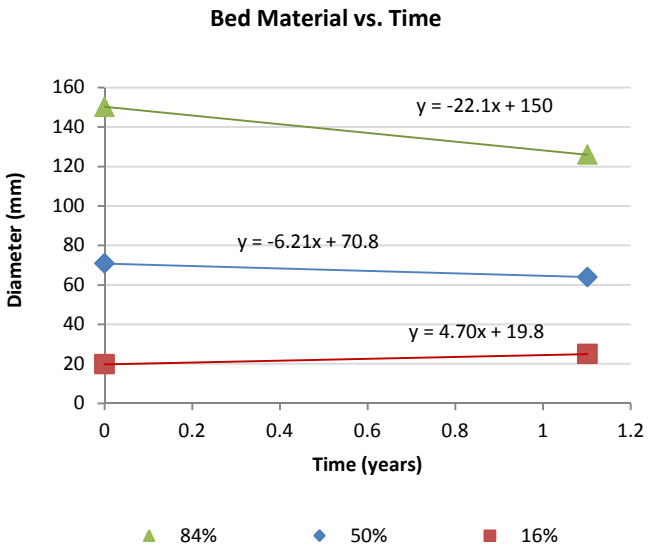






Site: **GPC 17.1 – UNT 0.1** (continued)





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Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

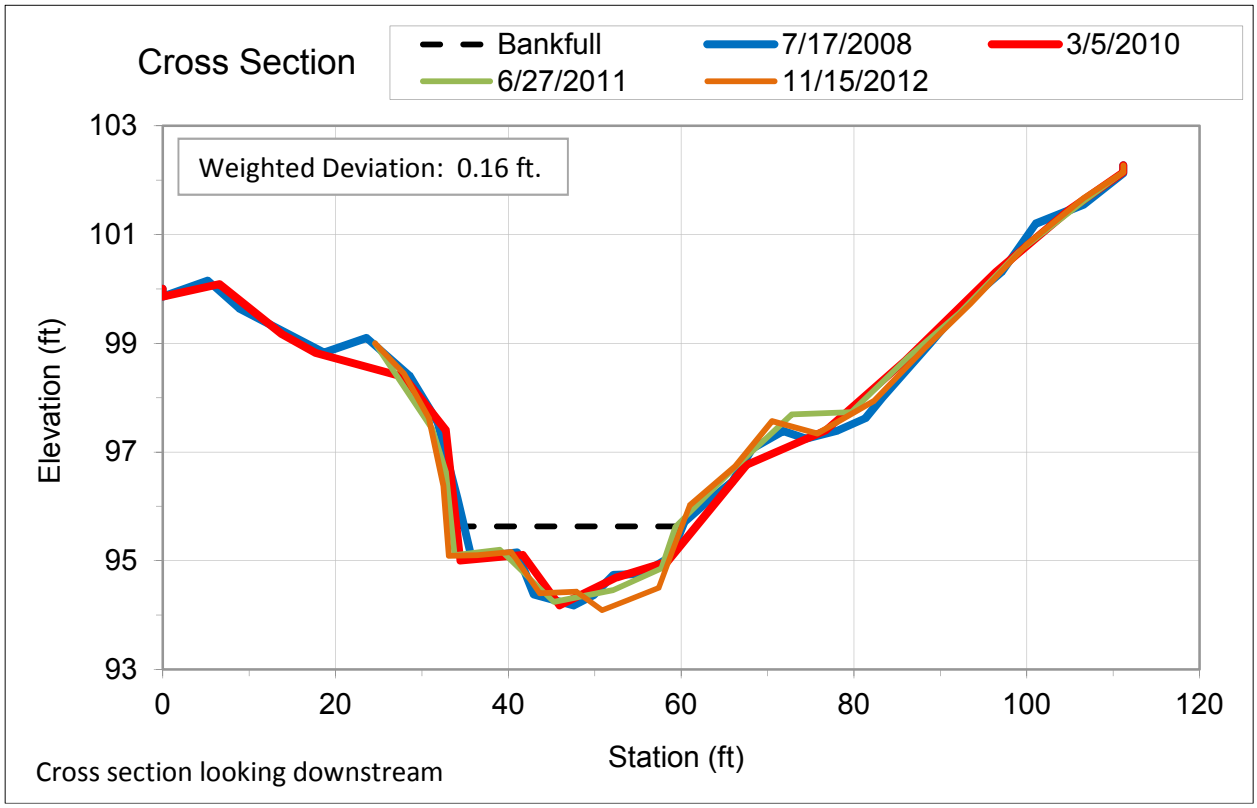
Site: SFG 5.3 DS

Imp: 27.6% Drainage Area: 6.91 mi^2

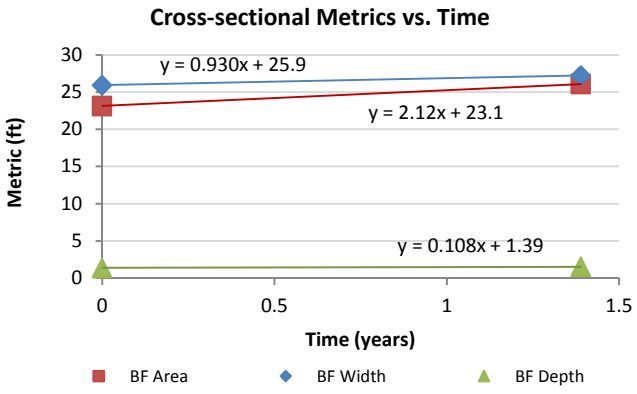
KDOW 2011 Grade: NA KDOW 2012 Grade: NA

Stream Condition Index: 4.3 Stability Index: 4.48

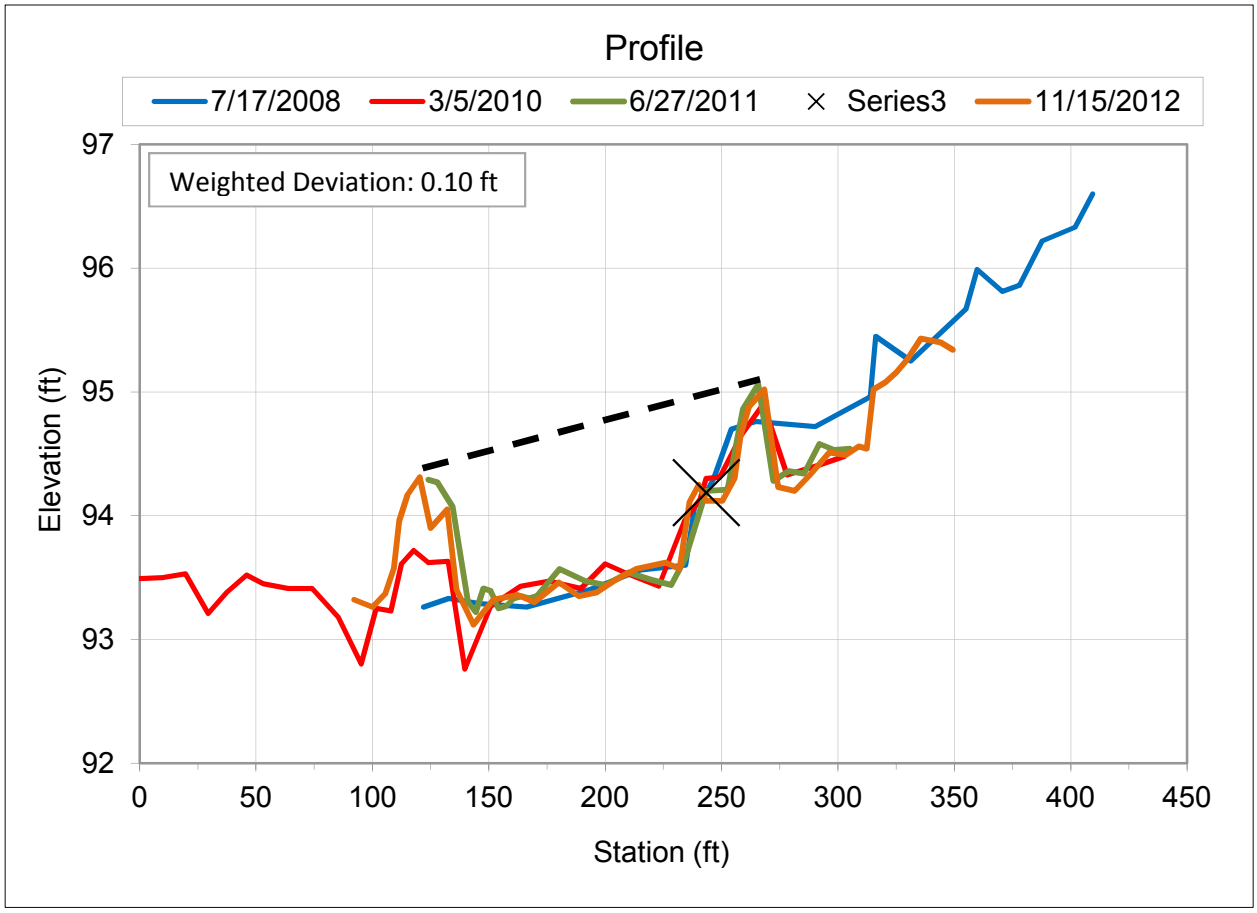
Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
3	6/27/2011	23.14	1.39	25.93	0.0054	10.51	45
4	11/15/2012	26.09	1.54	27.22	0.0048	10.63	400

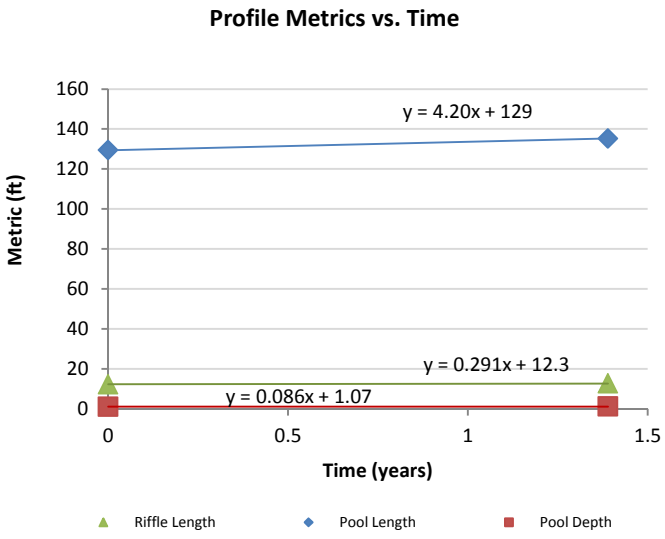


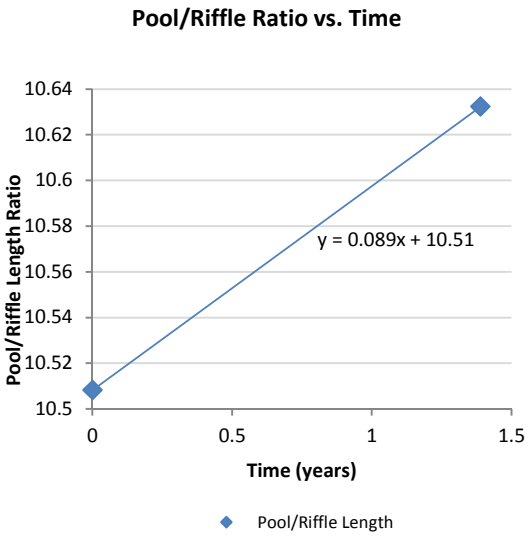
2012 photo looking upstream



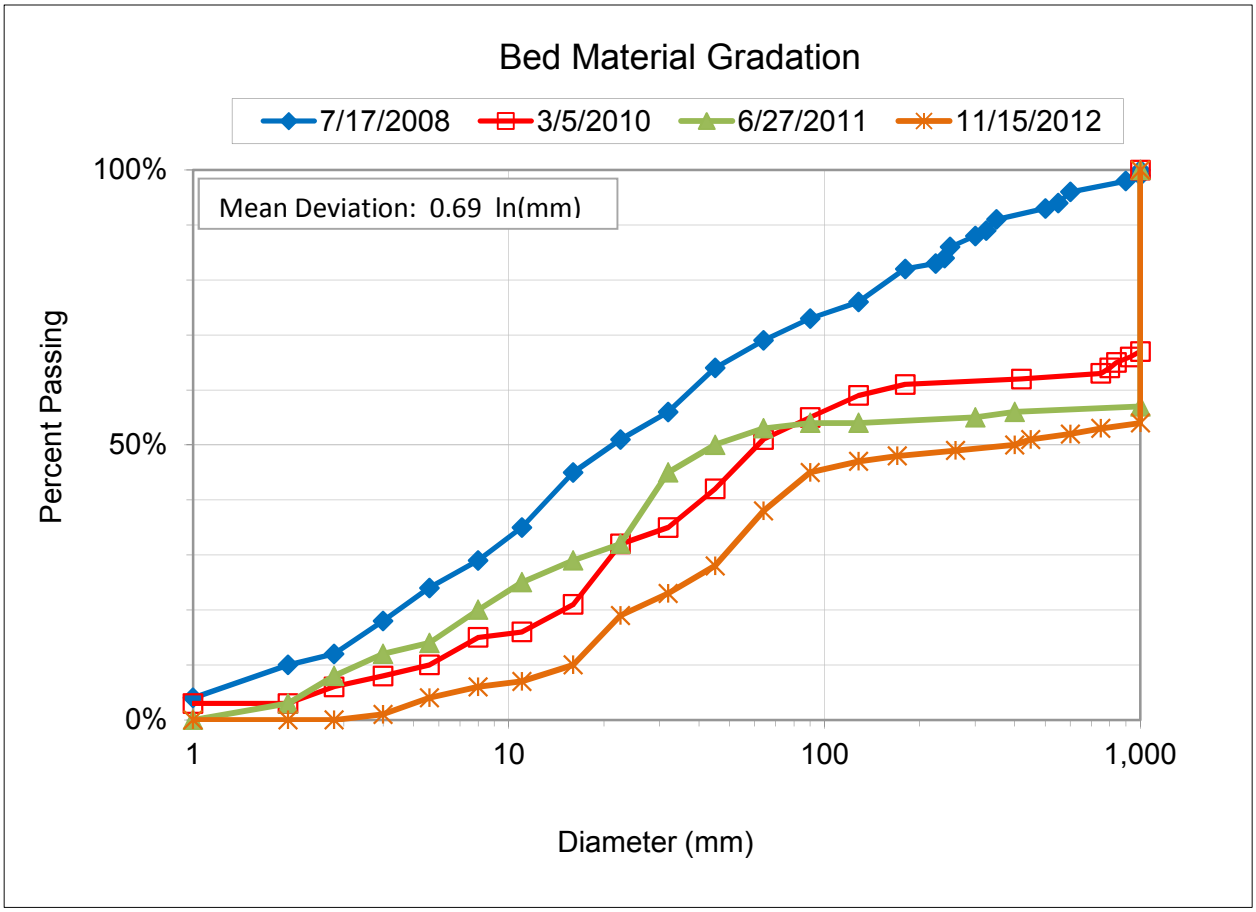
Site: **SFG 5.3 DS** (continued)

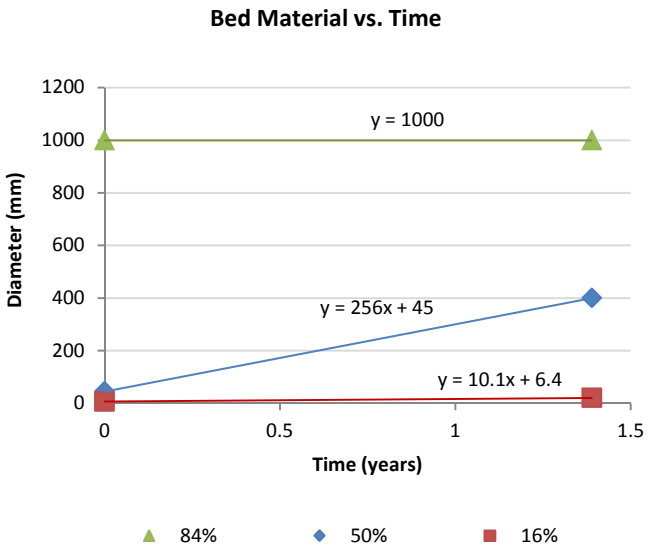






Site: **SFG 5.3 DS** (continued)





The average weighted deviation presented in the above figures was calculated sensu Baker et. al. (2012) and Hawley, et. al. (In Prep) and measures average change in survey points between 2012 and 2011.

Cross Section: measures change in the active channel bed ground surface.

Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

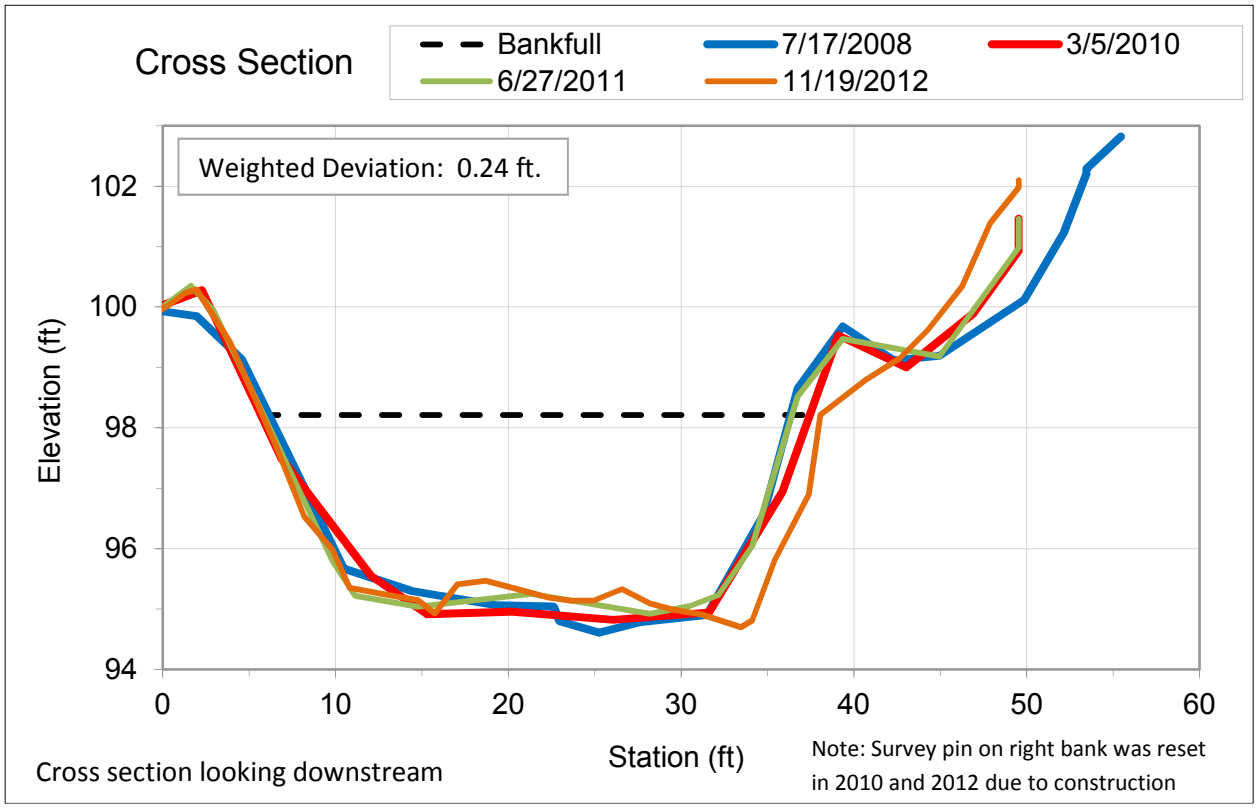
Site: SFG 5.3 UNT

Imp: 41.1% Drainage Area: 2.20 mi^2

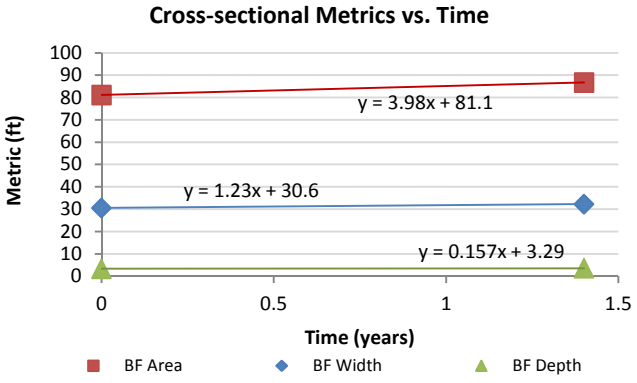
KDOW 2011 Grade: C- KDOW 2012 Grade: C-

Stream Condition Index: 4.3 Stability Index: 1.0

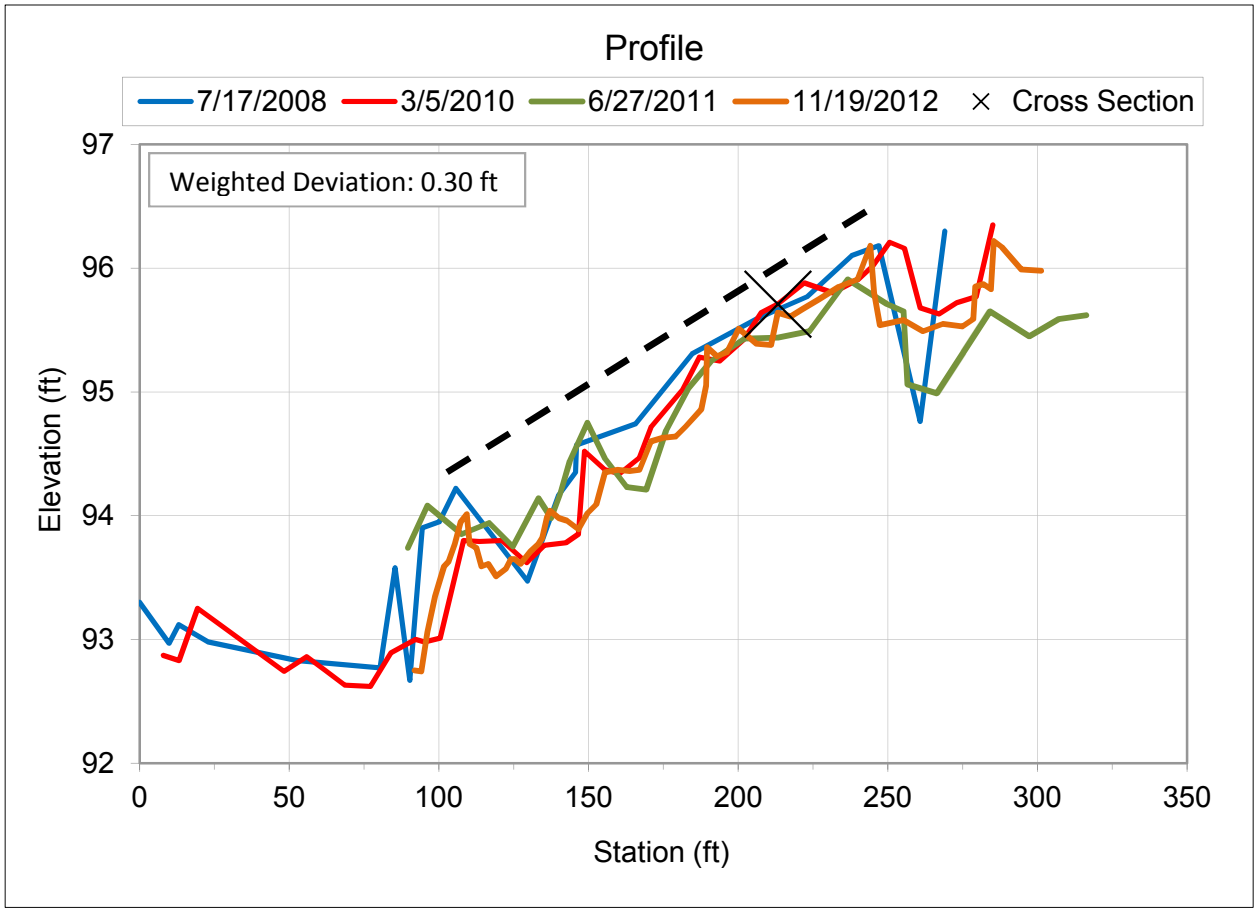
Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
3	6/27/2011	81.13	3.29	30.56	0.0130	1.00	38.8
4	11/19/2012	86.69	3.51	32.28	0.0161	0.96	50.7

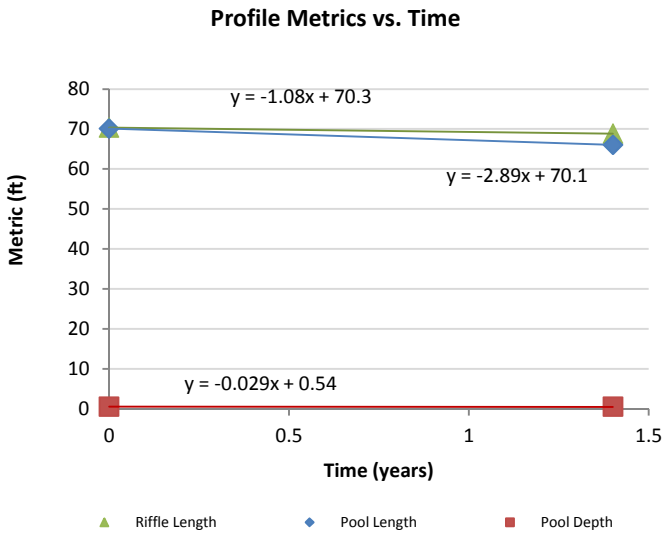


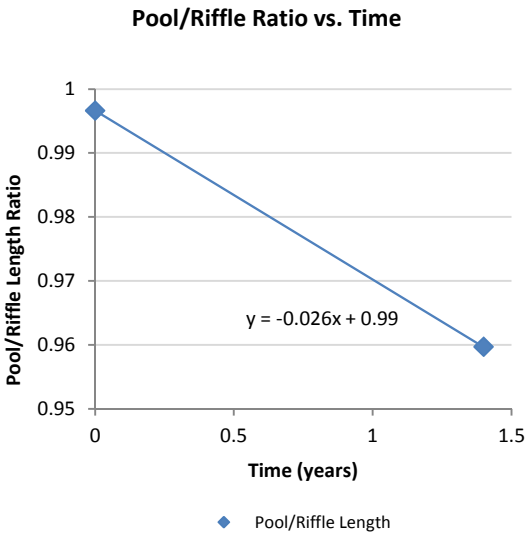
2012 photo looking upstream



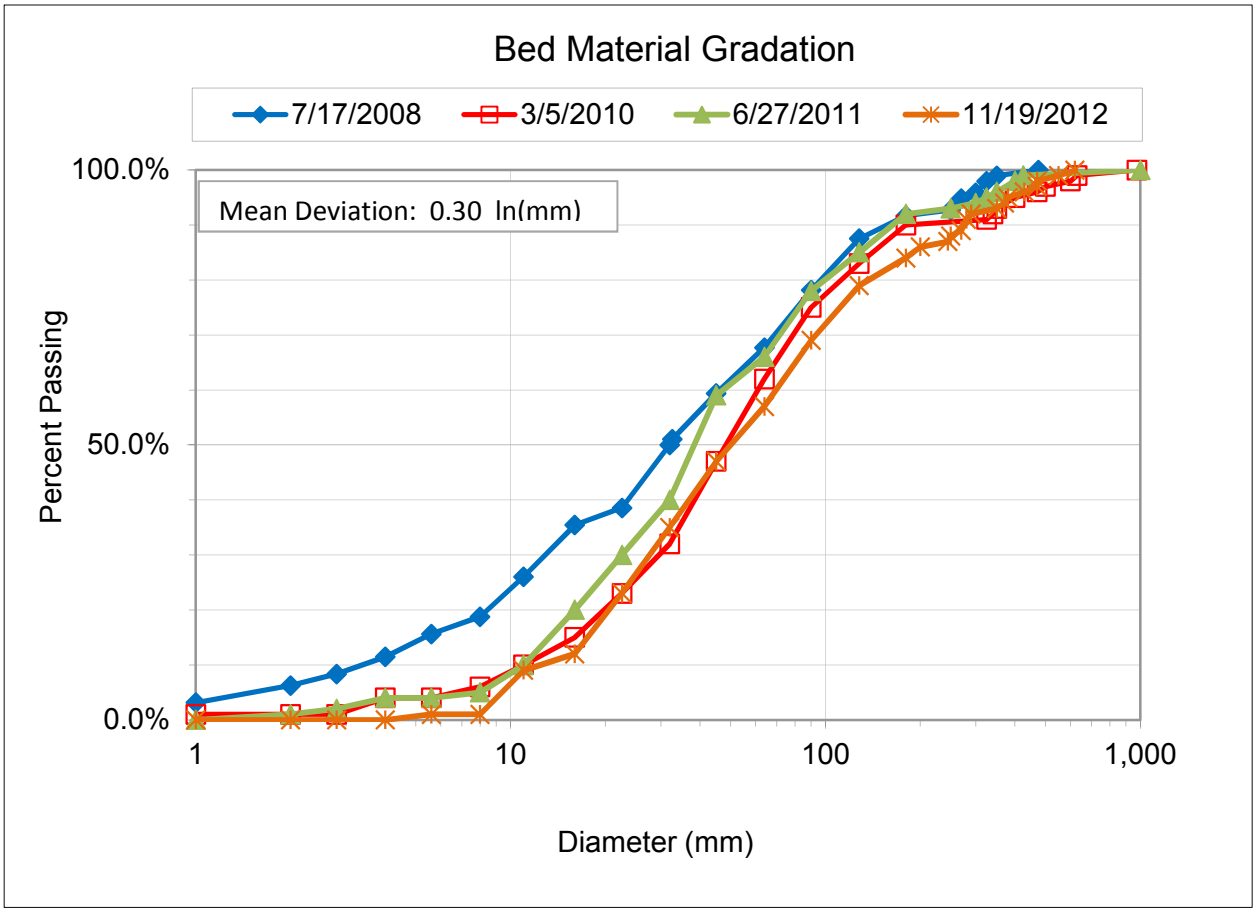
Site: **SFG 5.3 UNT** (continued)

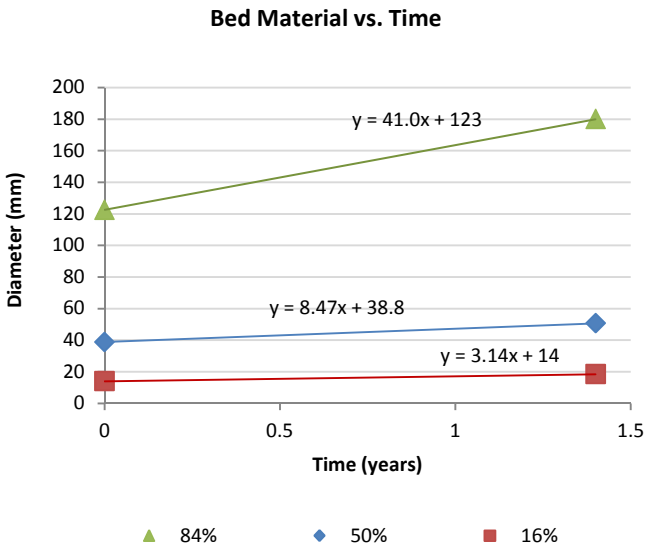






Site: **SFG 5.3 UNT** (continued)





The average weighted deviation presented in the above figures was calculated sensu Baker et. al. (2012) and Hawley, et. al. (In Prep) and measures average change in survey points between 2012 and 2011.

Cross Section: measures change in the active channel bed ground surface.

Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

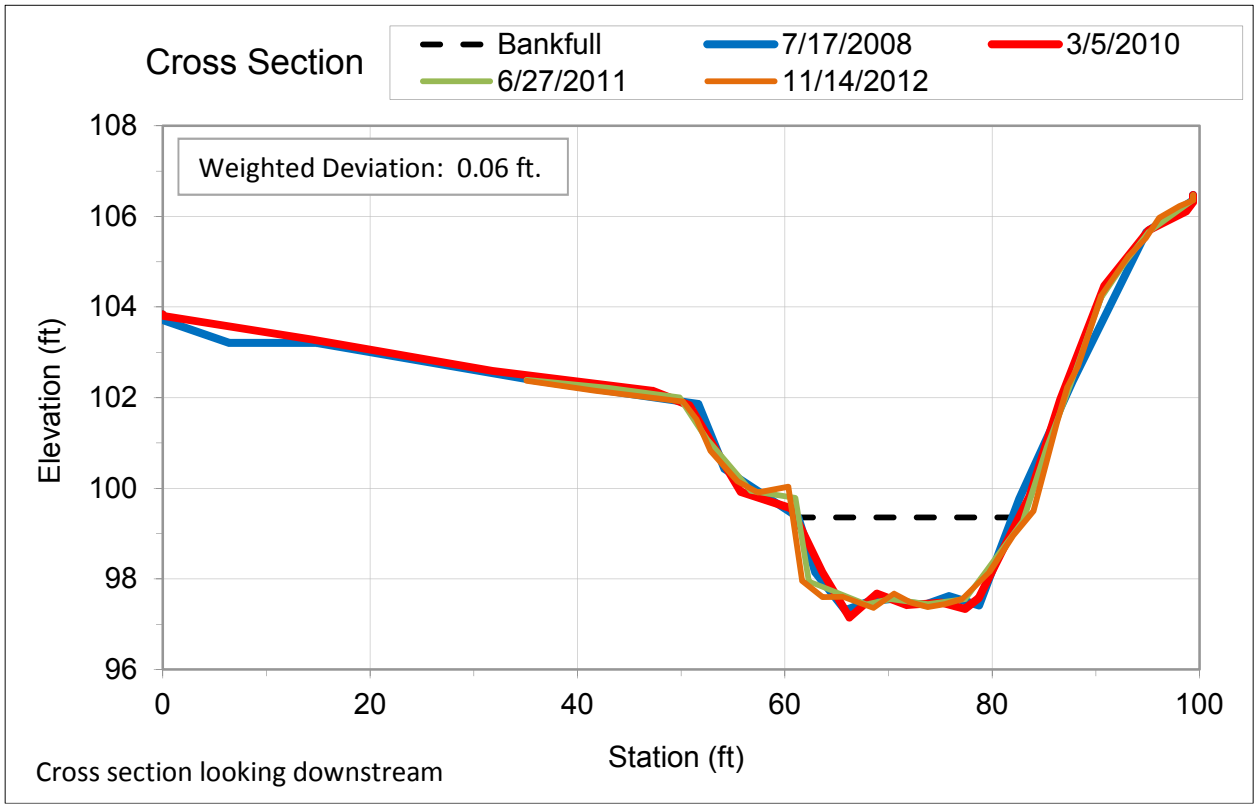
Site: SFG 5.3 US

Imp: 21.1% Drainage Area: 4.69 mi^2

KDOW 2011 Grade: NA KDOW 2012 Grade: NA

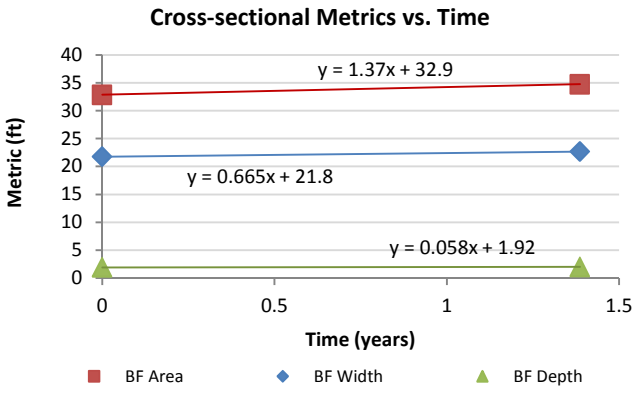
Stream Condition Index: 4.3 Stability Index: 4.8

Survey Round	Date	BF Area (ft^2)	BF Depth (ft)	BF Top Width (ft)	Slope	Pool/Riffle Ratio	d_{50} (mm)
3	6/27/2011	32.85	1.92	21.76	0.0052	10.23	22.6
4	11/14/2012	34.75	2.00	22.68	0.0062	25.21	34.4

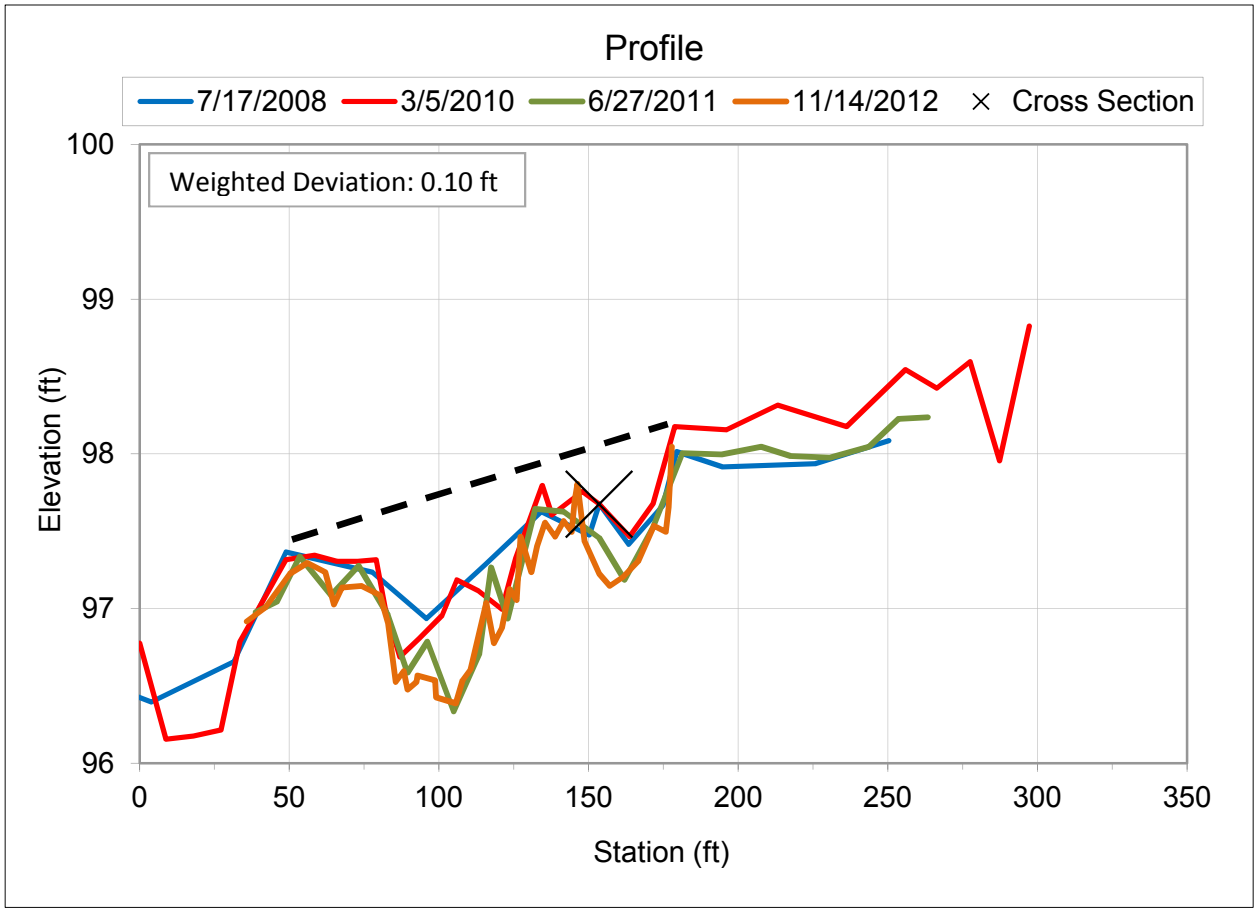


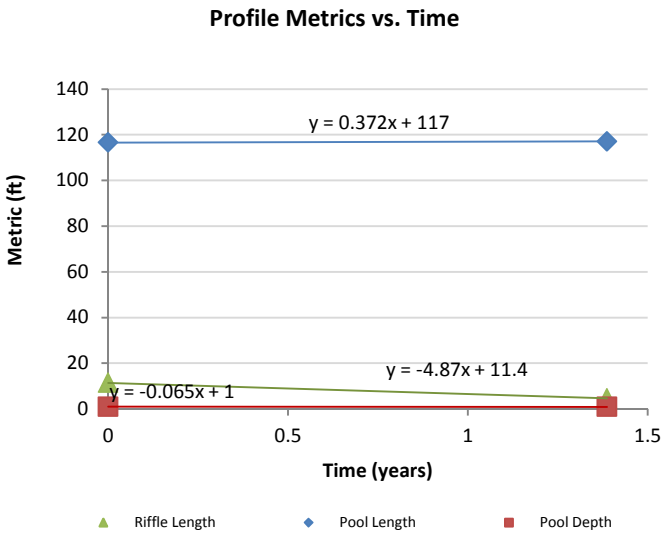
Cross section looking downstream

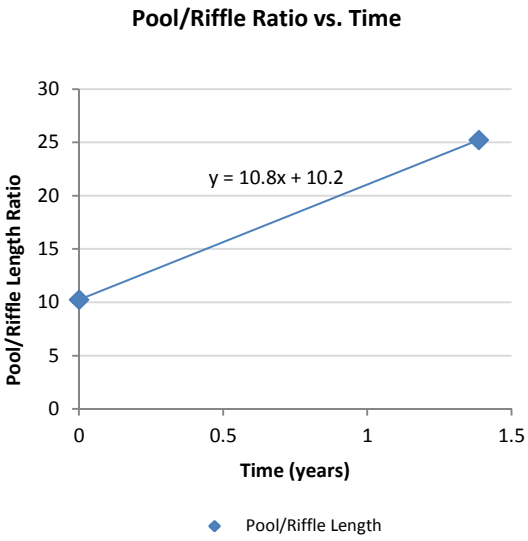
2012 photo looking downstream



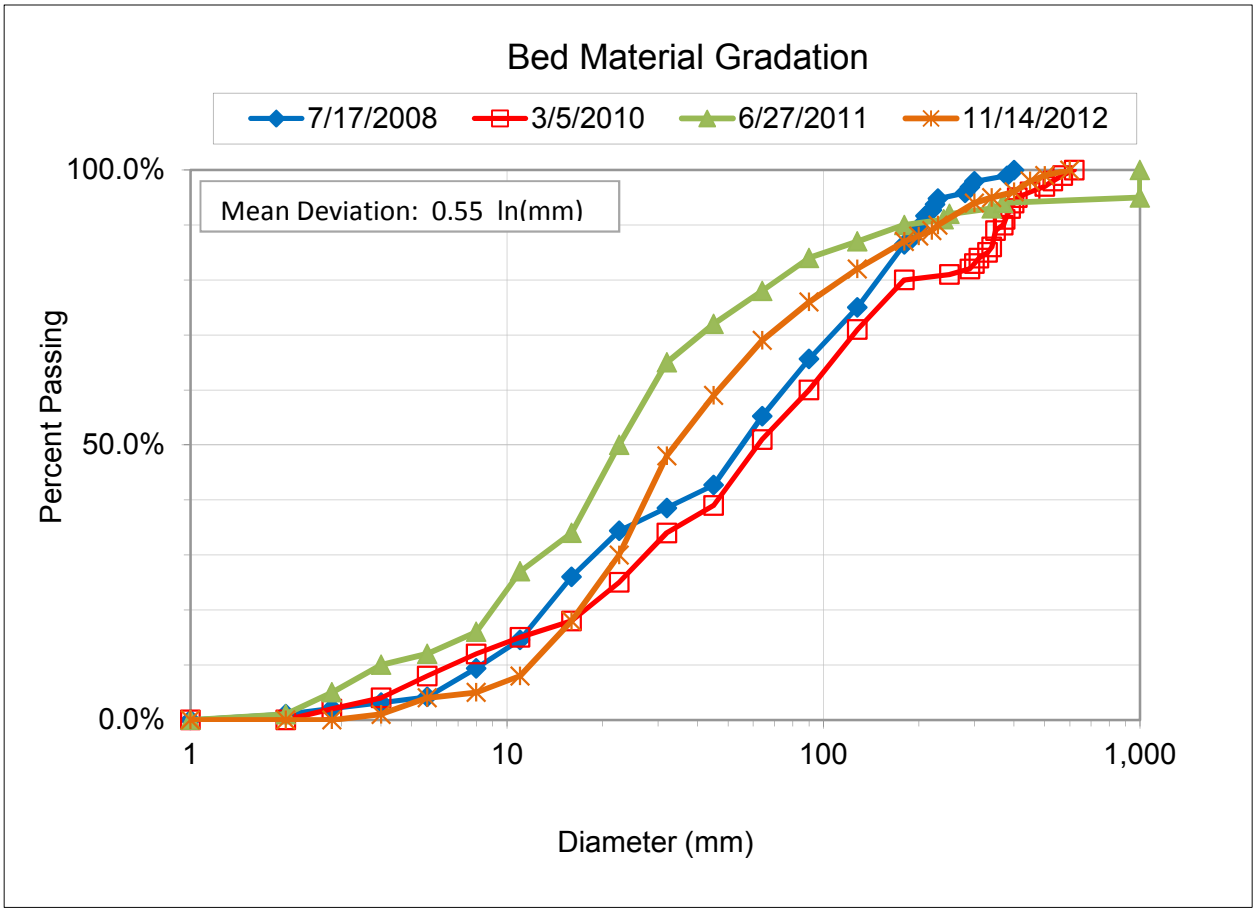
Site: **SFG 5.3 US** (continued)

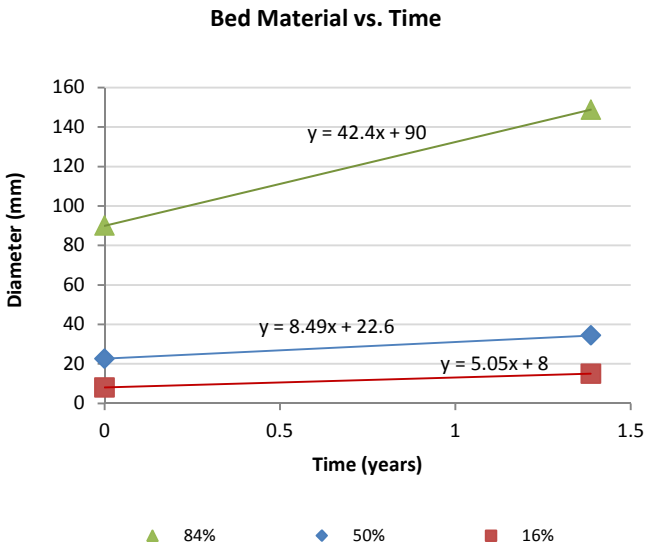






Site: **SFG 5.3 US** (continued)





The average weighted deviation presented in the above figures was calculated sensu Baker et. al. (2012) and Hawley, et. al. (In Prep) and measures average change in survey points between 2012 and 2011.

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Profile: measures change along the channel thalweg.

Bed material: measures change between the bed material gradation of the pebble count.

m

APPENDIX 4-B

Water Quality Box and Whisker Plots

Gunpowder Creek Watershed Plan

Prepared by the
Gunpowder Creek Watershed Initiative

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Overview of Water Quality Box Plots and Limitations

The following appendix presents several water quality box plots developed for the water quality data analysis. The first section includes water quality box plots for each pollutant analyzed and illustrates the variability in the data at each site regarding all samples collected as well as samples collected during wet conditions versus those collected during dry conditions. The second section includes water quality box plots for each monitoring site and presents the ratio of the sample concentrations to the targeted benchmark set by KDOW for every pollutant analyzed at that monitoring site. All ratios greater than one in this section have exceeded the benchmark set by KDOW.

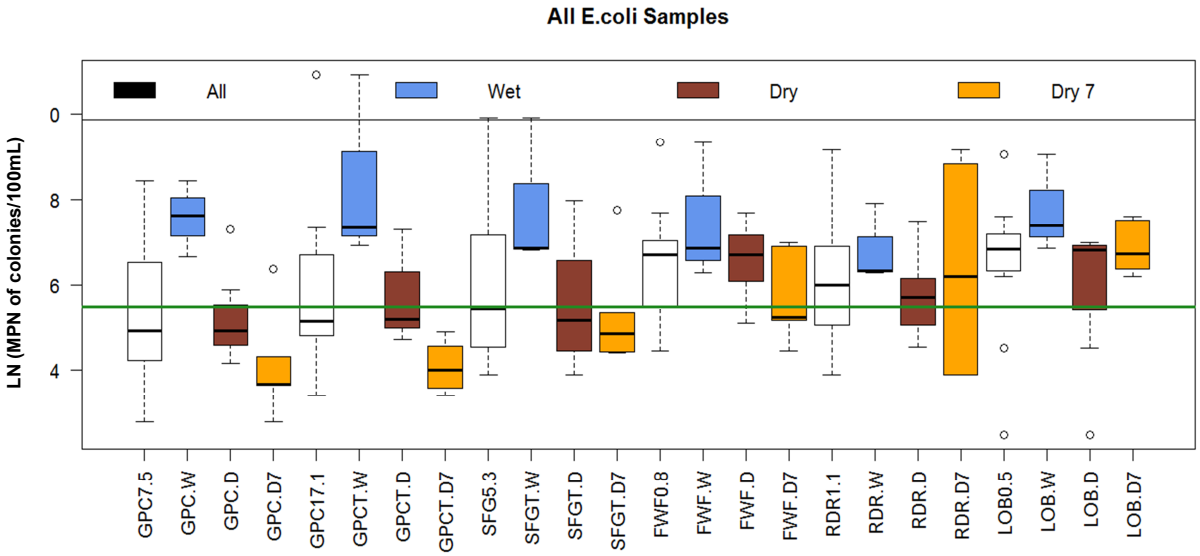
The use of box and whisker plots is typically done with larger datasets; however, these have been provided as a visual presentation of this dataset, despite its relatively small size. Ideally, this analysis would have included more data over a longer time frame to provide additional information relating to wet and dry weather sampling events. It should be noted that typically the box plots presented for the wet weather sampling for all parameters with the exception of *E.coli* are based on only three data points, sampling for the Dry 7 period is typically based on three points, and sampling for the Dry period is based on five points. The limited amount of data provided for this analysis the box plots is only intended to provide a general sense of the scale of the problem relative to each monitoring location and the weather conditions at the time the samples were collected, and should not be used beyond that context.

The water quality box plots were generated using a statistical program called R. This program automatically computes the upper and lower quartiles of the data (illustrated as the box), the variability outside the quartiles (illustrated as the dashed vertical lines), and statistical outliers (illustrated as circles above the dashed lines).

Unionized Ammonia Versus Ammonia-N Analysis

The ammonia water quality box plots present the results of the analysis utilizing ammonia-N instead of unionized ammonia, which is dependent on total ammonia-N, pH, and temperature. Additional review of the difference between the ammonia-N and unionized ammonia concentrations indicate the unionized ammonia sample concentrations never exceeded the standard of 0.05 mg/L. Given that a detailed analysis of unionized ammonia is not required of watershed plans and that all concentrations were less than 0.05 mg/L, this appendix includes the results of the ammonia-N analysis. The results of the ammonia-N analysis would slightly improve if concentrations were compared to the unionized ammonia analysis.

E.coli Samples

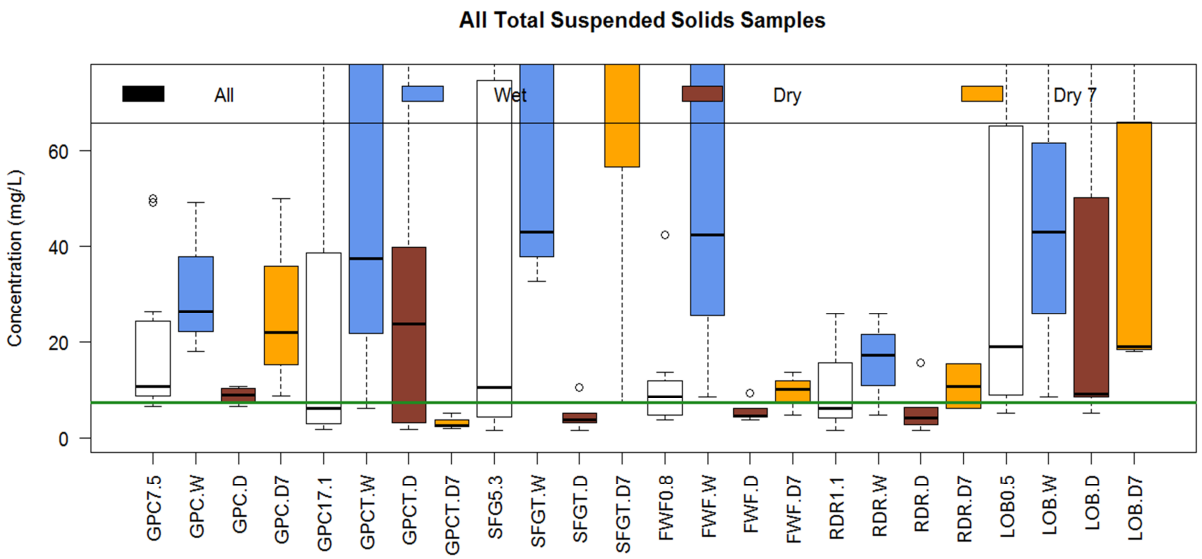


(Green Line Represents KDOW Water Quality Standard for E.coli (< LN(240 MPN of colonies/100mL)=5.48 LN(MPN of colonies/100mL))

KDOW Grades						
YEAR	GPC 7.5	GPC 17.1 - UNT	SFG 5.3 - UNT	FWF 0.8	RDR 1.1	LDB 0.5
2011	D	D	D	F	F	D
2012	A	A	B	C	A	F

Sample Date	Wet vs. Dry vs. Dry7	LN (E.coli Sample Concentrations (MPN of colonies /100mL))					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	8.44	10.91	9.91	9.35	7.91	9.06
06/24/11	Wet	6.66	6.92	6.81	6.29	6.29	7.38
08/04/11	Wet	7.63	7.35	6.86	6.85	6.31	6.85
06/26/12	Dry7	2.80	4.89	4.43	6.99	3.89	6.72
06/28/12	Dry7	3.67	3.78	4.85	6.90	3.89	6.18
07/10/12	Dry7	6.36	4.24	7.75	5.22	9.18	7.60
07/11/12	Dry7	4.31	3.40	4.40	5.16	8.49	7.52
08/07/12	Dry7	3.65	-	5.34	4.45	NA	6.37
07/05/11	Dry	5.19	6.15	5.68	6.60	5.79	6.98
07/07/11	Dry	5.88	6.47	7.45	7.27	7.49	6.90
07/13/11	Dry	4.86	5.21	4.66	5.79	6.30	6.82
07/29/11	Dry	7.29	4.88	3.89	6.38	5.63	4.51
08/18/11	Dry	4.30	4.70	7.97	5.09	4.83	2.48
06/22/12	Dry	4.16	7.29	4.24	6.82	4.53	6.27
07/05/12	Dry	4.93	5.12	4.84	7.06	5.26	6.79
07/23/12	Dry	4.90	5.06	5.48	7.69	6.00	6.92

Total Suspended Solids Samples

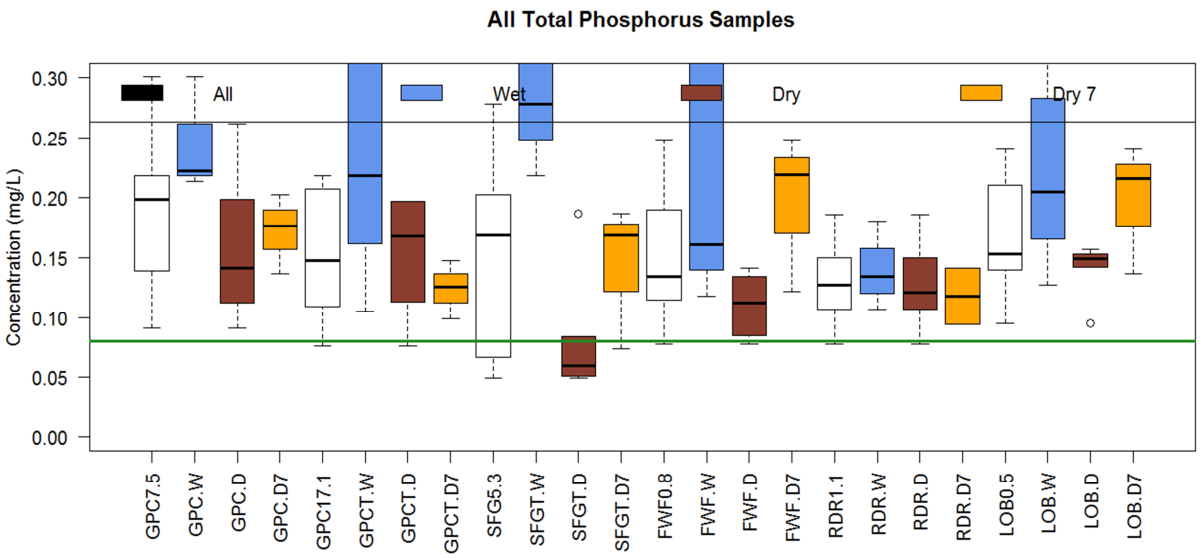


(Green Line Represents KDOW Water Quality Benchmark for TSS (< 7.25 mg/L)

KDOW Grades						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	D+	C	C-	C-	B-	C-
2012	D+	C	C	C+	C	F+

Sample Date	Wet vs. Dry vs. Dry7	TSS Sample Concentrations (mg/L)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	26.5	996.0	480.0	152.0	25.9	80.0
06/24/11	Wet	18.0	37.5	32.7	8.7	17.2	43.1
08/04/11	Wet	49.3	6.0	43.1	42.4	4.8	8.6
06/28/12	Dry7	8.8	5.0	106.0	4.7	15.5	18.0
07/10/12	Dry7	22.0	2.5	151.0	10.1	6.1	113.0
08/07/12	Dry7	50.0	2.0	7.0	13.7	-	19.0
07/07/11	Dry	6.4	3.2	10.6	4.4	4.0	5.0
07/29/11	Dry	10.8	1.7	3.2	9.3	2.8	8.7
08/18/11	Dry	7.4	86.9	1.5	3.8	1.5	9.3
06/22/12	Dry	10.4	23.8	5.0	4.5	15.7	50.3
07/23/12	Dry	9.1	39.8	3.8	6.1	6.2	81.0

Total Phosphorus Samples

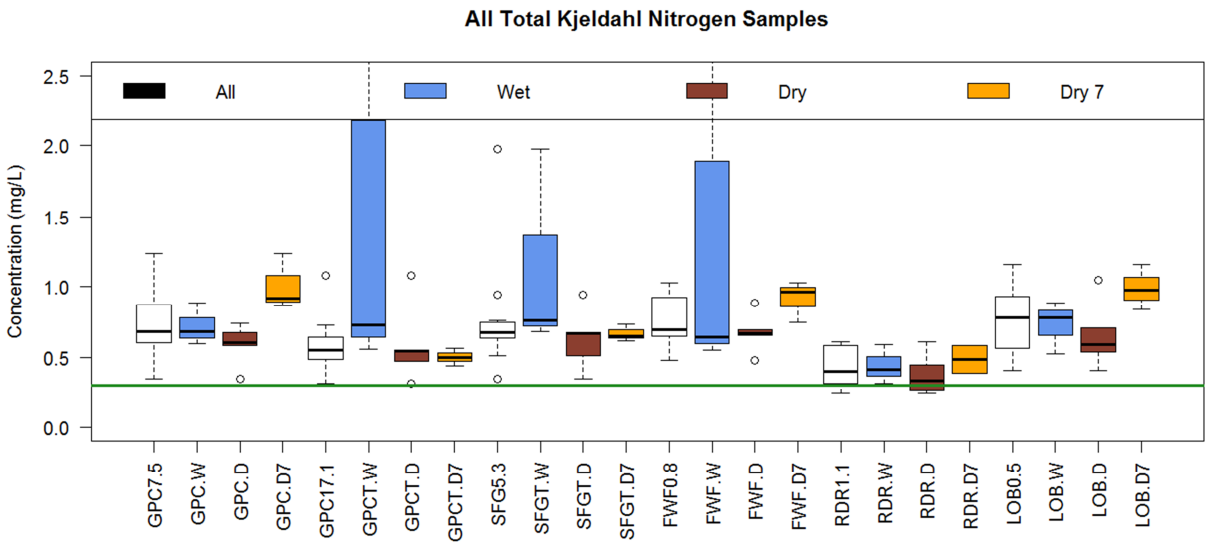


(Green Line Represents KDOW Water Quality Benchmark for TP (< 0.08 mg/L))

KDOW Grades (for nutrients)						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	B-	C+	B	C+	B-	C+
2012	C	C+	B-	C+	B-	C

Sample Date	Wet vs. Dry vs. Dry7	TP Sample Concentrations (mg/L)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	0.21	1.62	1.11	1.03	0.18	0.36
06/24/11	Wet	0.22	0.22	0.22	0.16	0.13	0.21
08/04/11	Wet	0.30	0.11	0.28	0.12	0.11	0.13
06/28/12	Dry7	0.18	0.15	0.17	0.25	0.09	0.14
07/10/12	Dry7	0.14	0.13	0.19	0.12	0.14	0.22
08/07/12	Dry7	0.20	0.10	0.07	0.22	-	0.24
07/07/11	Dry	0.11	0.08	0.06	0.11	0.12	0.15
07/29/11	Dry	0.09	0.11	0.05	0.09	0.11	0.16
08/18/11	Dry	0.14	0.39	0.05	0.08	0.08	0.10
06/22/12	Dry	0.20	0.17	0.08	0.13	0.15	0.14
07/23/12	Dry	0.26	0.20	0.19	0.14	0.19	0.15

Total Kjeldahl Nitrogen Samples

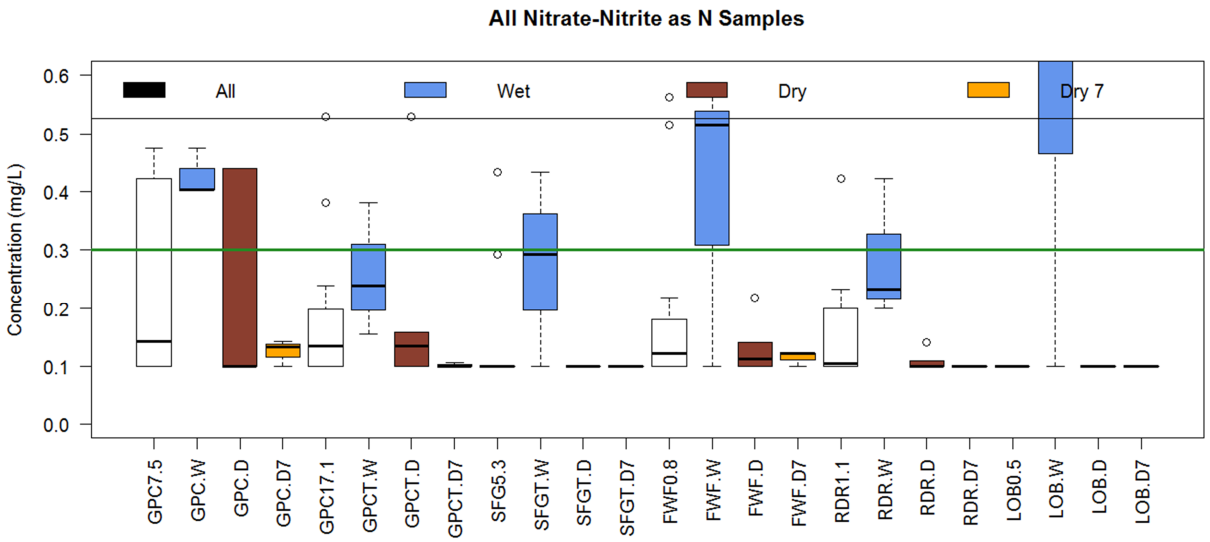


(Green Line Represents KDOW Water Quality Benchmark for TKN (< 0.3 mg/L))

KDOW Grades (for nutrients)						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	B-	C+	B	C+	B-	C+
2012	C	C+	B-	C+	B-	C

Sample Date	Wet vs. Dry vs. Dry7	TKN Sample Concentrations (mg/L)					
		GPC 7.5	**GPC 17.1**	**SFG 5.3**	**FWF 0.8**	**RDR 1.1**	**LOB 0.5**
06/20/11	Wet	0.88	3.65	1.98	3.14	0.59	0.89
06/24/11	Wet	0.60	0.73	0.76	0.55	0.41	0.53
08/04/11	Wet	0.68	0.56	0.68	0.64	0.31	0.78
06/28/12	Dry7	0.92	0.44	0.61	0.75	0.39	0.84
07/10/12	Dry7	1.24	0.56	0.73	1.03	0.59	0.97
08/07/12	Dry7	0.86	0.50	0.65	0.96	_	1.16
07/07/11	Dry	0.60	0.55	0.67	0.70	0.33	0.59
07/29/11	Dry	0.67	0.47	0.94	0.66	0.26	0.54
08/18/11	Dry	0.34	0.31	0.35	0.48	0.24	0.41
06/22/12	Dry	0.58	0.55	0.51	0.66	0.44	0.71
07/23/12	Dry	0.74	1.08	0.67	0.88	0.61	1.05

Total Nitrate-Nitrite Samples

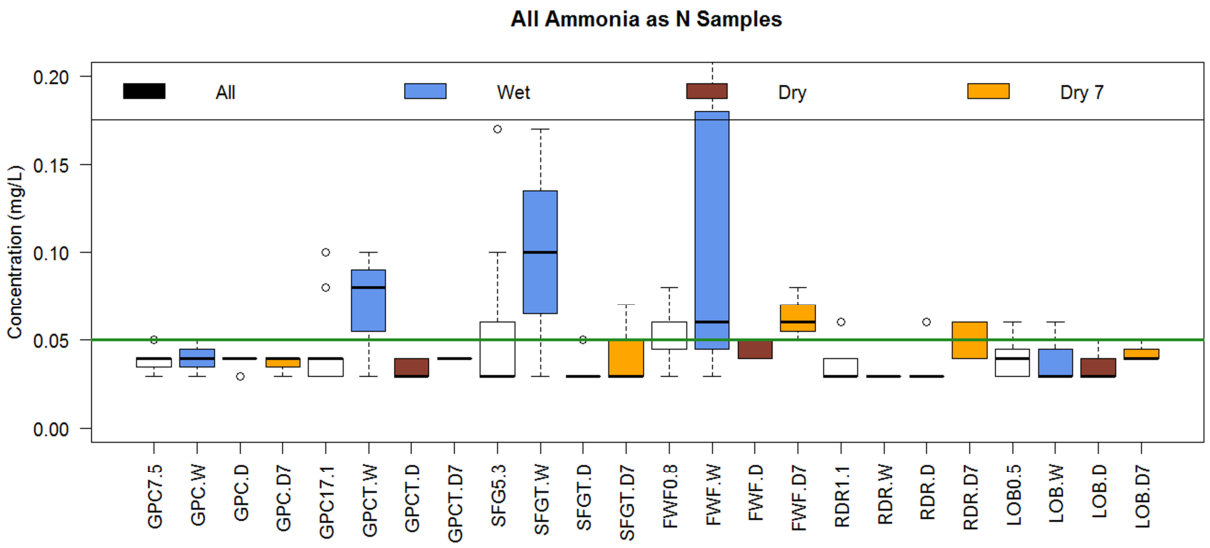


(Green Line Represents KDOW Water Quality Benchmark for NN (< 0.3 mg/L))

KDOW Grades (for nutrients)						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	B-	C+	B	C+	B-	C+
2012	C	C+	B-	C+	B-	C

Sample Date	Wet vs. Dry vs. Dry7	NN Sample Concentrations (mg/L)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	0.48	0.24	0.43	0.52	0.59	1.13
06/24/11	Wet	0.40	0.38	0.29	0.56	0.41	0.83
08/04/11	Wet	0.40	0.16	< 0.10	< 0.10	0.31	< 0.10
06/28/12	Dry7	< 0.10	< 0.10	< 0.10	0.12	0.39	< 0.10
07/10/12	Dry7	0.13	0.11	< 0.10	0.12	0.59	< 0.10
08/07/12	Dry7	0.14	< 0.10	< 0.10	< 0.10	_	< 0.10
07/07/11	Dry	< 0.10	< 0.10	< 0.10	0.14	0.33	< 0.10
07/29/11	Dry	< 0.10	< 0.10	< 0.10	< 0.10	0.26	< 0.10
08/18/11	Dry	< 0.10	0.53	< 0.10	< 0.10	0.24	< 0.10
06/22/12	Dry	0.44	0.16	< 0.10	0.22	0.44	< 0.10
07/23/12	Dry	1.16	0.14	< 0.10	0.11	0.61	< 0.10

Ammonia as Nitrogen Samples



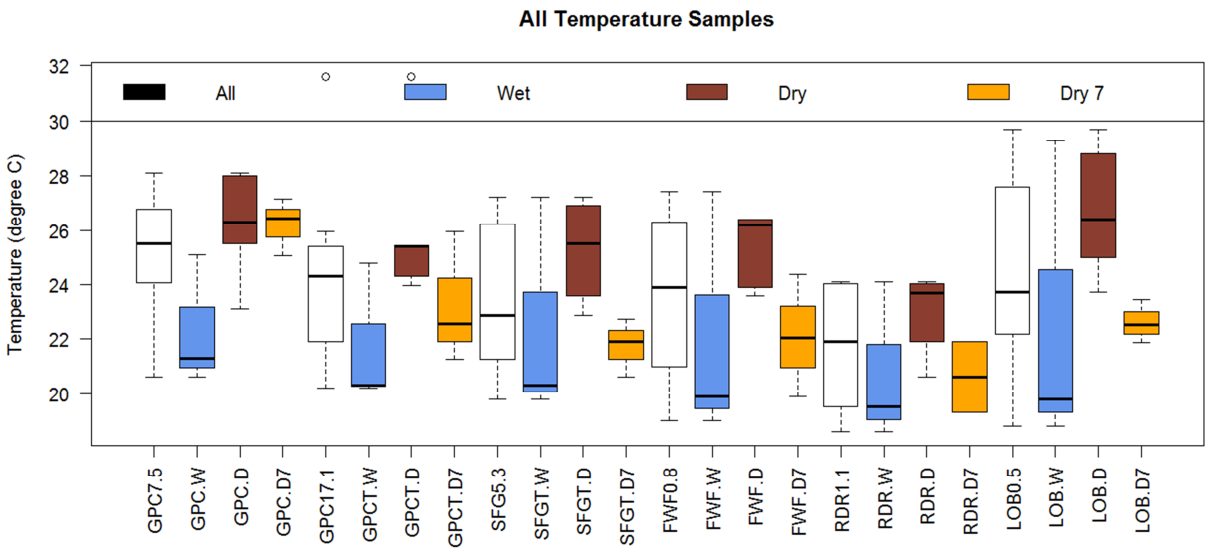
(Green Line Represents KDOW Water Quality Benchmark for Unionized Ammonia (< 0.05 mg/L))

*NOTE: THE **UNIONIZED AMMONIA** CONCENTRATIONS, AS A FUNCTION OF AMMONIA-N, pH, AND TEMPERATURE NEVER EXCEED THE STANDARD OF 0.05 mg/L*

KDOW Grades						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA

Sample Date	Wet vs. Dry vs. Dry7	Ammonia-N Sample Concentrations (mg/L)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	0.05	0.1	0.1	0.06	< 0.03	0.06
06/24/11	Wet	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
08/04/11	Wet	0.04	0.08	0.17	0.3	< 0.03	< 0.03
06/28/12	Dry7	< 0.03	0.04	< 0.03	0.08	0.04	0.04
07/10/12	Dry7	0.04	0.04	0.07	0.05	0.06	0.04
08/07/12	Dry7	0.04	0.04	< 0.03	0.06	-	0.05
07/07/11	Dry	0.04	< 0.03	< 0.03	0.04	< 0.03	< 0.03
07/29/11	Dry	0.04	< 0.03	0.05	0.05	< 0.03	0.04
08/18/11	Dry	0.04	< 0.03	< 0.03	0.05	< 0.03	< 0.03
06/22/12	Dry	0.04	0.04	< 0.03	0.05	< 0.03	0.05
07/23/12	Dry	< 0.03	0.04	< 0.03	0.04	0.06	< 0.03

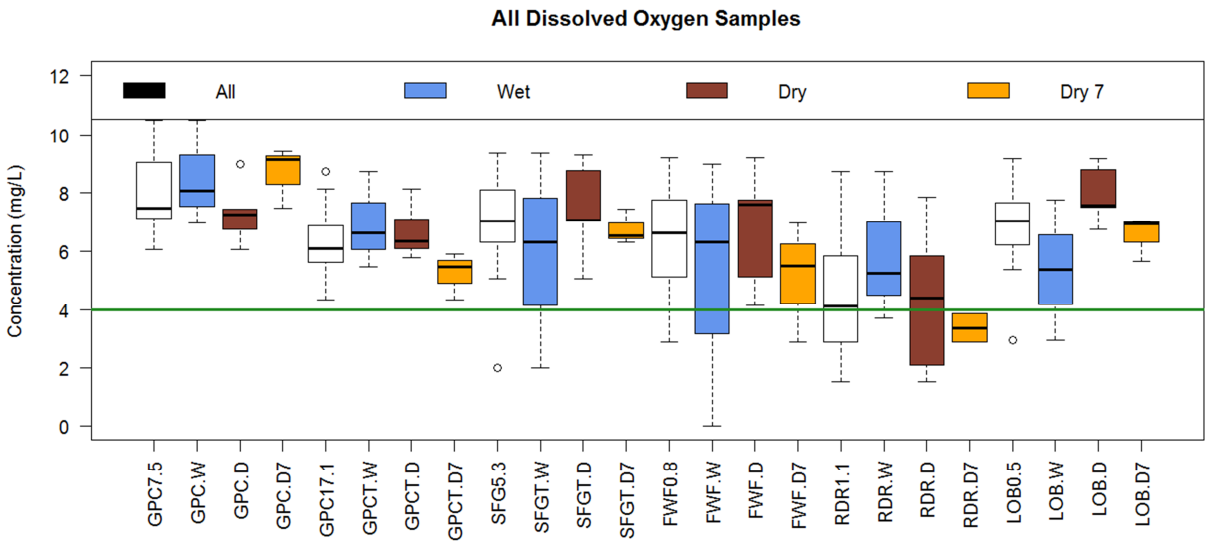
Temperature Samples



KDOW Grades						
YEAR	GPC 7.5	GPC 17.1 - UNT	SFG 5.3 - UNT	FWF 0.8	RDR 1.1	LDB 0.5
2011	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA

Sample Date	Wet vs. Dry vs. Dry7	Temperature Sample Concentrations (degree C)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	20.60	20.20	19.80	19.90	18.60	18.80
06/24/11	Wet	21.27	20.30	20.30	19.00	19.50	19.80
08/04/11	Wet	25.10	24.80	27.20	27.40	24.10	29.30
06/28/12	Dry7	25.06	21.25	20.60	19.89	19.30	21.85
07/10/12	Dry7	26.42	25.95	22.72	24.39	21.90	23.47
08/07/12	Dry7	27.15	22.54	21.90	22.03	-	22.52
07/07/11	Dry	26.30	25.40	26.90	26.40	23.70	26.40
07/29/11	Dry	28.00	31.60	27.20	26.20	24.10	29.70
08/18/11	Dry	23.10	24.30	23.60	26.40	20.60	28.80
06/22/12	Dry	28.09	23.97	22.86	23.60	24.05	23.75
07/23/12	Dry	25.51	25.44	25.52	23.90	21.91	24.99

Dissolved Oxygen Samples



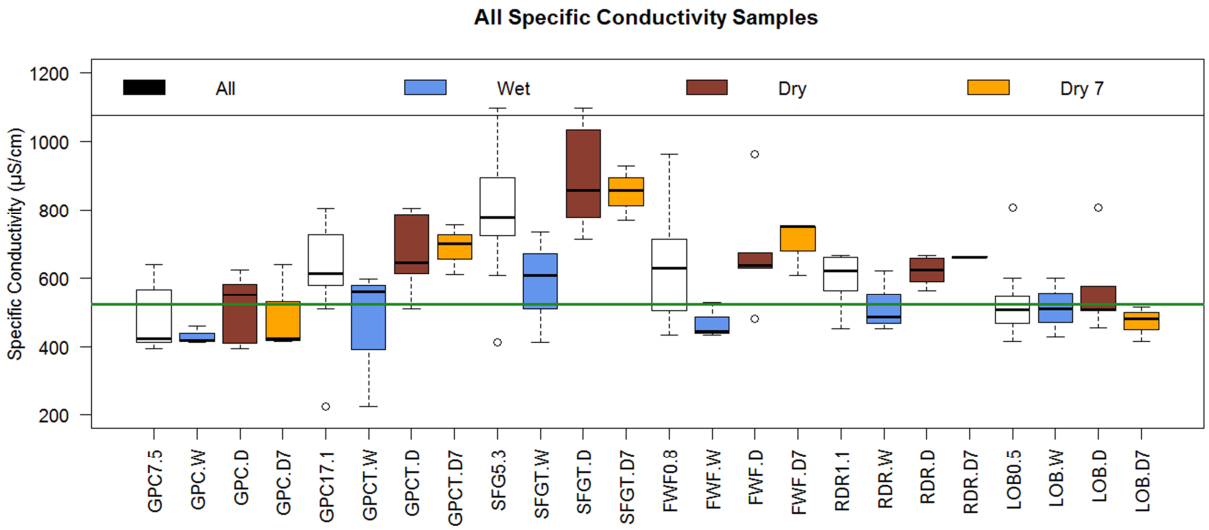
(Green Line Represents KDOW Water Quality Standard for DO (> 4 mg/L))

Note: A dissolved oxygen sample <u>below</u> the benchmark is an indicator of poor water quality. The majority of the pollutant averages are above this benchmark; and therefore, the dissolved oxygen levels are good throughout the Gunpowder Creek Watershed.

KDOW Grades						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	A-	B	B	B+	C+	B
2012	A	C+	B+	C	D+	B

Sample Date	Wet vs. Dry vs. Dry7	DO Sample Concentrations (mg/L)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	6.99	6.64	6.30	6.31	5.24	5.38
06/24/11	Wet	8.08	8.72	9.35	8.98	8.75	7.77
08/04/11	Wet	10.50	5.48	2.01	_	3.72	2.95
06/28/12	Dry7	9.14	4.32	6.32	5.51	3.85	7.04
07/10/12	Dry7	7.47	5.45	6.53	6.97	2.88	6.95
08/07/12	Dry7	9.43	5.90	7.44	2.90	_	5.66
07/07/11	Dry	6.06	7.09	8.77	7.75	7.84	9.16
07/29/11	Dry	6.77	5.78	5.05	4.15	2.11	8.80
08/18/11	Dry	7.45	8.15	7.08	9.20	4.40	7.50
06/22/12	Dry	8.99	6.09	7.05	7.59	5.84	6.75
07/23/12	Dry	7.26	6.35	9.30	5.11	1.54	7.58

Specific Conductance Samples

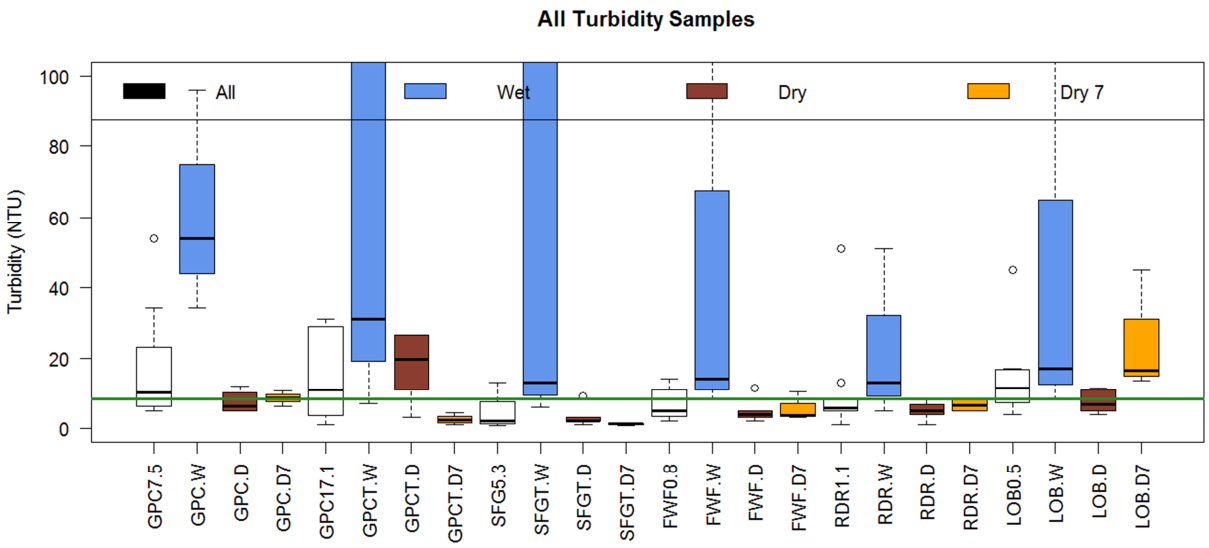


(Green Line Represents KDOW Water Quality Benchmark for Specific Conductance (< 522.5 µS/cm))

KDOW Grades						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	C	D+	D-	C	C-	C
2012	B	D	F+	D-	D	C+

Sample Date	Wet vs. Dry vs. Dry7	Specific Conductance Sample Concentrations (µS/cm)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	412	224	411	442	450	427
06/24/11	Wet	418	560	735	433	485	510
08/04/11	Wet	460	597	607	527	622	600
06/28/12	Dry7	414	754	857	609	660	415
07/10/12	Dry7	640	701	929	750	663	481
08/07/12	Dry7	422	610	769	750	_	514
07/07/11	Dry	581	806	858	480	565	453
07/29/11	Dry	625	785	1098	961	665	576
08/18/11	Dry	550	613	1036	628	623	808
06/22/12	Dry	393	646	776	636	591	505
07/23/12	Dry	408	509	714	675	658	504

Turbidity Samples



(Green Line Represents KDOW Water Quality Benchmark for TP (< 8.3 NTU))

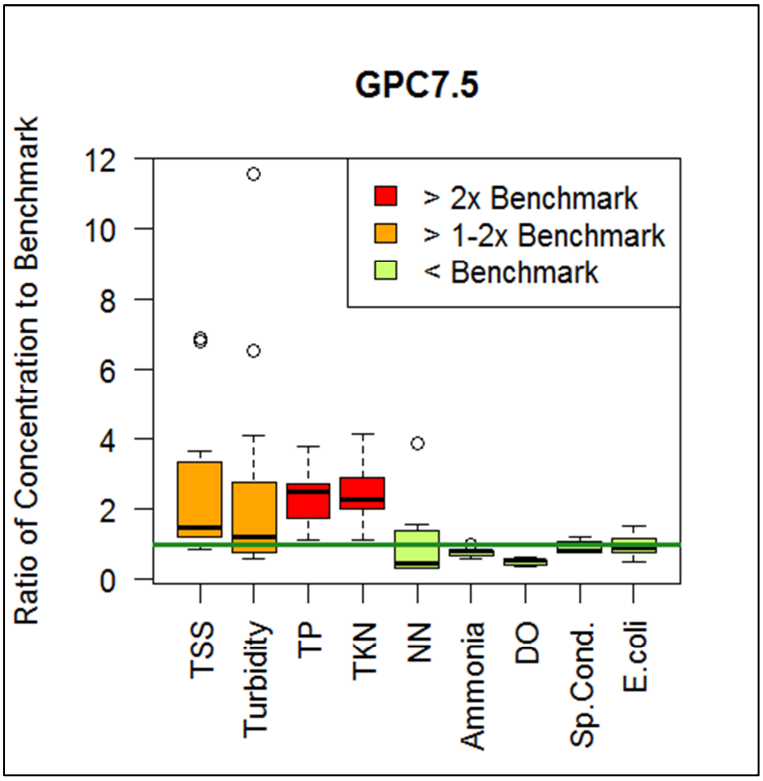
KDOW Grades						
YEAR	**GPC 7.5**	**GPC 17.1 - UNT**	**SFG 5.3 - UNT**	**FWF 0.8**	**RDR 1.1**	**LDB 0.5**
2011	NA	NA	NA	NA	NA	NA
2012	NA	NA	NA	NA	NA	NA

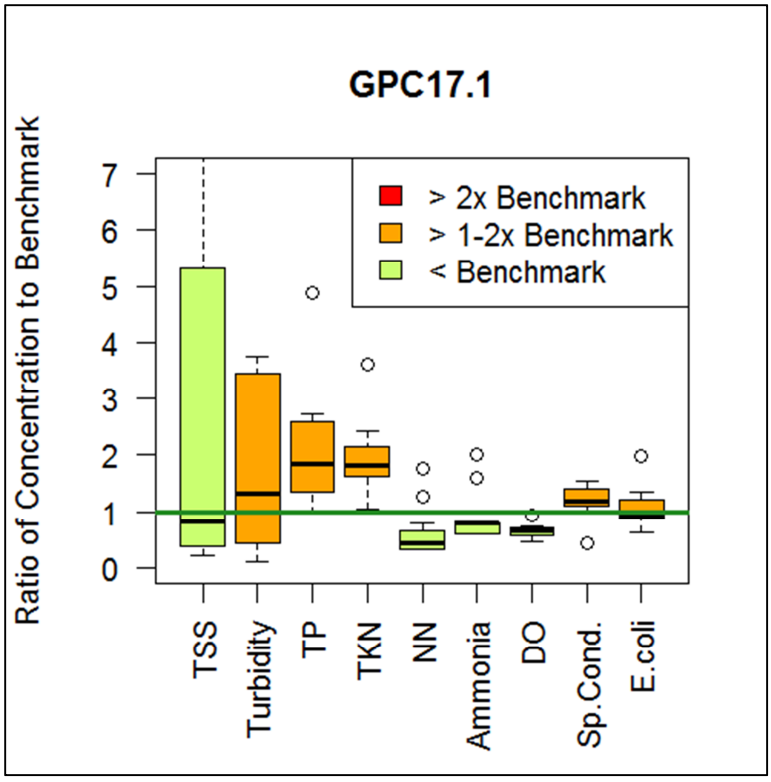
Sample Date	Wet vs. Dry vs. Dry7	Turbidity (NTU)					
		GPC 7.5	GPC 17.1	SFG 5.3	FWF 0.8	RDR 1.1	LOB 0.5
06/20/11	Wet	54.0	945.0	636.0	121.0	51.0	113.0
06/24/11	Wet	34.0	31.0	6.0	14.0	13.0	17.0
08/04/11	Wet	96.0	7.0	13.0	8.0	5.0	8.0
06/28/12	Dry7	10.7	1.0	1.3	3.7	8.1	45.0
07/10/12	Dry7	8.7	2.2	1.2	10.5	5.0	13.5
08/07/12	Dry7	6.2	4.4	0.8	3.1	-	16.5
07/07/11	Dry	5.0	11.0	9.0	5.0	4.0	11.0
07/29/11	Dry	5.0	3.0	2.0	2.0	5.0	4.0
08/18/11	Dry	12.0	157.0	2.0	4.0	1.0	5.0
06/22/12	Dry	6.3	19.5	1.0	3.1	8.0	11.5
07/23/12	Dry	10.1	26.4	3.1	11.4	6.7	6.7

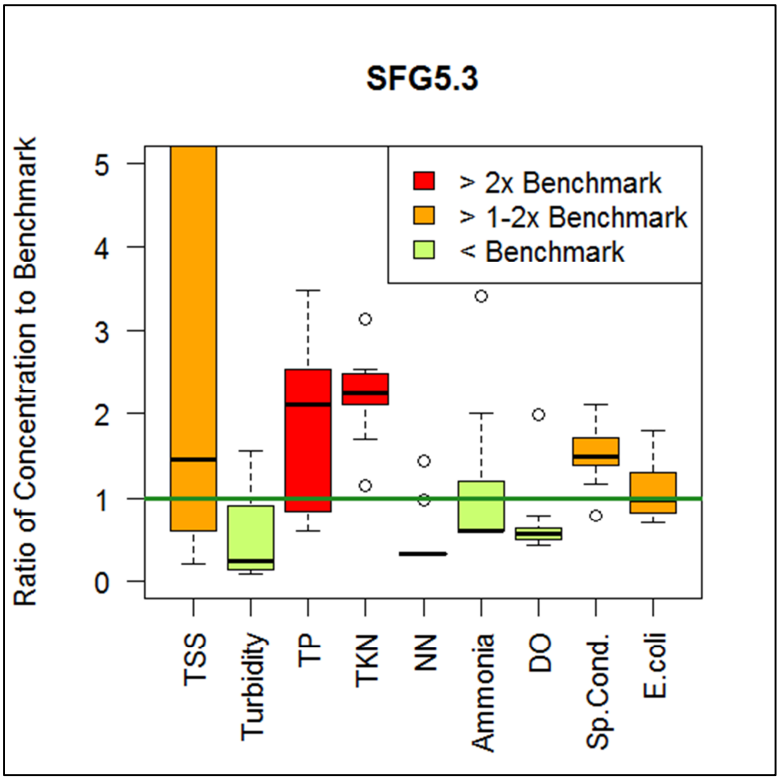
Monitoring Site Water Quality Box & Whisker Plots

Water quality box plots for each monitoring site present the ratio of the sample concentrations to the allowable benchmark set by KDOW. Large outliers were automatically removed from the data set with the *R Statistical Computing Program*.

*NOTE: THESE WATER QUALITY BOX PLOTS PRESENT TOTAL AMMONIA AS N, AND **UNIONIZED AMMONIA** CONCENTRATIONS, AS A FUNCTION OF AMMONIA-N, pH, AND TEMPERATURE NEVER EXCEED THE STANDARD OF 0.05 mg/L. ALSO, THE DISSOLVED OXYGEN (DO) INFORMATION IS PRESENTED AS A RATIO OF THE BENCHMARK TO CONCENTRATION TO PROPERLY ILLUSTRATE THAT DO LEVELS ARE GOOD (BELOW THE GREEN BENCHMARK LINE) THROUGHOUT THE WATERSHED.*




GPC17.1
Ratio of Concentration to Benchmark
> 2x Benchmark
> 1-2x Benchmark
< Benchmark
0
1
2
3
4
5
6
7
TSS
Turbidity
TP
TKN
NN
Ammonia
DO
Sp.Cond.
E.coli


SFG5.3
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> 1-2x Benchmark
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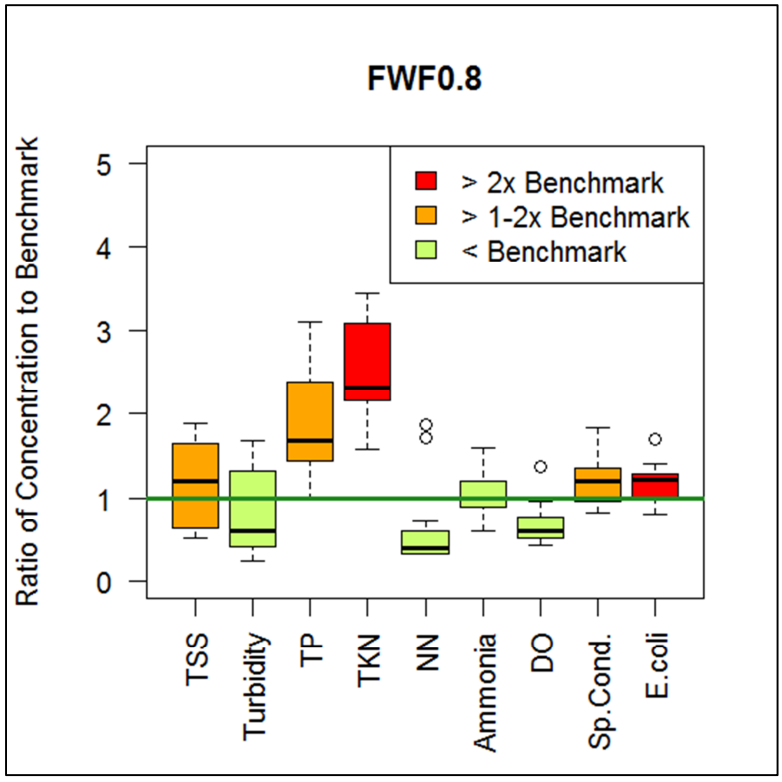
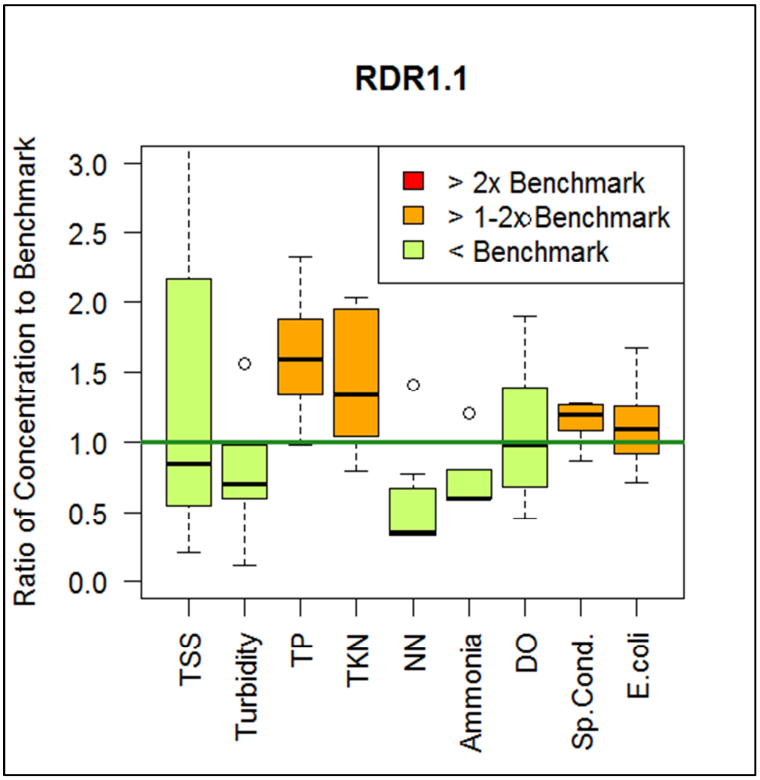
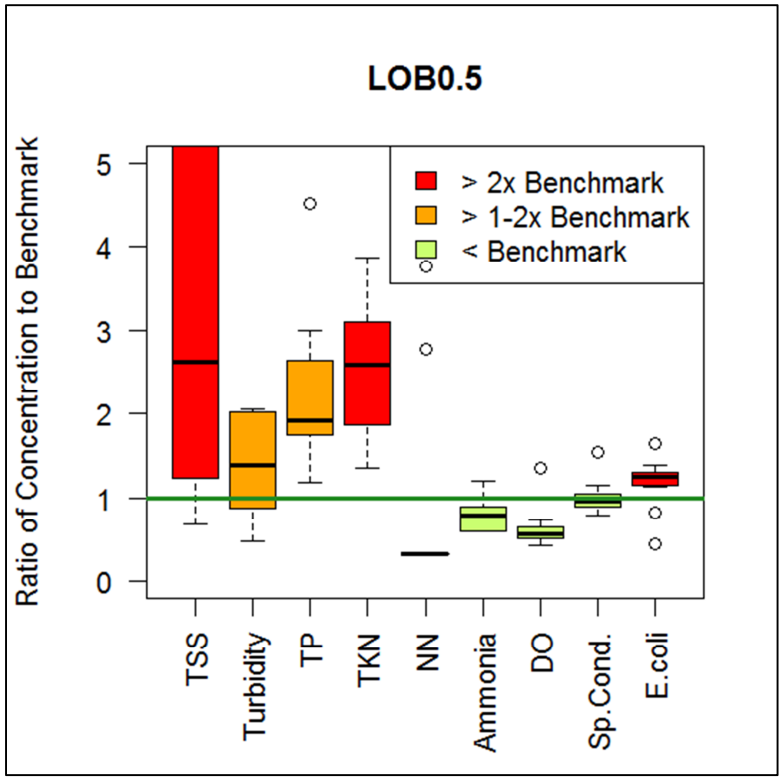
1
2
3
4
5
TSS
Turbidity
TP
TKN
NN
Ammonia
DO
Sp.Cond.
E.coli


FWF0.8
Ratio of Concentration to Benchmark
0
1
2
3
4
5
> 2x Benchmark
> 1-2x Benchmark
< Benchmark
TSS
Turbidity
TP
TKN
NN
Ammonia
DO
Sp.Cond.
E.coli


RDR1.1
Ratio of Concentration to Benchmark
0.0
0.5
1.0
1.5
2.0
2.5
3.0
> 2x Benchmark
> 1-2x Benchmark
< Benchmark
TSS
Turbidity
TP
TKN
NN
Ammonia
DO
Sp.Cond.
E.coli


LOB0.5
Ratio of Concentration to Benchmark
0
1
2
3
4
5
> 2x Benchmark
> 1-2x Benchmark
< Benchmark
TSS
Turbidity
TP
TKN
NN
Ammonia
DO
Sp.Cond.
E.coli

APPENDIX 4-C

Pollutant Loadings

Gunpowder Creek Watershed Plan

Prepared by the
Gunpowder Creek Watershed Initiative

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Load Duration Approach

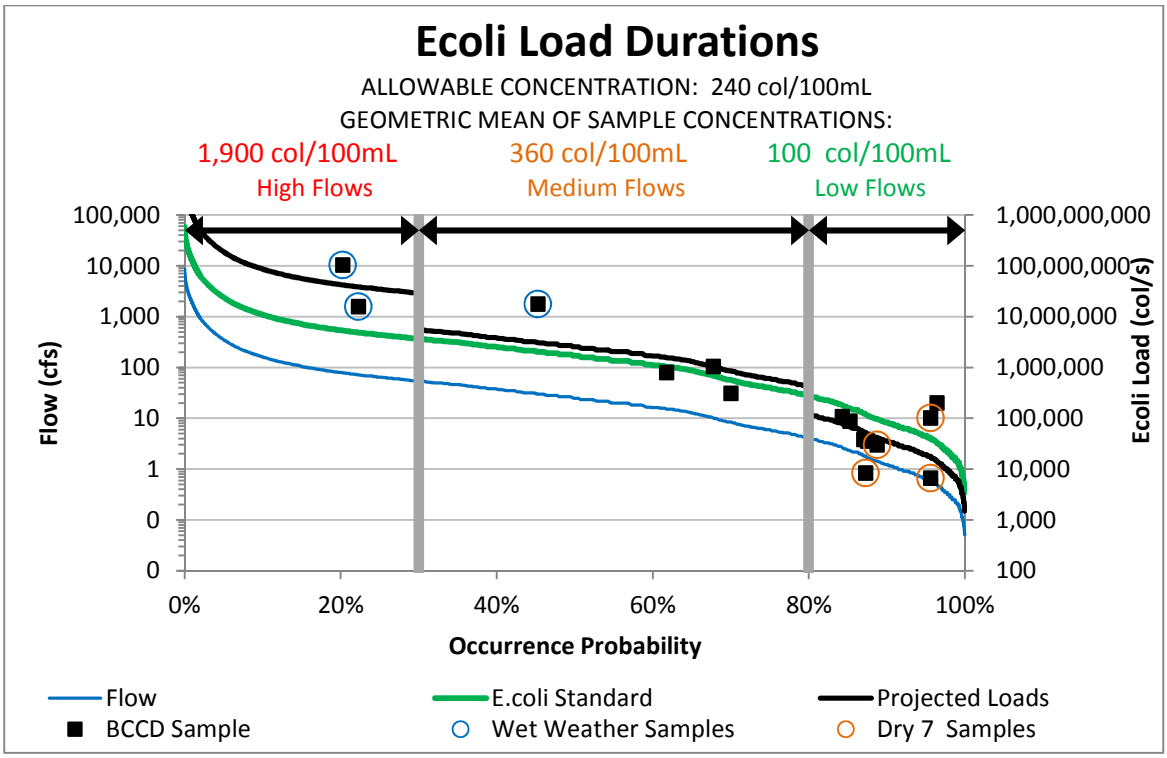
The load duration approach presented throughout this Appendix is meant to provide estimates of the scale of the problem in each subwatershed and not indicate exact loads necessary to achieve water quality targets. The Phase II Water Quality Data Analysis utilized a limited amount of water quality data; and therefore, the pollutant loads presented throughout should not be treated as precise values but as general estimates. The values illustrated above each flow bin represent the average concentration of the corresponding samples and the geometric mean for the E.coli samples.

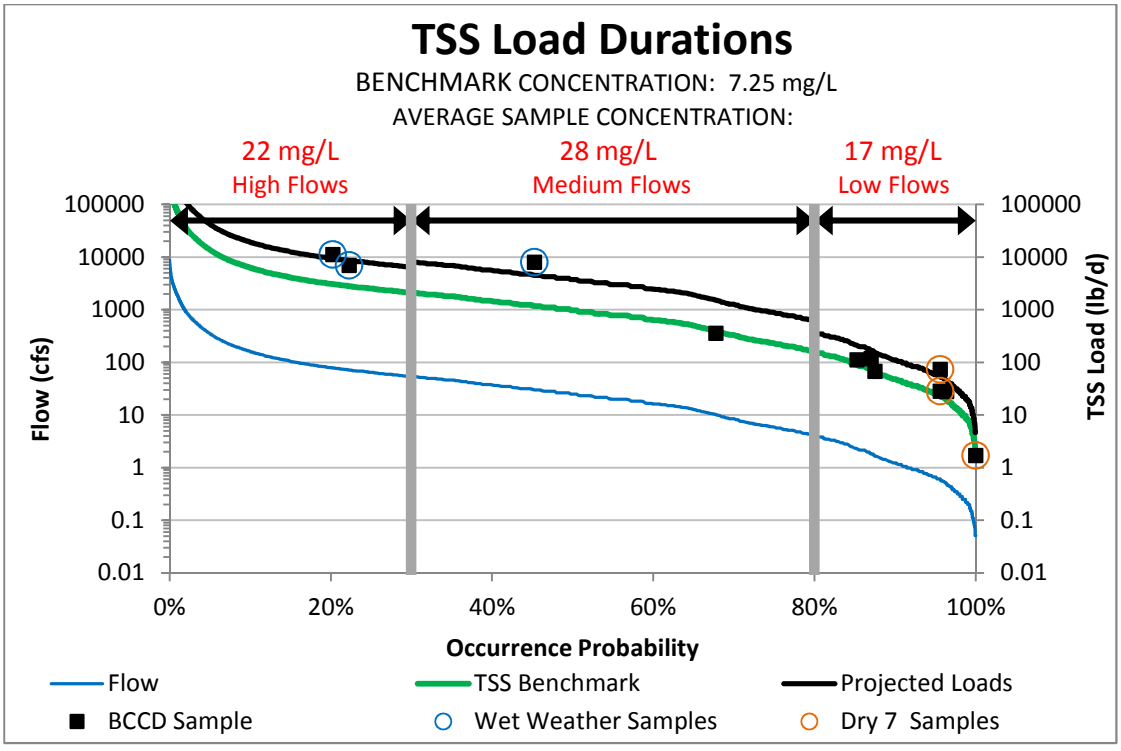
Additionally, with the limited dataset, the flow bins were split based on logical breakpoints that attempted to equally space the flow bins as much as possible while allowing each bin to have at least a couple data points, to the greatest extent possible. Ideally the analysis would have had more data over a longer time frame and more data across the high, medium, and low flow bins, but given the circumstances the load duration curves are adequate at providing a general sense of scale of the problem during high, medium, and low flows.

Unionized Ammonia Versus Ammonia-N Analysis

The ammonia load duration curves present the results of the analysis utilizing ammonia-N. The water quality lab results were reported as Ammonia-N and KDOW provided a benchmark for this parameter. Another measurement of ammonia includes unionized ammonia, which is dependent on total ammonia-N, pH, and temperature. Review of the difference between the ammonia-N and unionized ammonia concentrations indicate the unionized ammonia sample concentrations never exceeded the standard of 0.05 mg/L. Given that a detailed analysis of unionized ammonia is not required of watershed plans and that all concentrations were less than 0.05 mg/L, this appendix includes the results of the ammonia-N analysis. The results of the ammonia-N analysis would slightly improve if concentrations were compared to the unionized ammonia analysis.

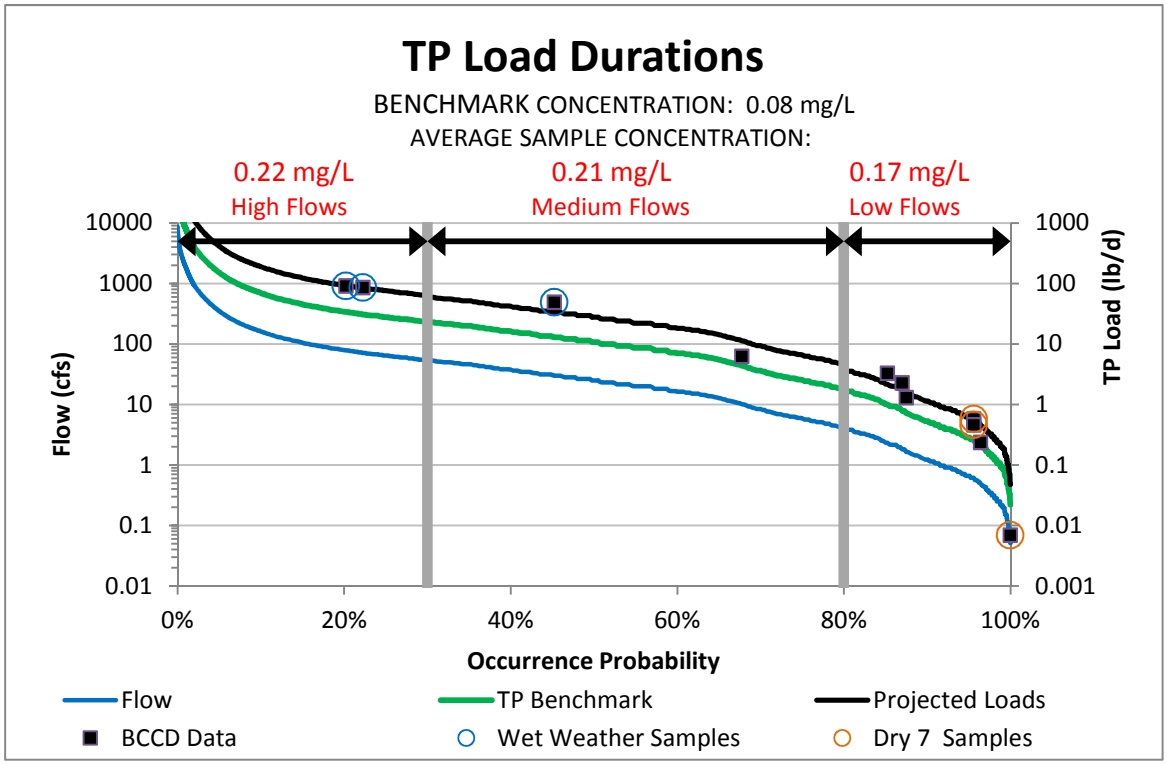
Site: GPC 7.5

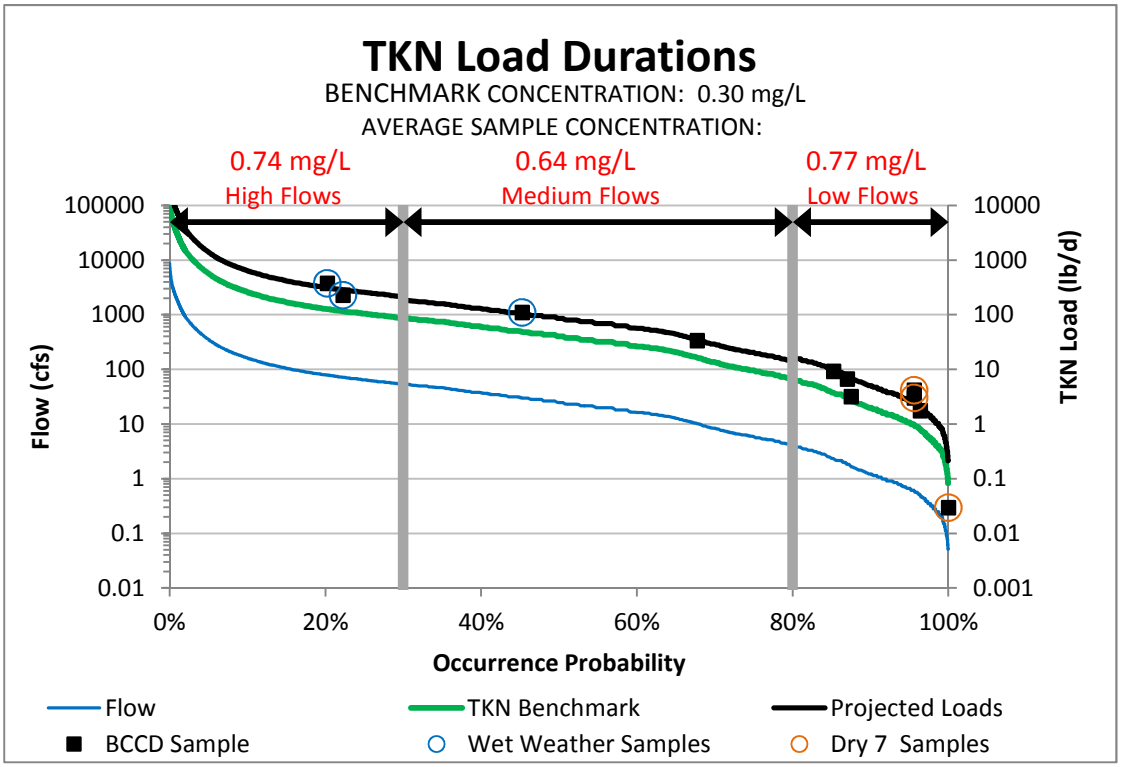




Average Sample Concentration Text:			
> 2x Benchmark	1-2x Benchmark	< Benchmark	

Site: **GPC 7.5** (continued)





Average Sample Concentration Text:			
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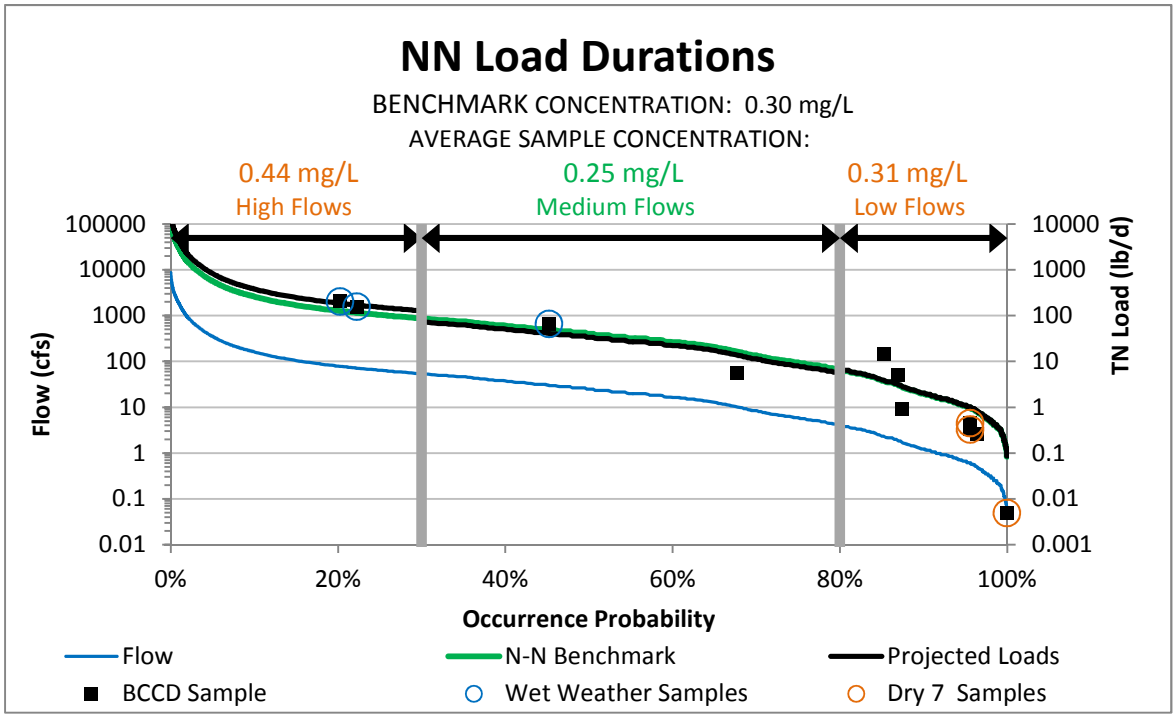
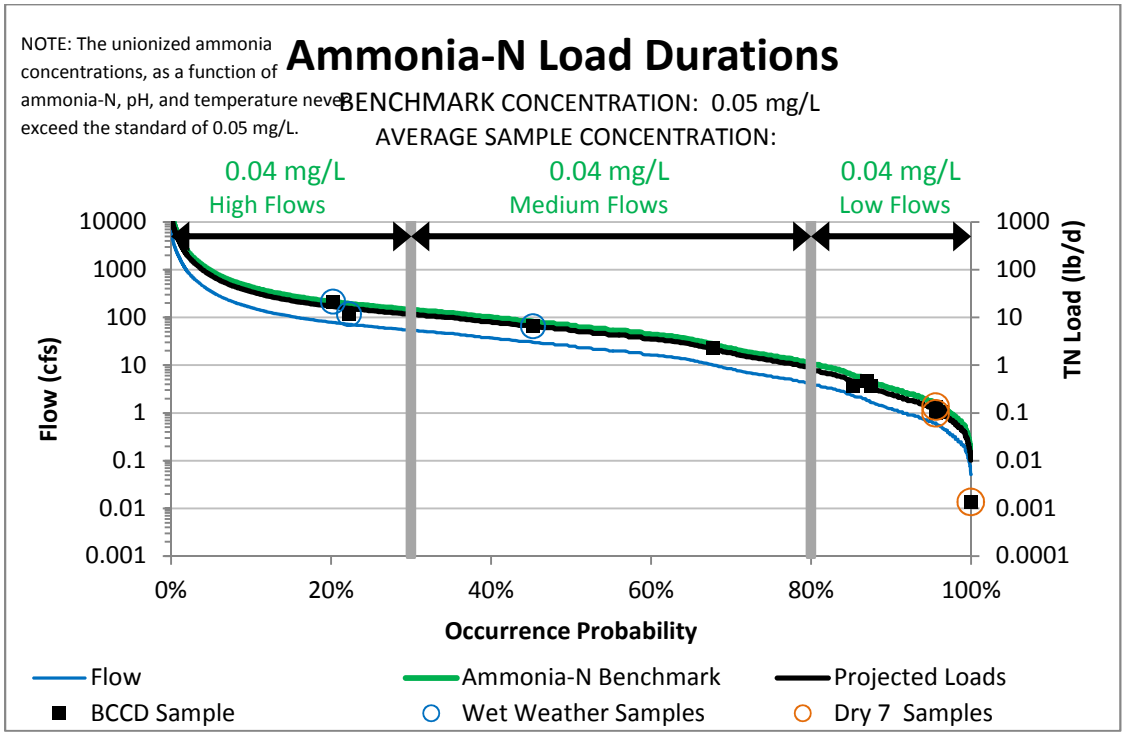
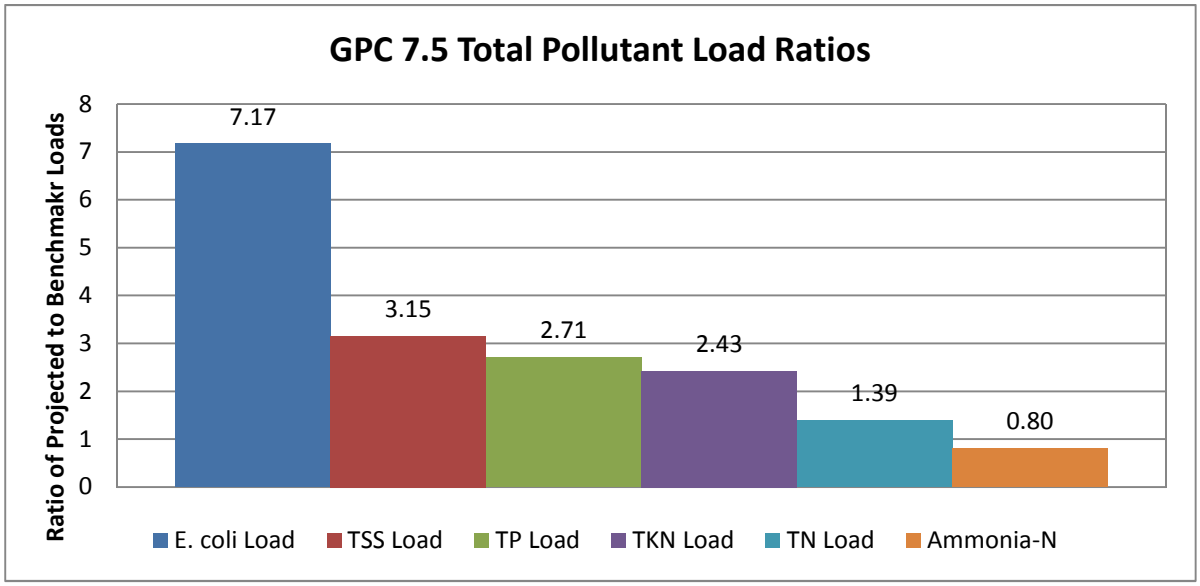
Site: **GPC 7.5** (continued)

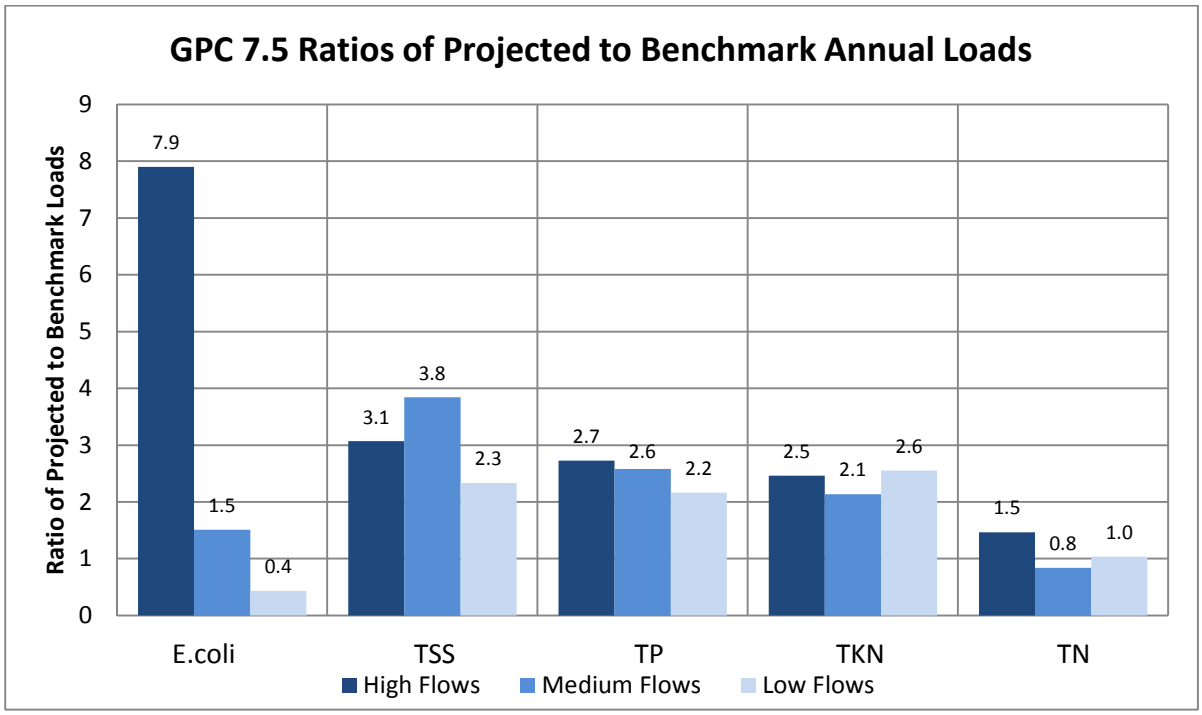




Average Sample Concentration Text:			
> 2x Benchmark	1-2x Benchmark	< Benchmark	

Site: **GPC 7.5** (continued)





NOTE: Ratios greater than 1 are above the benchmark limit set by KDOW benchmarks and ratios less than 1 are below the benchmark limit.

Site: **GPC 7.5** (continued)

CALCULATED ANNUAL LOADS

Flow Category	TOTAL BENCHMARK LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	2.0E+14	1,302,132	14,361	53,853	53,853	8,975
Medium Flows	2.5E+13	163,550	1,805	6,768	6,768	1,128
Low Flows	6.6E+11	4,406	48.62	182.34	182.34	30.39
TOTAL	2.2E+14	1,470,088	16,214	60,803	60,803	10,134

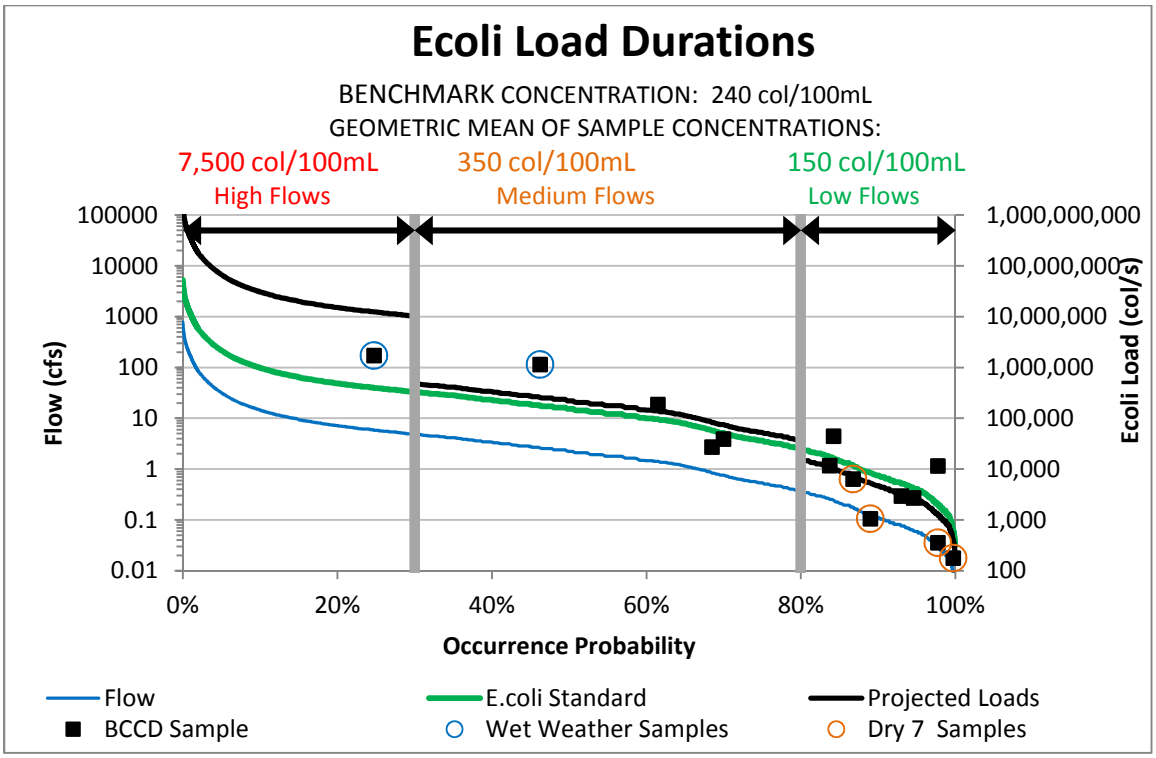
Flow Category	TOTAL PROJECTED LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	1.5E+15	3,996,198	39,154	132,638	78,936	7,184
Medium Flows	3.7E+13	628,257	4,658	14,449	5,685	902
Low Flows	2.8E+11	10,283	105.06	465.13	188.93	22.57
TOTAL	1.6E+15	4,634,738	43,917	147,552	84,810	8,109

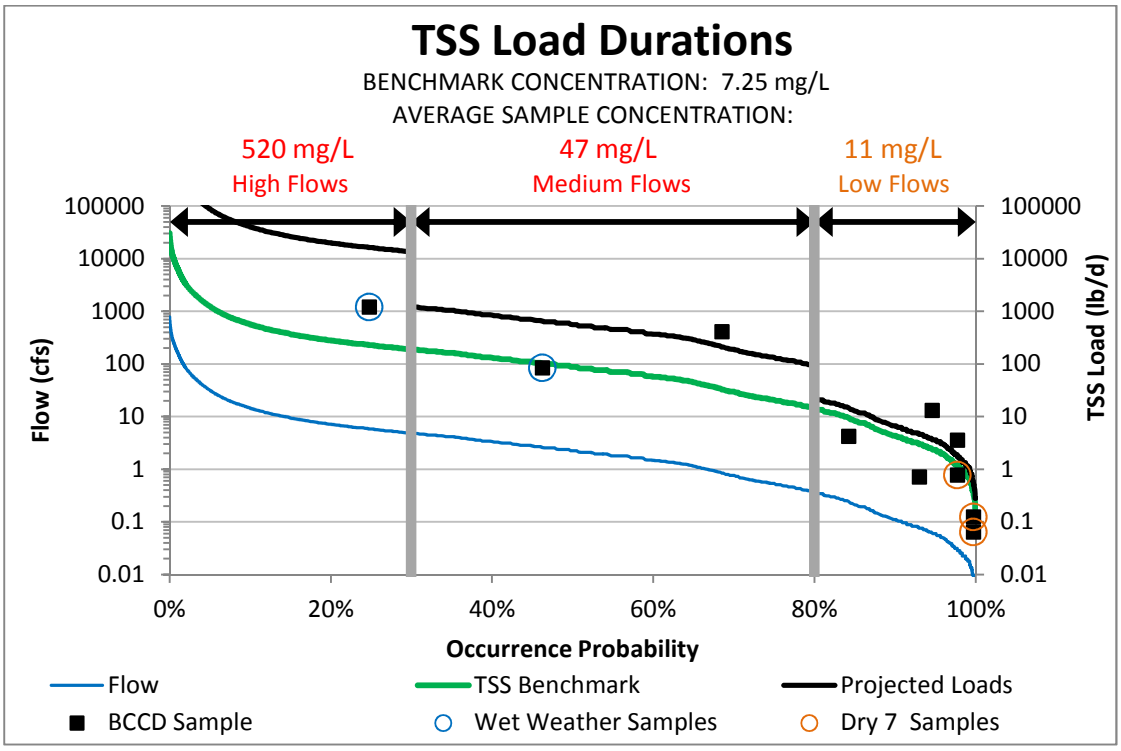
Flow Category	PERCENT DIFFERENCE: ((projected-target)/projected)*100					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	87%	67%	63%	59%	32%	-25%
Medium Flows	34%	74%	61%	53%	-19%	-25%
Low Flows	-132%	57%	54%	61%	3%	-35%
TOTAL	86%	68%	63%	59%	28%	-25%

NOTE: The percent difference presented in the above table represents the percent load reduction needed to meet the KDOW water quality benchmark or standard. Negative numbers indicate the projected load is below the target for the pollutant of concern.

Flow Category	**CALCULATED POLLUTANT YIELDS: total projected load/drainage area**					
	E. coli Yield	TSS Yield	TP Yield	TKN Yield	TN Yield	Ammonia-N
	(col/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)
High Flows	5.54E+10	143.3	1.4	4.8	2.8	0.3
Medium Flows	1.33E+09	22.5	0.167	0.5	0.2	0.0
Low Flows	1.02E+07	0.4	0.004	0.0	0.0	0.0
TOTAL	5.67E+10	166.2	1.6	5.3	3.0	0.3

Site: GPC 17.1-UNT 0.1





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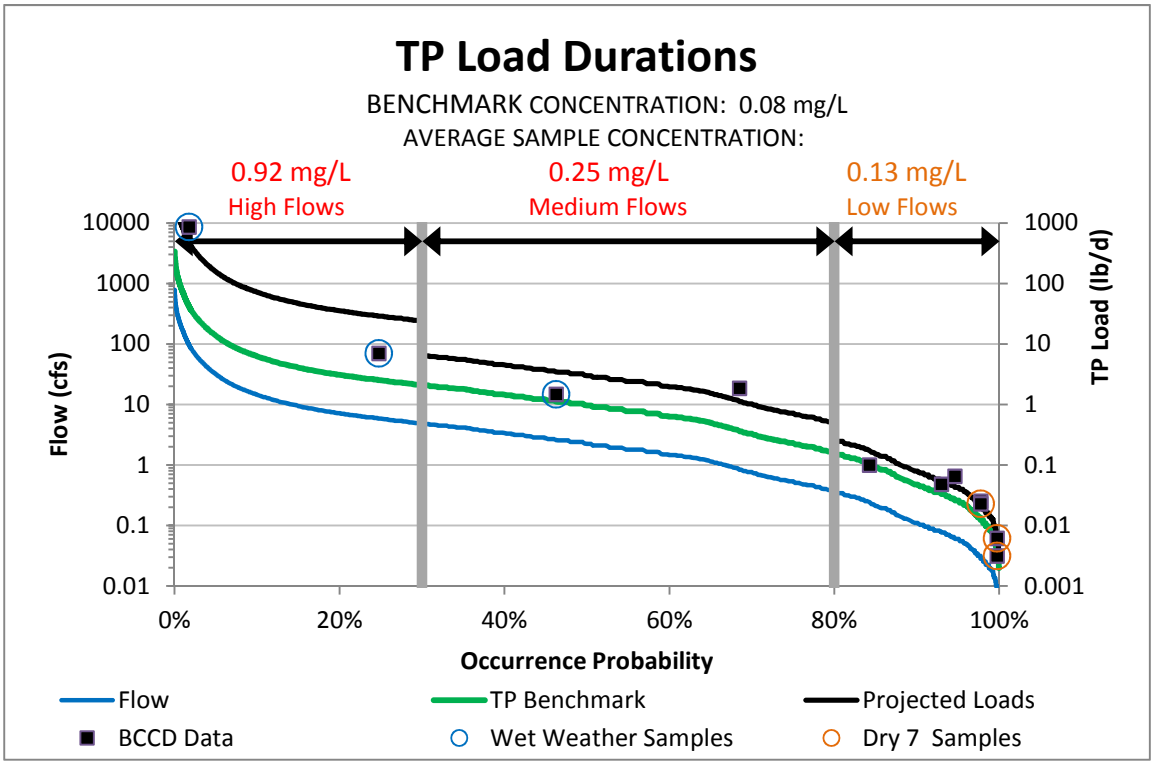
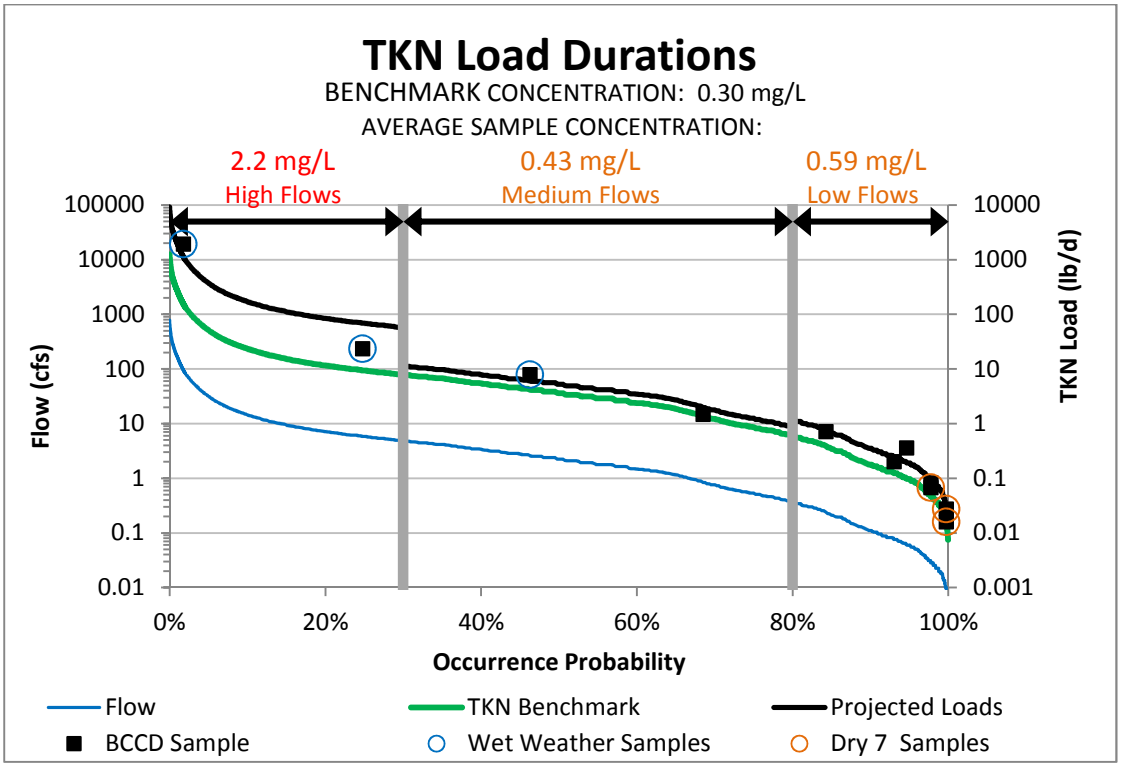
Site: **GPC 17.1-UNT 0.1** (continued)





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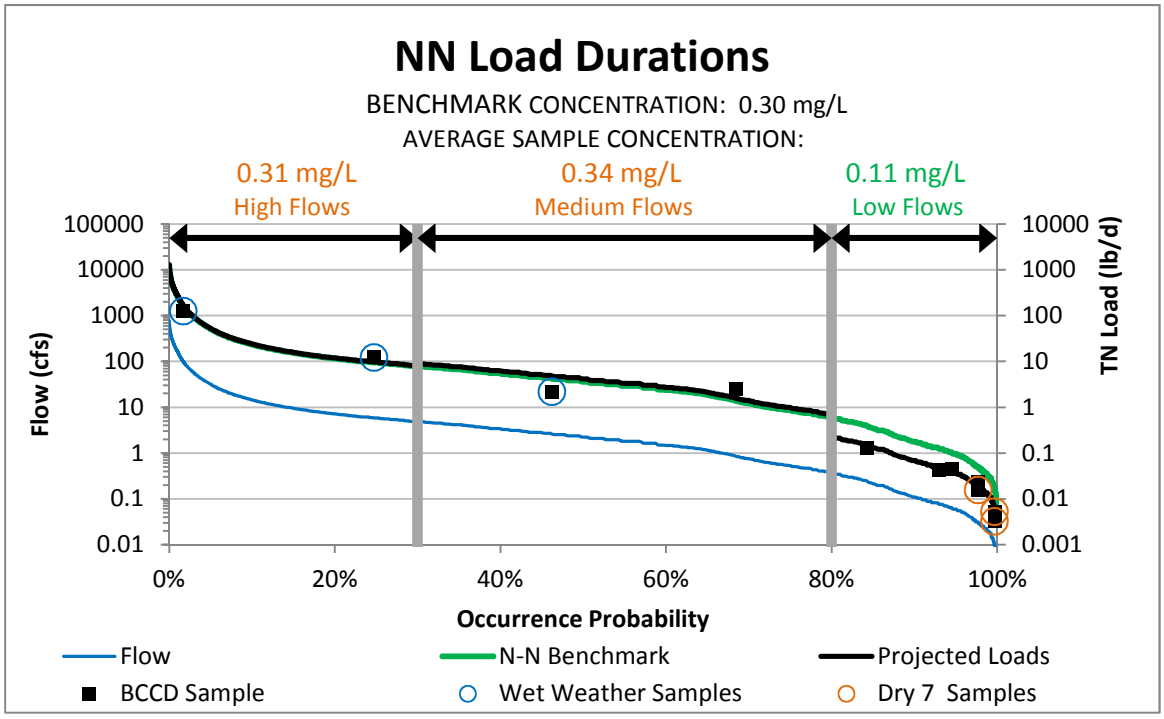
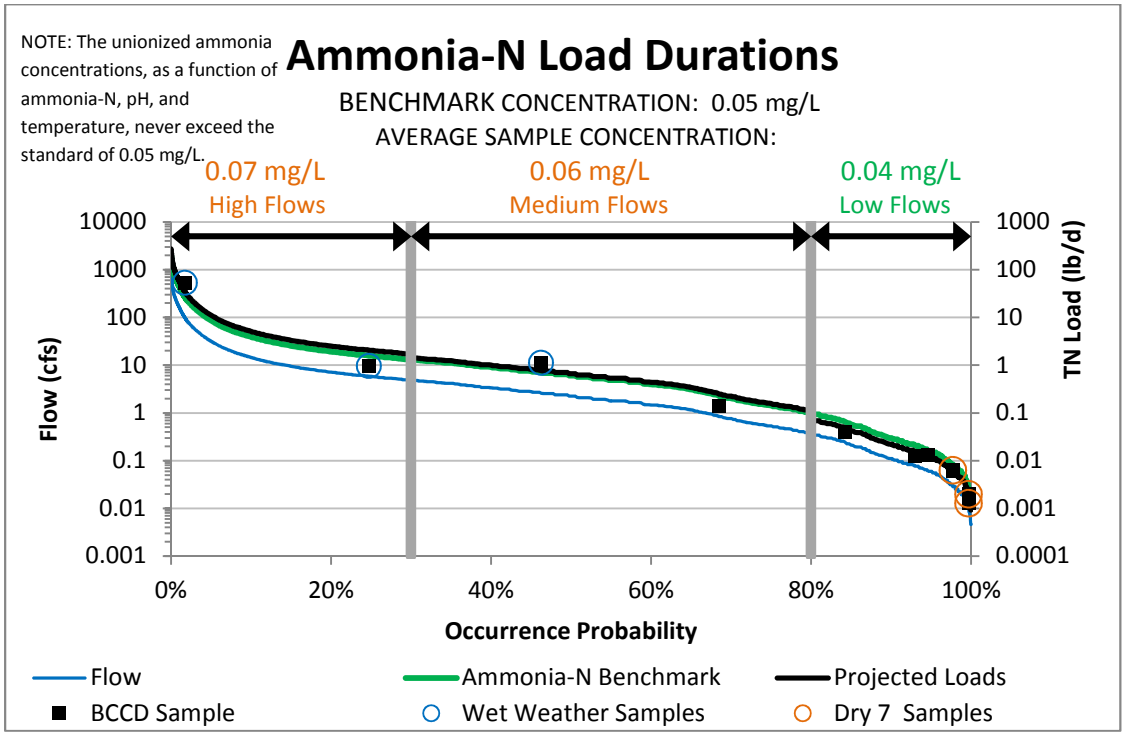
Site: **GPC 17.1-UNT 0.1** (continued)





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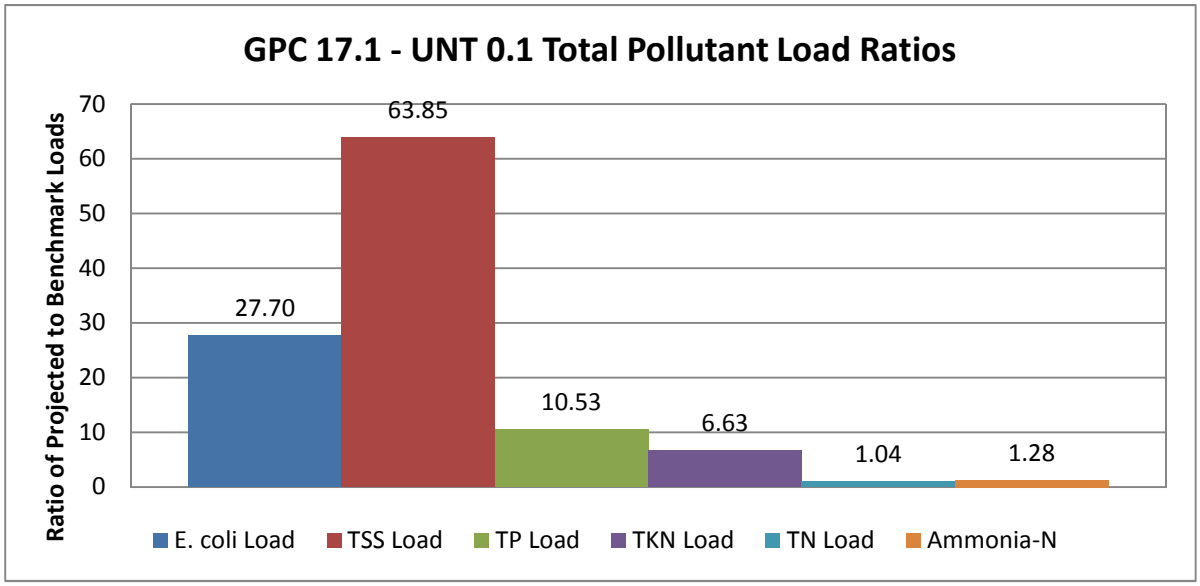
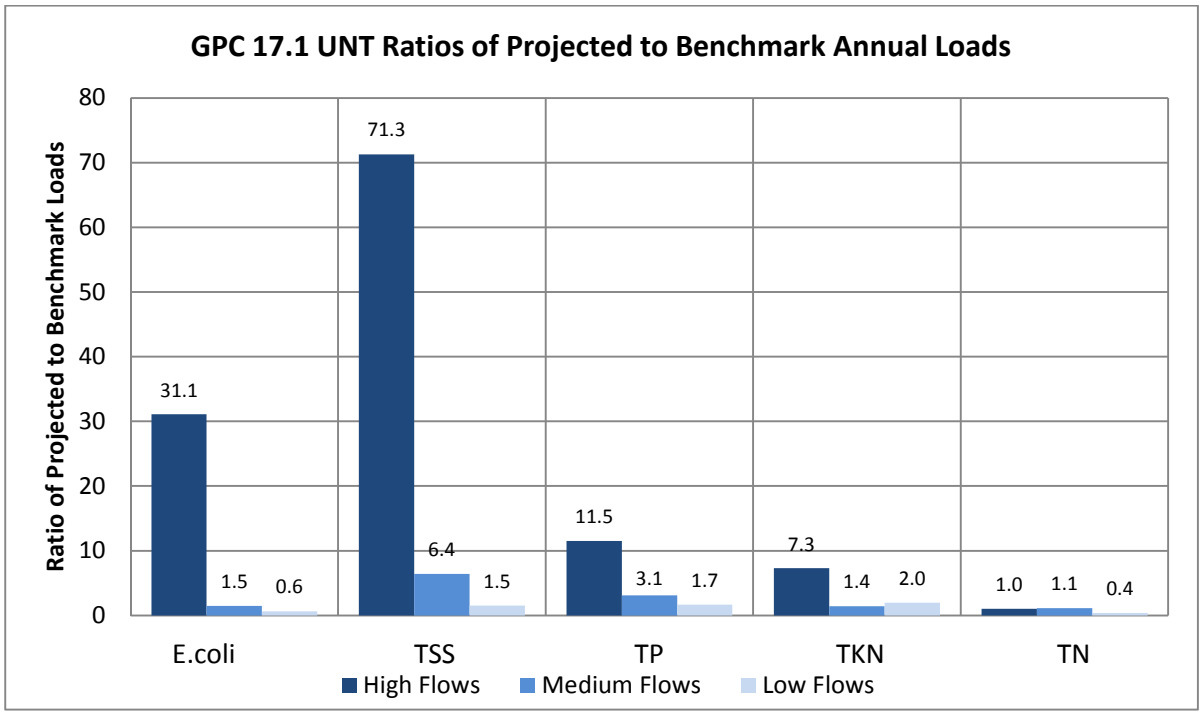
Site: **GPC 17.1-UNT 0.1** (continued)





NOTE: Ratios greater than 1 are above the benchmark limit set by KDOW benchmarks and ratios less than 1 are below the benchmark limit.

Site: **GPC 17.1-UNT 0.1** (continued)

CALCULATED ANNUAL LOADS

Flow Category	TOTAL BENCHMARK LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	1.8E+13	117,365	1,294	4,854	4,854	809
Medium Flows	2.2E+12	14,741	163	610	610	102
Low Flows	6.0E+10	397	4.38	16.43	16.43	2.74
TOTAL	2.0E+13	132,503	1,461	5,480	5,480	913

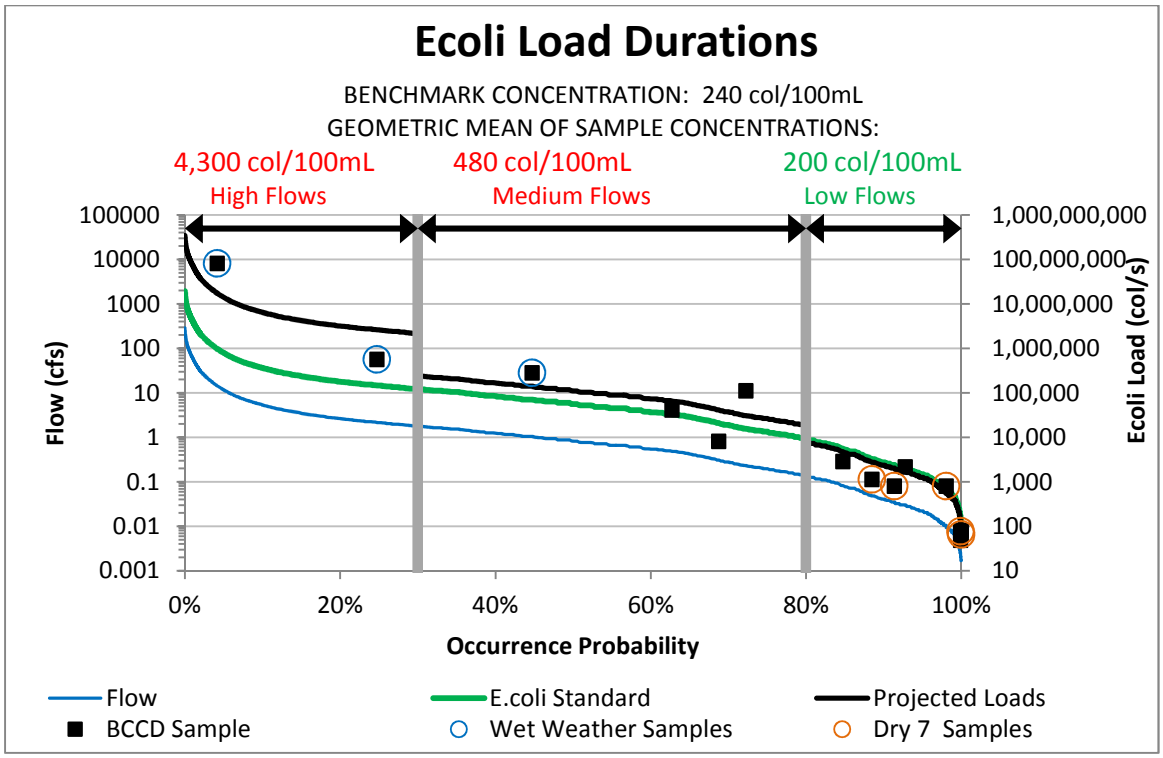
Flow Category	TOTAL PROJECTED LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	5.5E+14	8,365,260	14,877	35,412	5,010	1,052
Medium Flows	3.2E+12	94,445	504	883	696	112
Low Flows	3.7E+10	610	7.25	32.36	6.27	2.03
TOTAL	5.5E+14	8,460,316	15,388	36,328	5,713	1,166

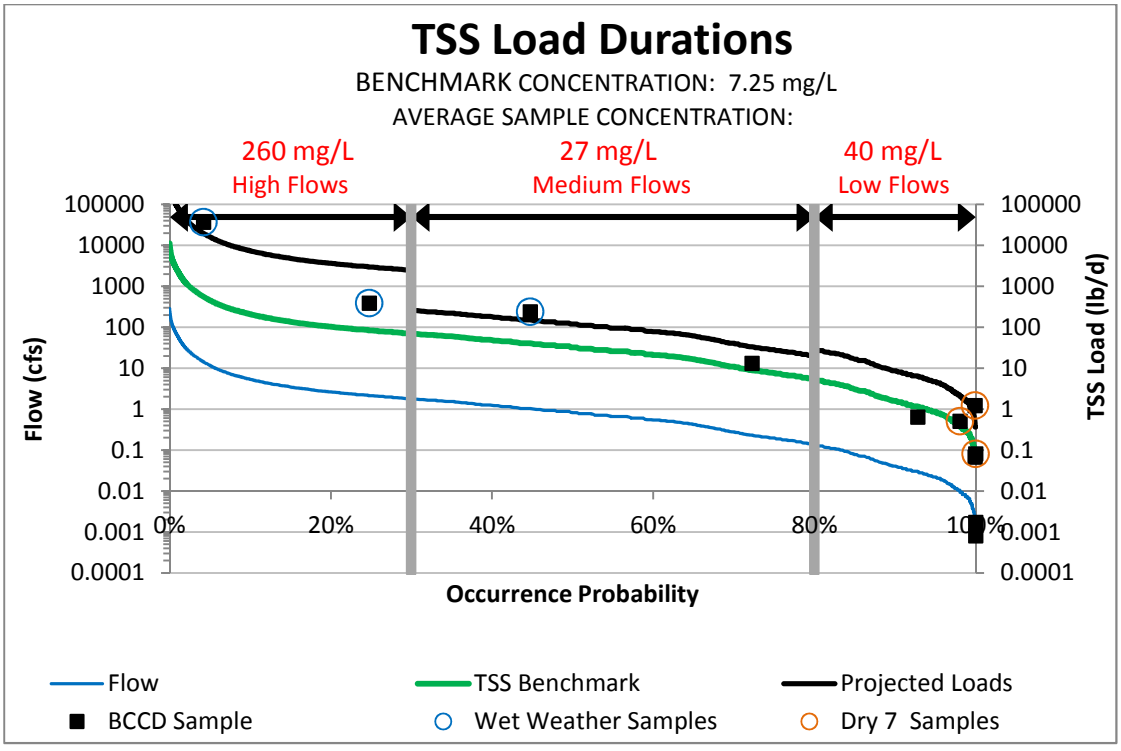
Flow Category	PERCENT DIFFERENCE: ((projected-target)/projected)*100					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	97%	99%	91%	86%	3%	23%
Medium Flows	31%	84%	68%	31%	12%	9%
Low Flows	-59%	35%	40%	49%	-162%	-35%
TOTAL	96%	98%	91%	85%	4%	22%

NOTE: The percent difference presented in the above table represents the percent load reduction needed to meet the KDOW water quality benchmark or standard. Negative numbers indicate the projected load is below the target for the pollutant of concern.

Flow Category	**CALCULATED POLLUTANT YIELDS: total projected load/drainage area**					
	E. coli Yield	TSS Yield	TP Yield	TKN Yield	TN Yield	Ammonia-N
	(col/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)
High Flows	8.20E+10	1,084.3	2.8	5.8	1.5	0.3
Medium Flows	1.15E+09	14.3	0.090	0.4	0.1	0.1
Low Flows	1.32E+07	0.6	0.002	0.0	0.0	0.0
TOTAL	8.31E+10	1,099.1	2.9	6.2	1.6	0.3

Site: SFG 5.3-UNT 0.1





Average Sample Concentration Text:			
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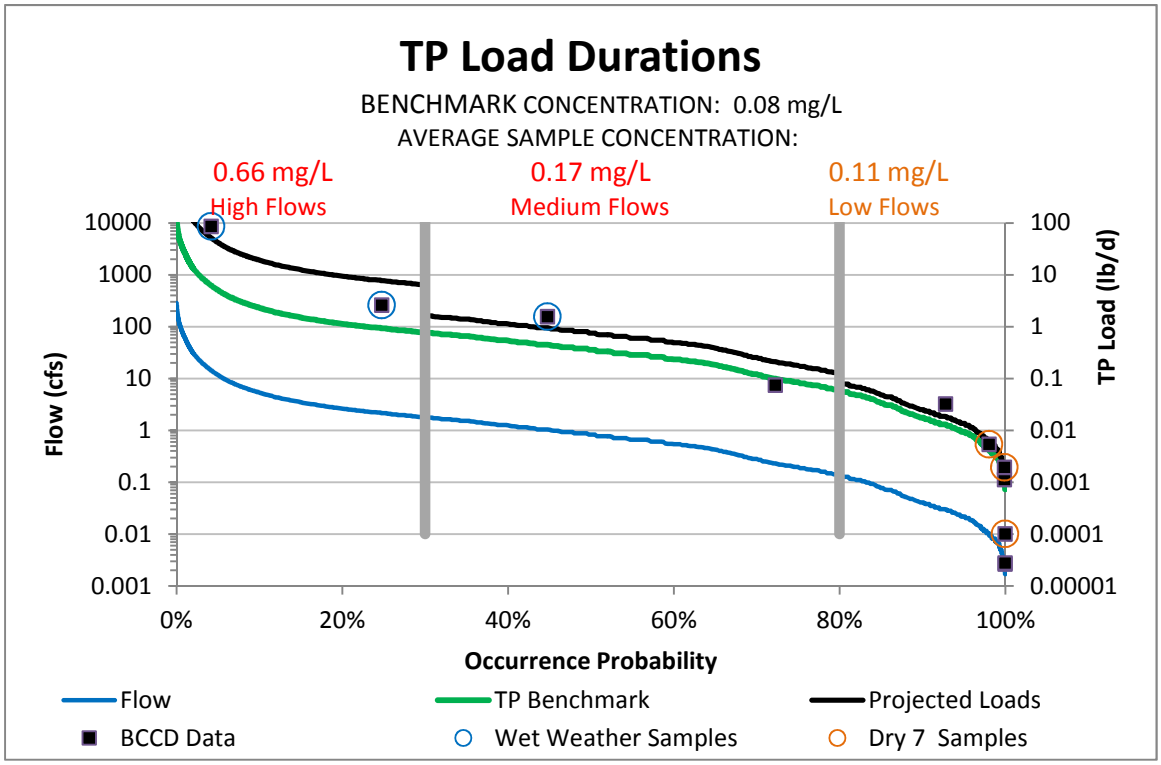
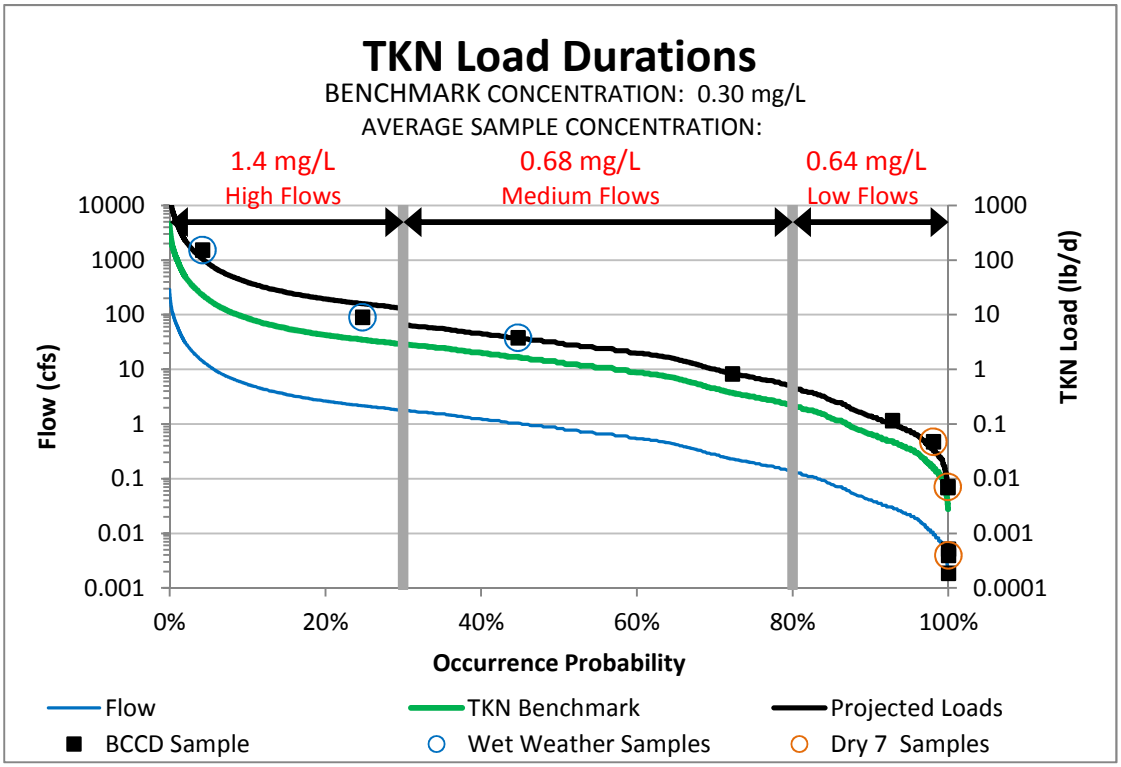
Site: **SFG 5.3-UNT 0.1** (continued)





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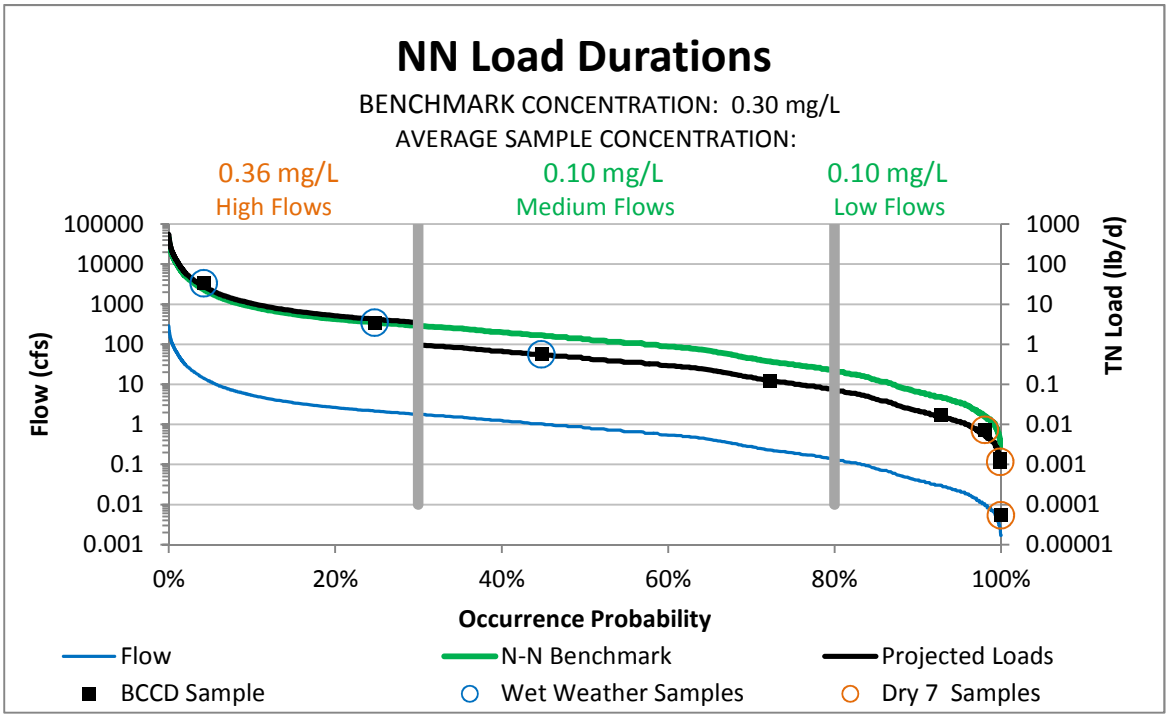
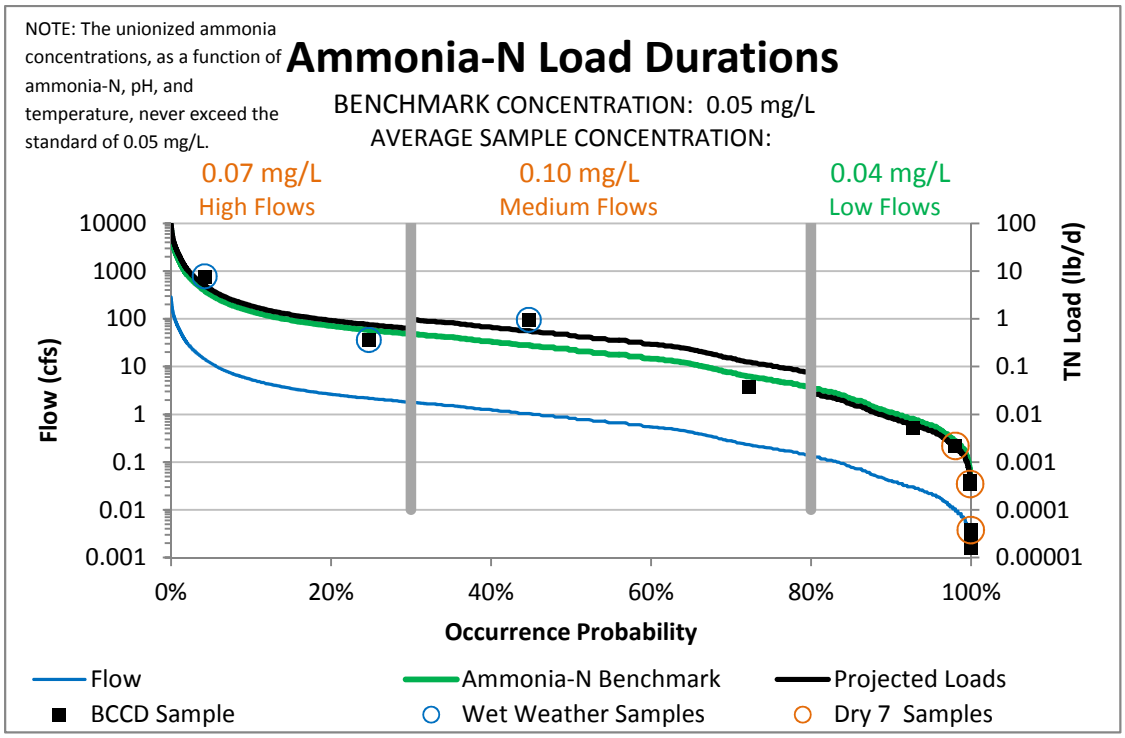
Site: **SFG 5.3-UNT 0.1** (continued)





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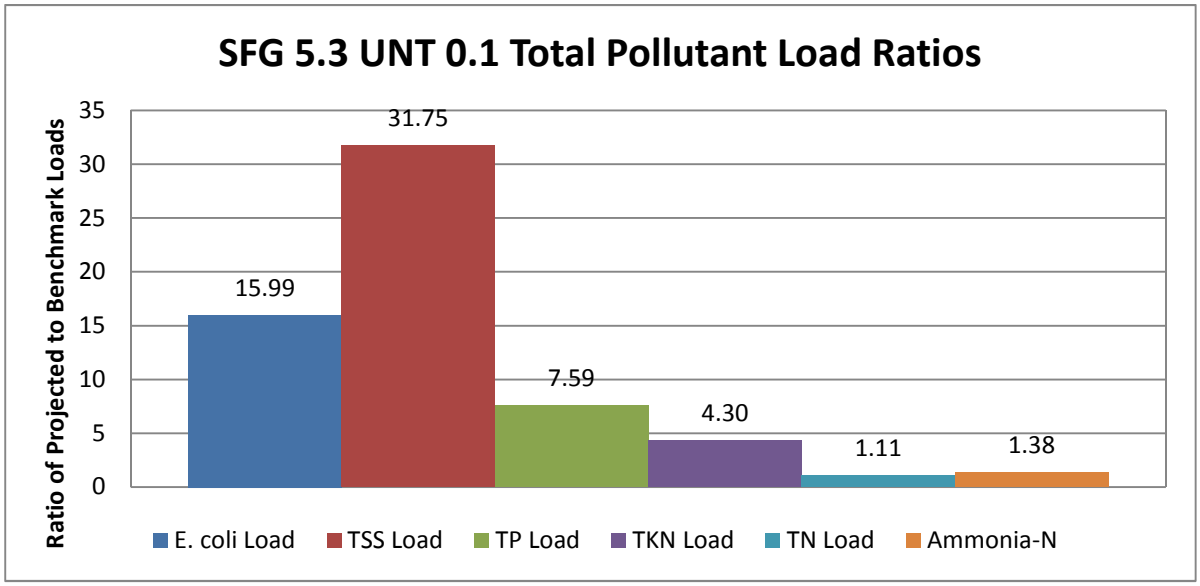
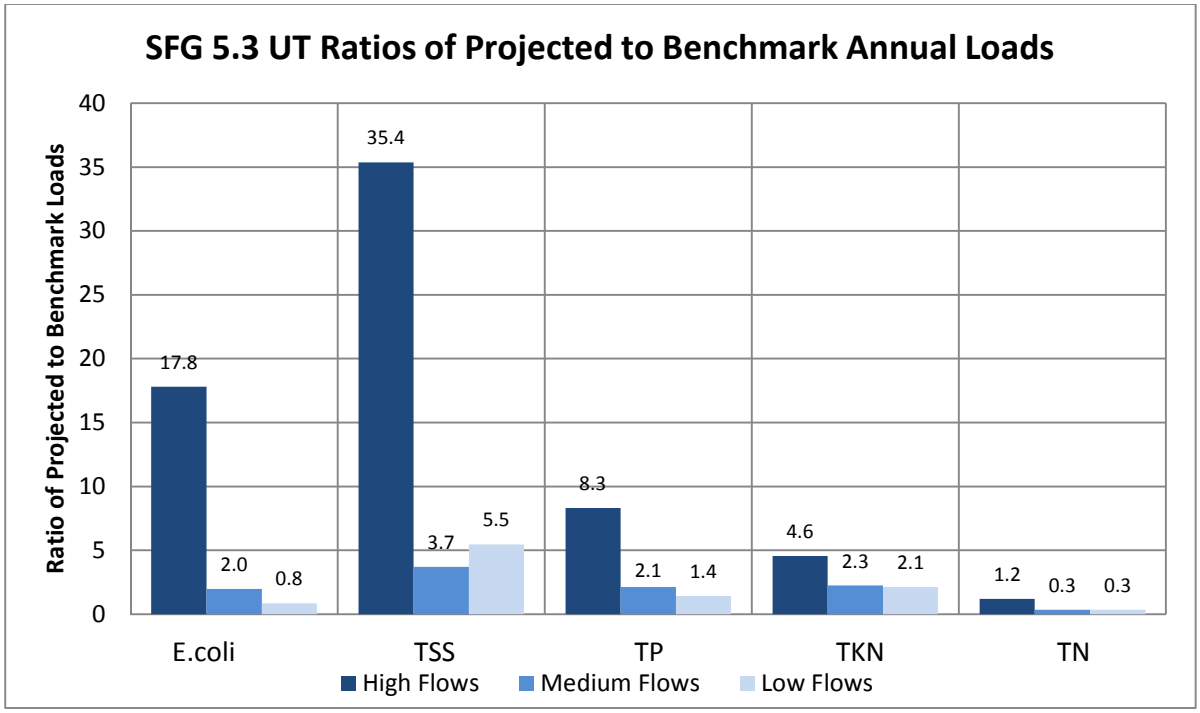
Site: **SFG 5.3-UNT 0.1** (continued)





NOTE: Ratios greater than 1 are above the benchmark limit set by KDOW benchmarks and ratios less than 1 are below the benchmark limit.

Site: **SFG 5.3-UNT 0.1** (continued)

CALCULATED ANNUAL LOADS

Flow Category	TOTAL BENCHMARK LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/year)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	6.5E+12	43,232	477	1,788	1,788	298
Medium Flows	8.2E+11	5,430	60	225	225	37
Low Flows	2.2E+10	146	1.61	6.05	6.05	1.01
TOTAL	7.3E+12	48,808	538	2,019	2,019	336

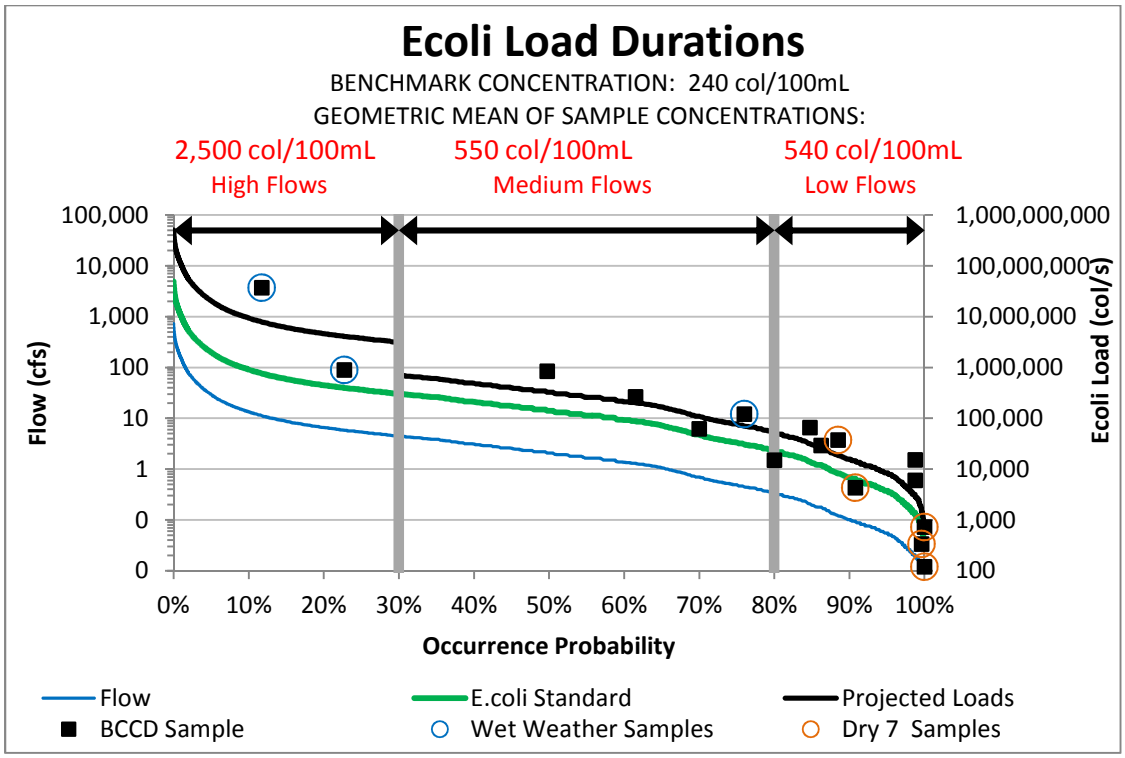
Flow Category	TOTAL PROJECTED LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/year)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	1.2E+14	1,528,624	3,959	8,163	2,162	388
Medium Flows	1.6E+12	20,110	127	506	75	75
Low Flows	1.9E+10	800	2.31	12.86	2.02	0.78
TOTAL	1.2E+14	1,549,534	4,088	8,683	2,239	463

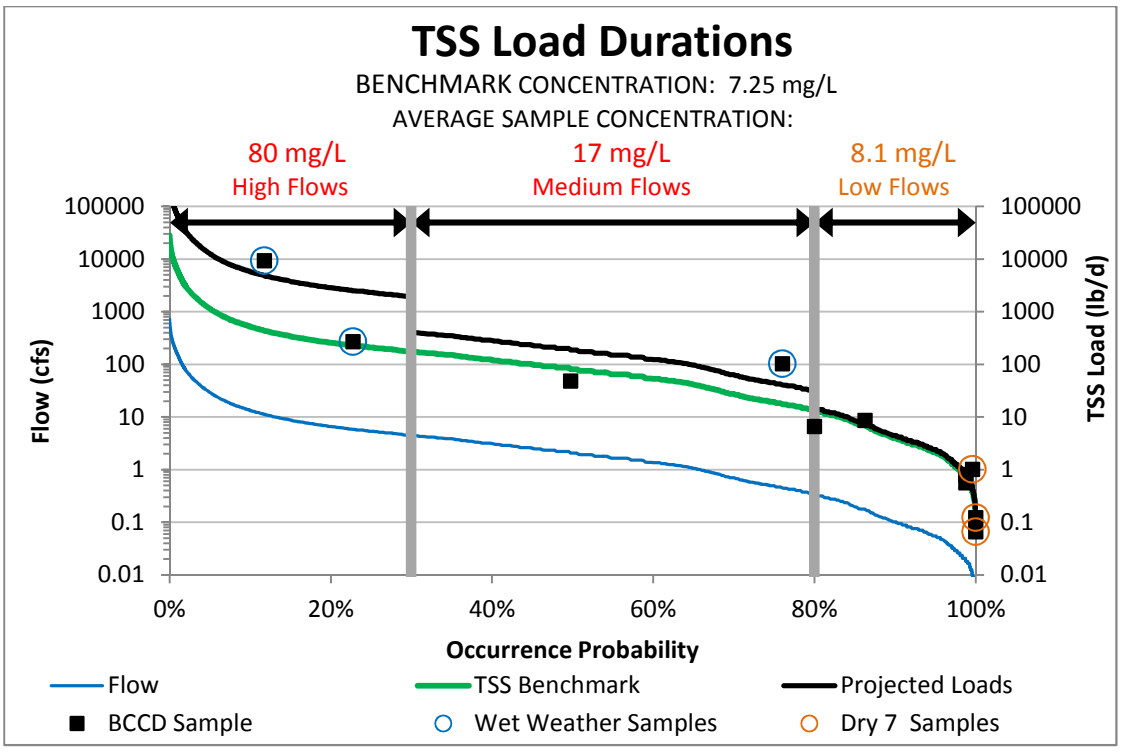
Flow Category	PERCENT DIFFERENCE: ((projected-target)/projected)*100					
	E. coli Yield	TSS Yield	TP Yield	TKN Yield	TN Yield	Ammonia-N
	(col/year)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	94%	97%	88%	78%	17%	23%
Medium Flows	49%	73%	53%	56%	-200%	50%
Low Flows	-18%	82%	30%	53%	-200%	-30%
TOTAL	94%	97%	87%	77%	10%	27%

NOTE: The percent difference presented in the above table represents the percent load reduction needed to meet the KDOW water quality benchmark or standard. Negative numbers indicate the projected load is below the target for the pollutant of concern.

Flow Category	**CALCULATED POLLUTANT YIELDS: total projected load/drainage area**					
	E. coli Yield	TSS Yield	TP Yield	TKN Yield	TN Yield	Ammonia-N
	(col/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)
High Flows	8.20E+10	1,084.3	2.8	5.8	1.5	0.3
Medium Flows	1.15E+09	14.3	0.090	0.4	0.1	0.1
Low Flows	1.32E+07	0.6	0.002	0.0	0.0	0.0
TOTAL	8.31E+10	1,099.1	2.9	6.2	1.6	0.3

Site: FWF 0.8





Average Sample Concentration Text:			
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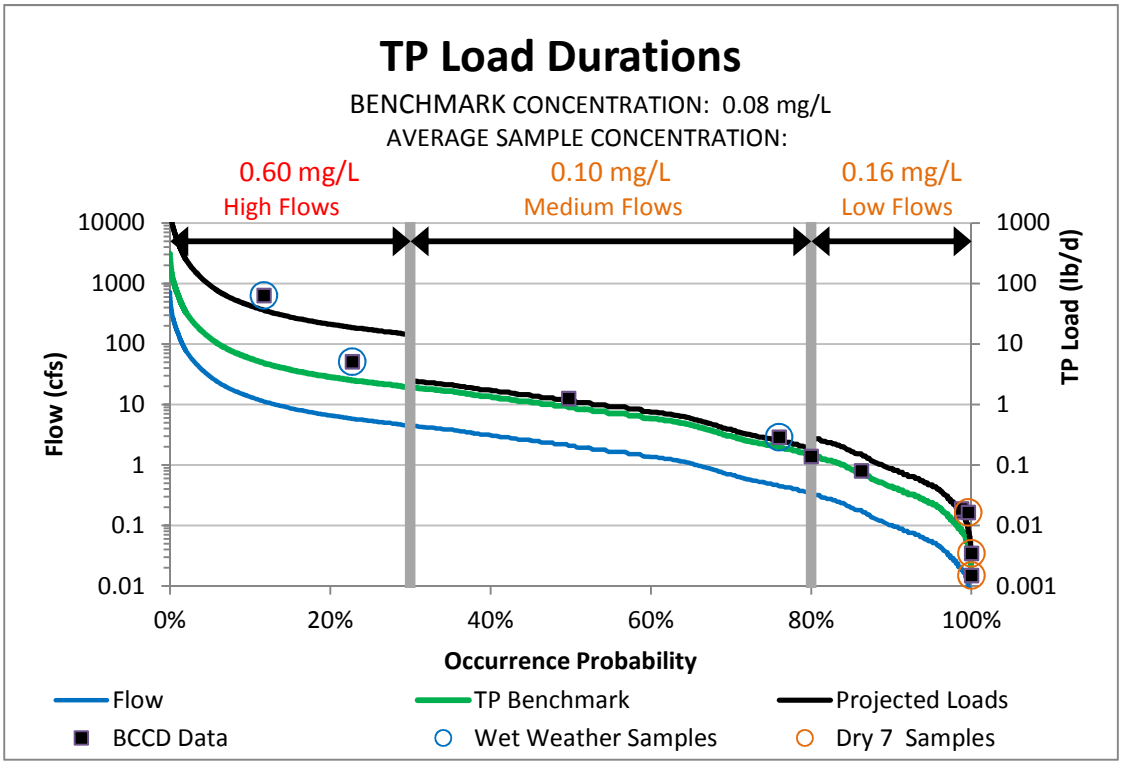
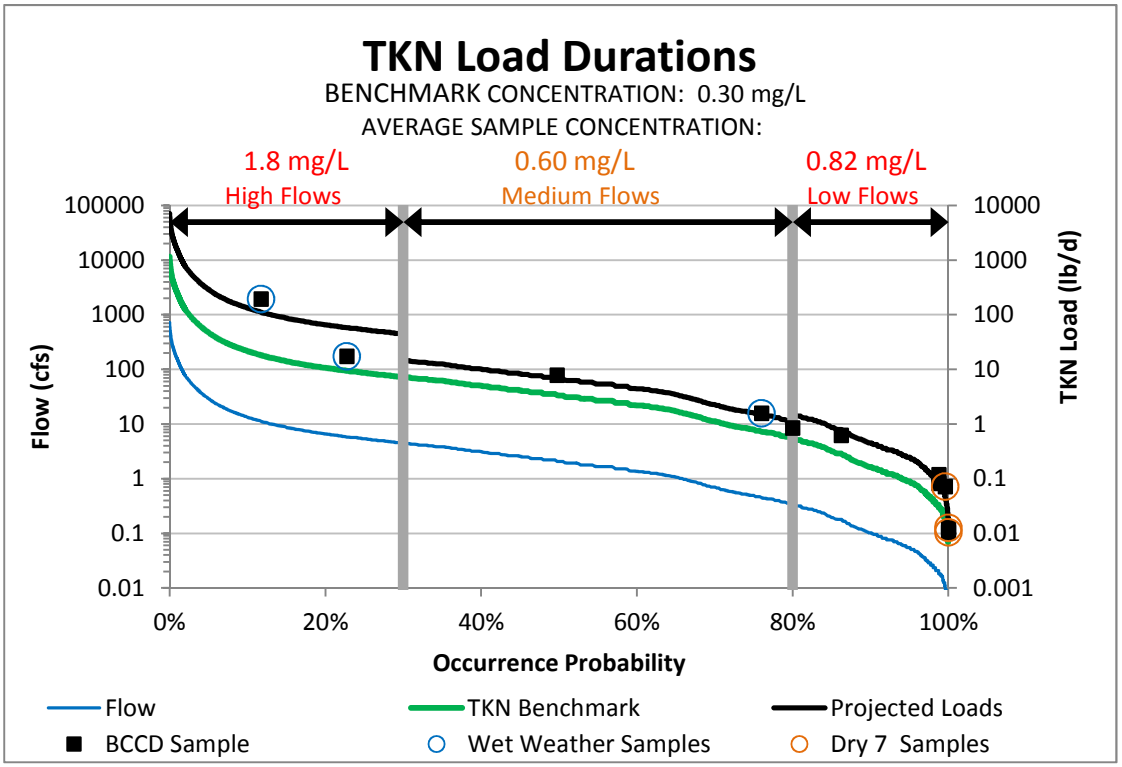
Site: **FWF 0.8** (continued)





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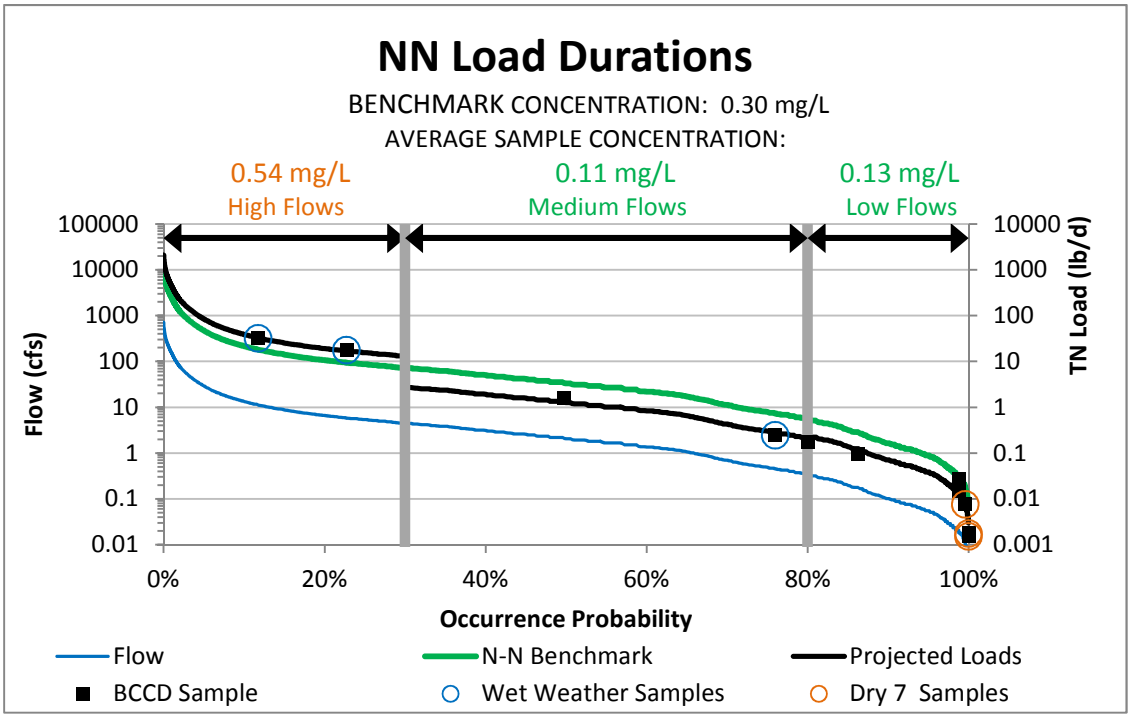
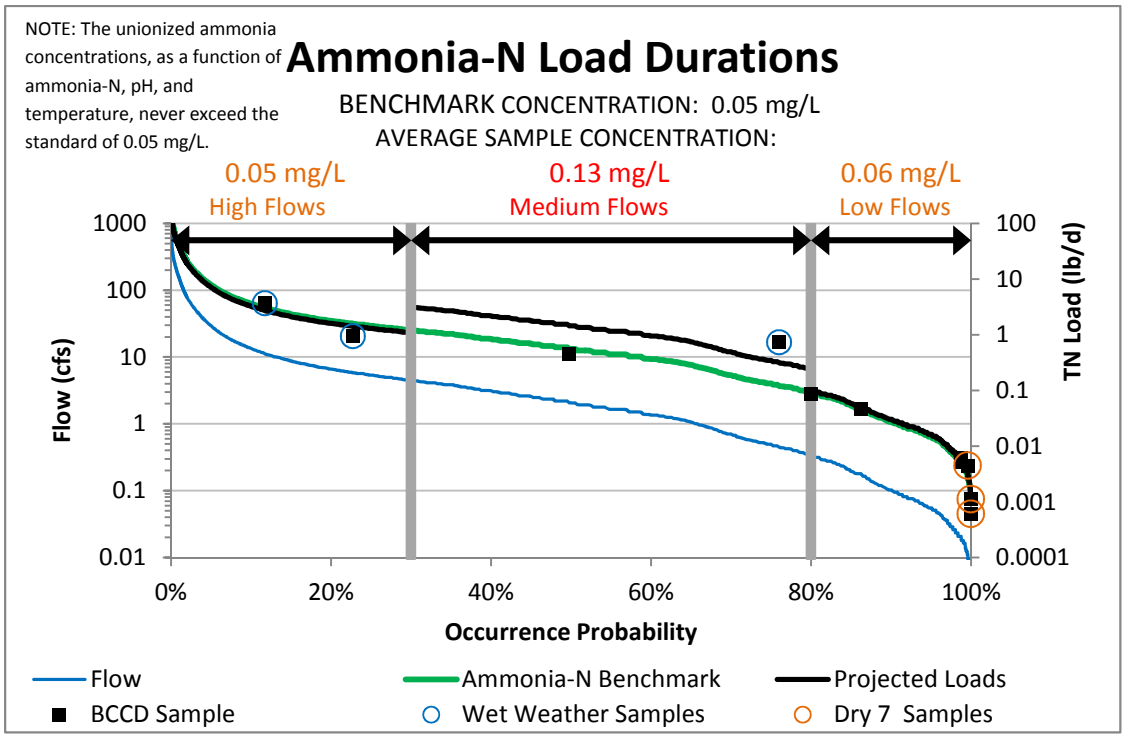
Site: **FWF 0.8** (continued)





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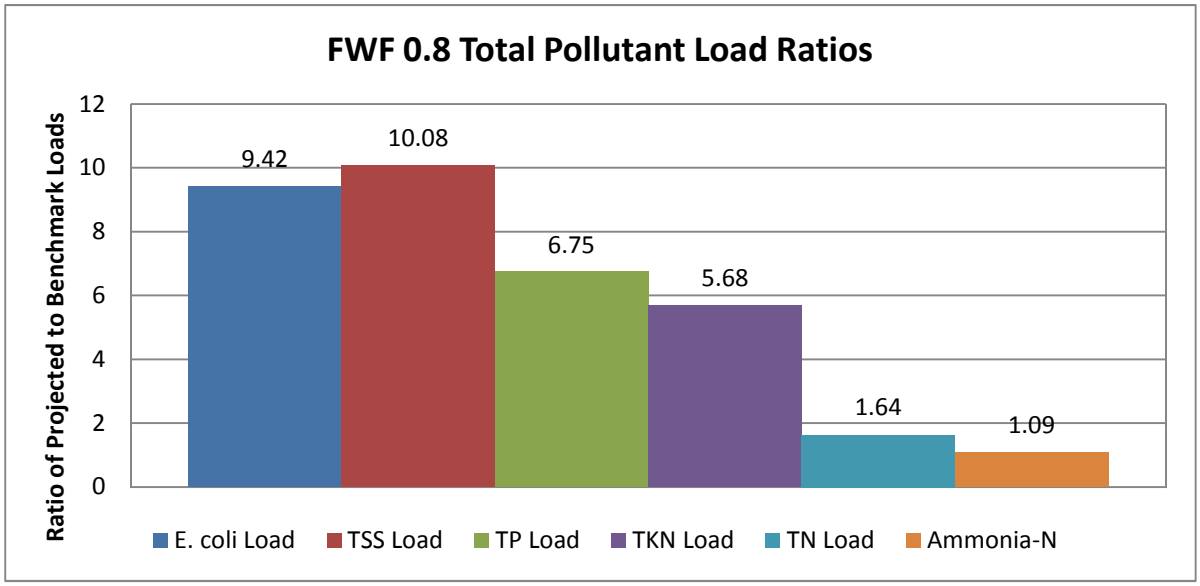
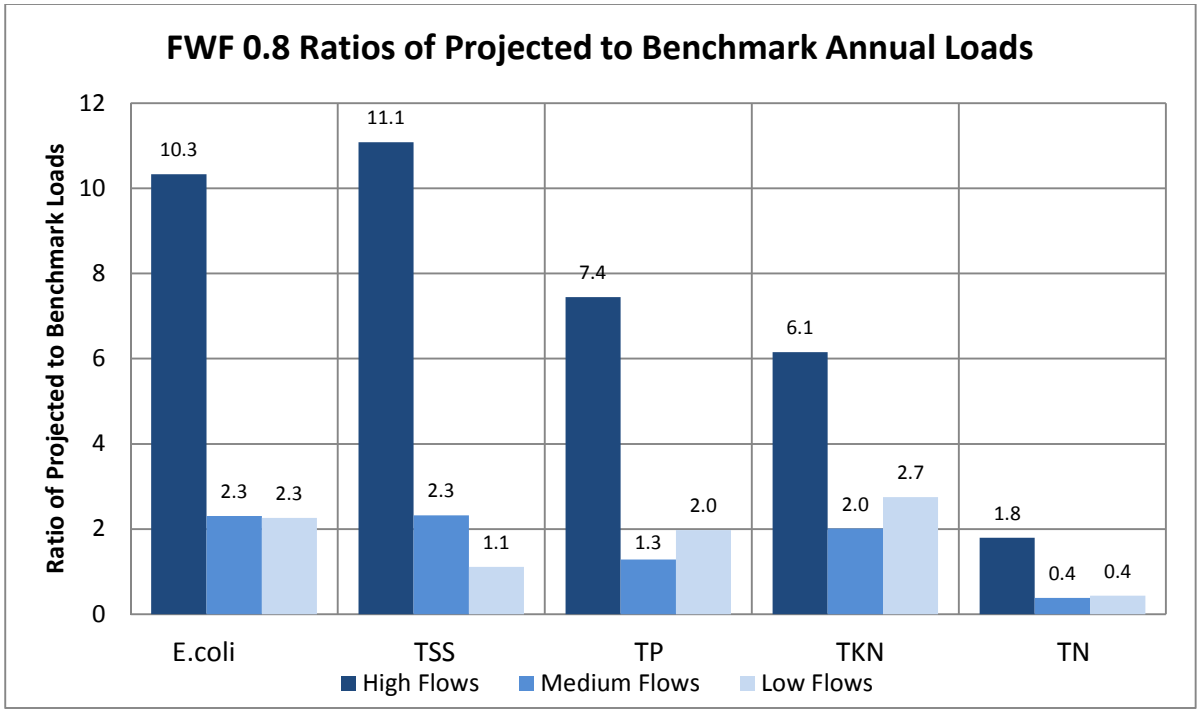
Site: **FWF 0.8** (continued)





NOTE: Ratios greater than 1 are above the benchmark limit set by KDOW benchmarks and ratios less than 1 are below the benchmark limit.

Site: **FWF 0.8** (continued)

CALCULATED ANNUAL LOADS

Flow Category	TOTAL BENCHMARK LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	1.6E+13	108,263	1,194	4,477	4,477	746
Medium Flows	2.0E+12	13,598	150	563	563	94
Low Flows	5.5E+10	366	4.04	15.16	15.16	2.53
TOTAL	1.8E+13	122,227	1,348	5,055	5,055	843

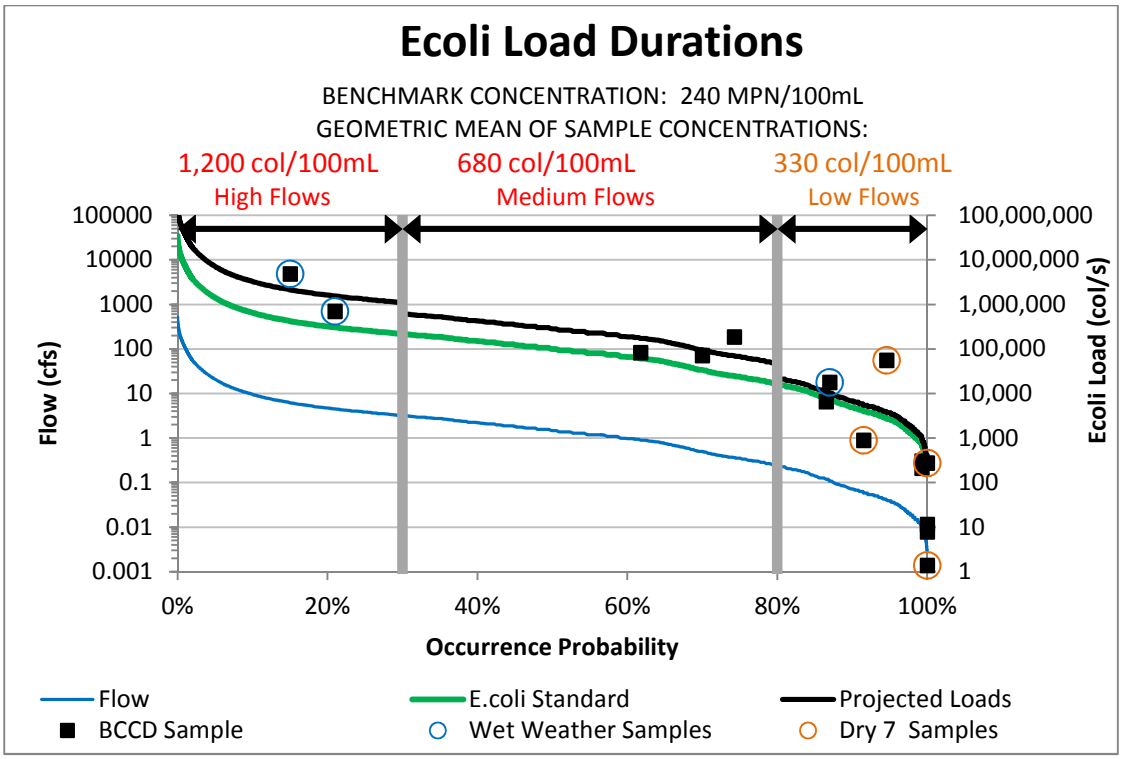
Flow Category	TOTAL PROJECTED LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	1.7E+14	1,199,626	8,892	27,536	8,049	672
Medium Flows	4.7E+12	31,579	193	1,133	214	244
Low Flows	1.2E+11	408	7.99	41.63	6.54	2.78
TOTAL	1.7E+14	1,231,613	9,093	28,711	8,269	919

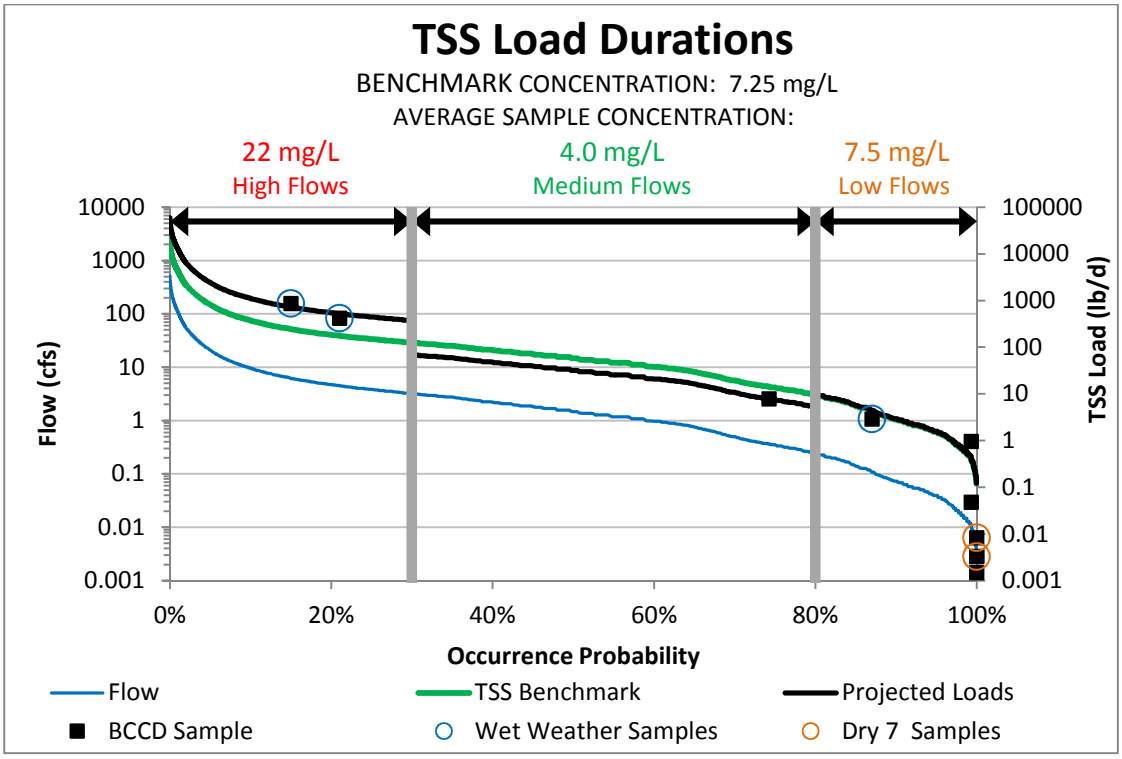
Flow Category	PERCENT DIFFERENCE: ((projected-target)/projected)*100					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	90%	91%	87%	84%	44%	-11%
Medium Flows	57%	57%	22%	50%	-163%	62%
Low Flows	56%	10%	49%	64%	-132%	9%
TOTAL	89%	90%	85%	82%	39%	8%

NOTE: The percent difference presented in the above table represents the percent load reduction needed to meet the KDOW water quality benchmark or standard. Negative numbers indicate the projected load is below the target for the pollutant of concern.

Flow Category	**CALCULATED POLLUTANT YIELDS: total projected load/drainage area**					
	E. coli Yield	TSS Yield	TP Yield	TKN Yield	TN Yield	Ammonia-N
	(col/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)
High Flows	6.11E+10	436.7	3.2	10.0	2.9	0.2
Medium Flows	1.72E+09	11.5	0.070	0.4	0.1	0.1
Low Flows	4.53E+07	0.1	0.003	0.0	0.0	0.0
TOTAL	6.29E+10	448.4	3.3	10.5	3.0	0.3

Site: RDR 1.1





Average Sample Concentration Text:		
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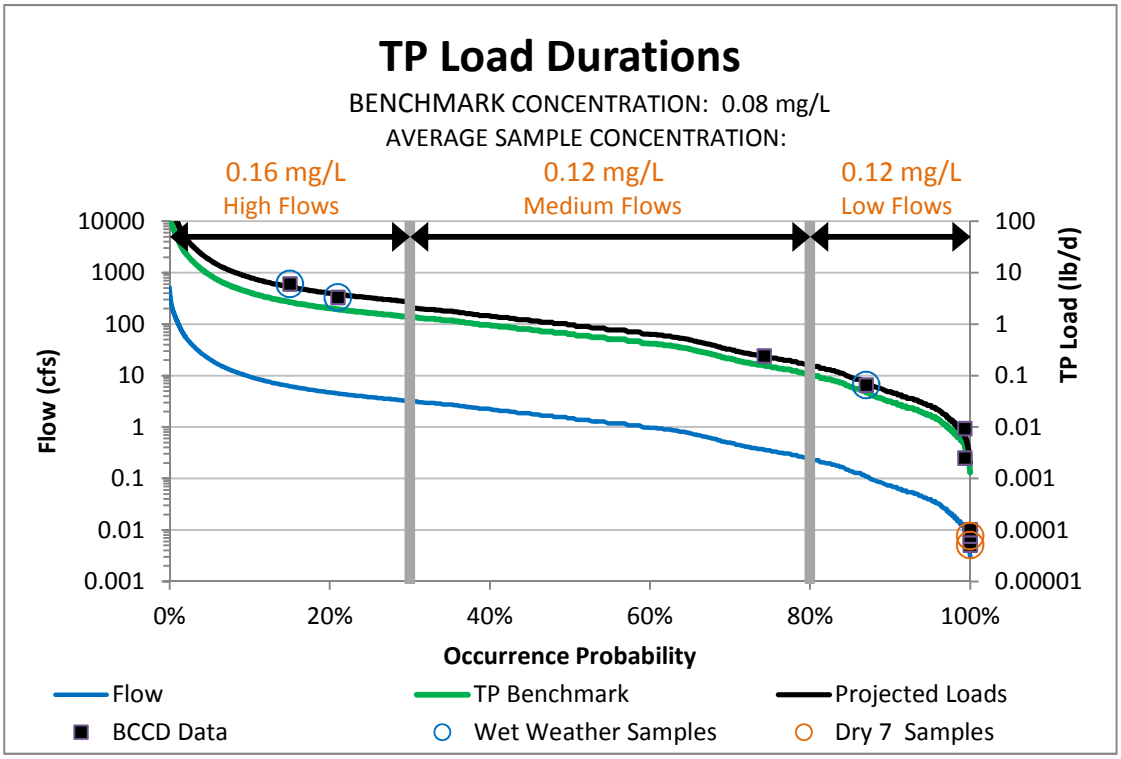
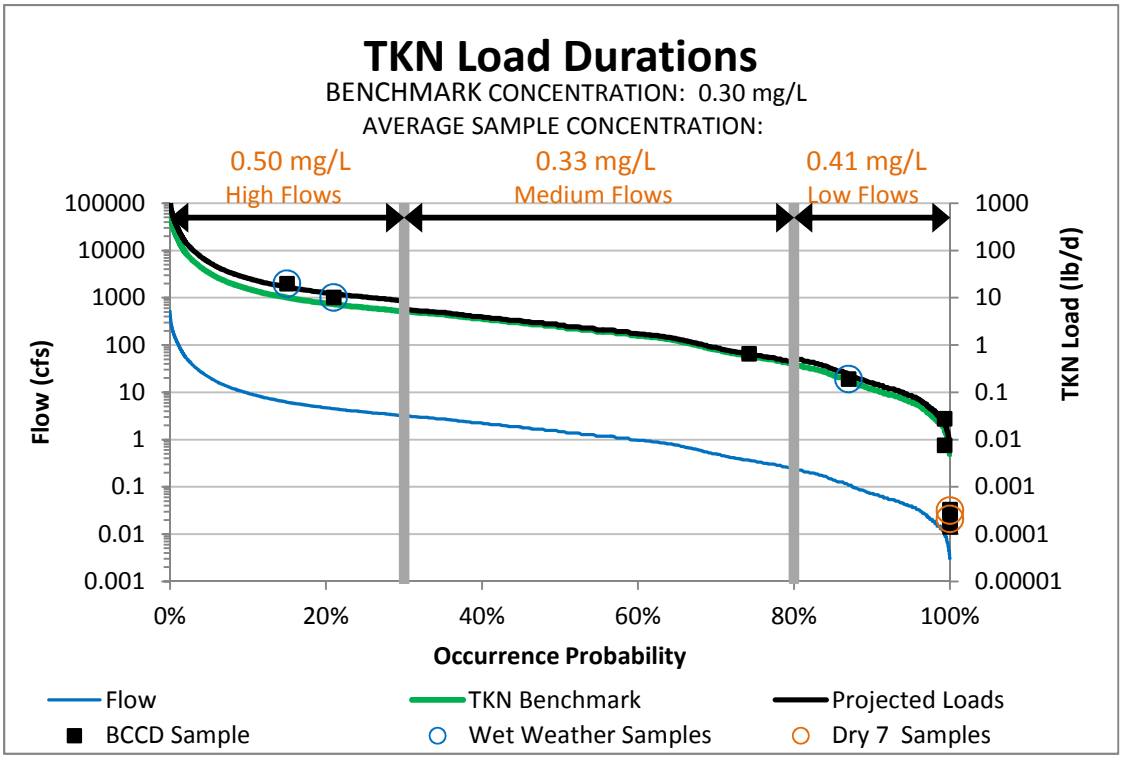
Site: **RDR 1.1** (continued)





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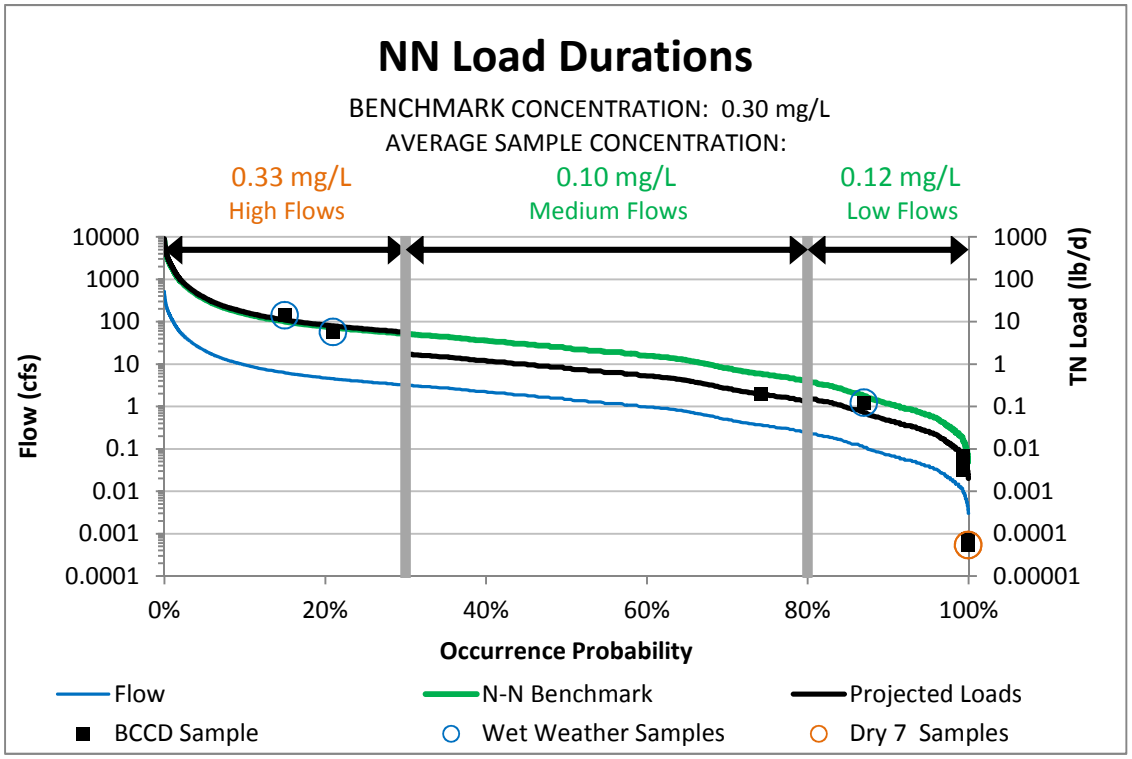
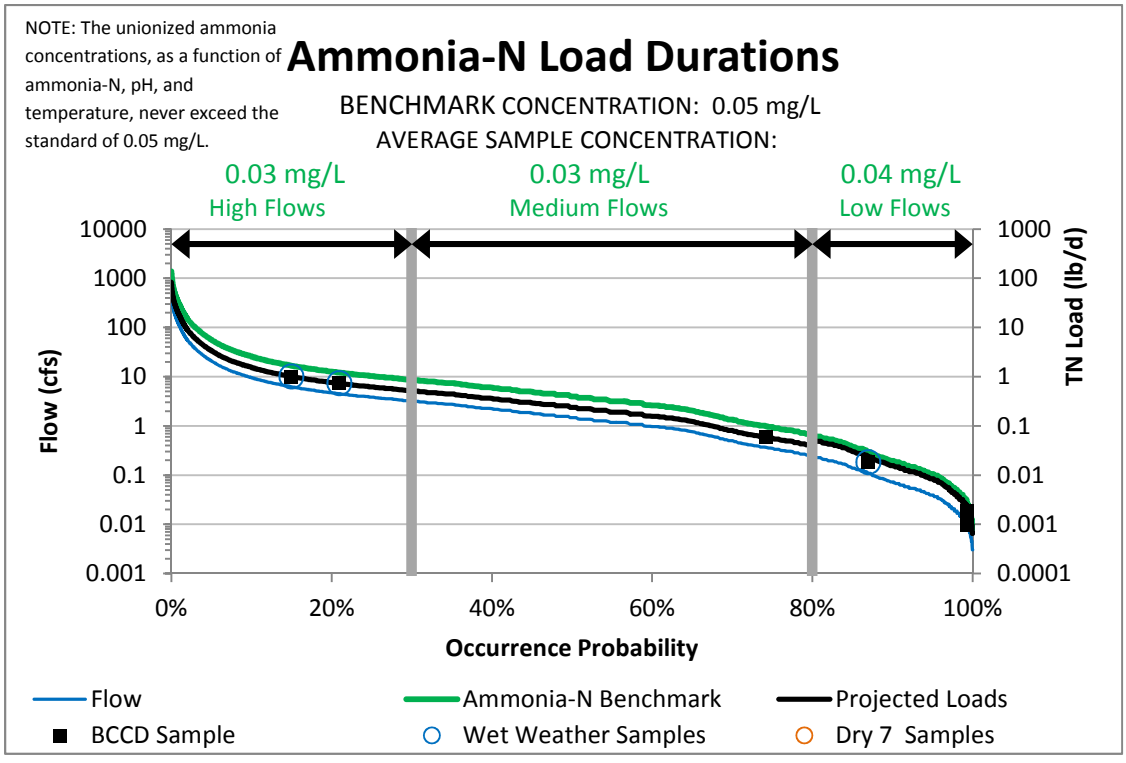
Site: **RDR 1.1** (continued)





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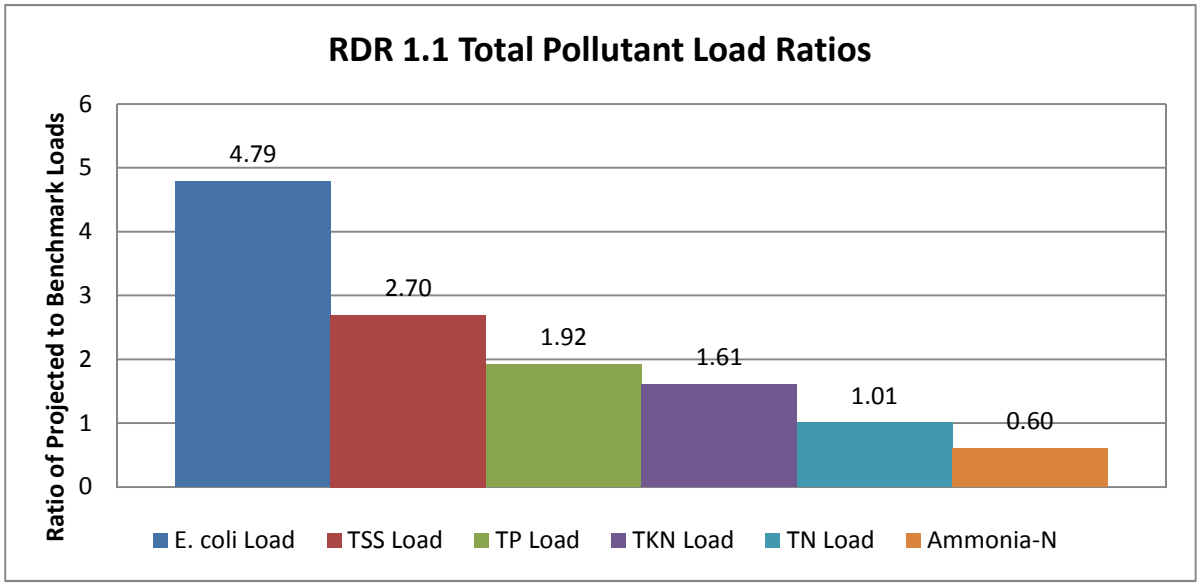
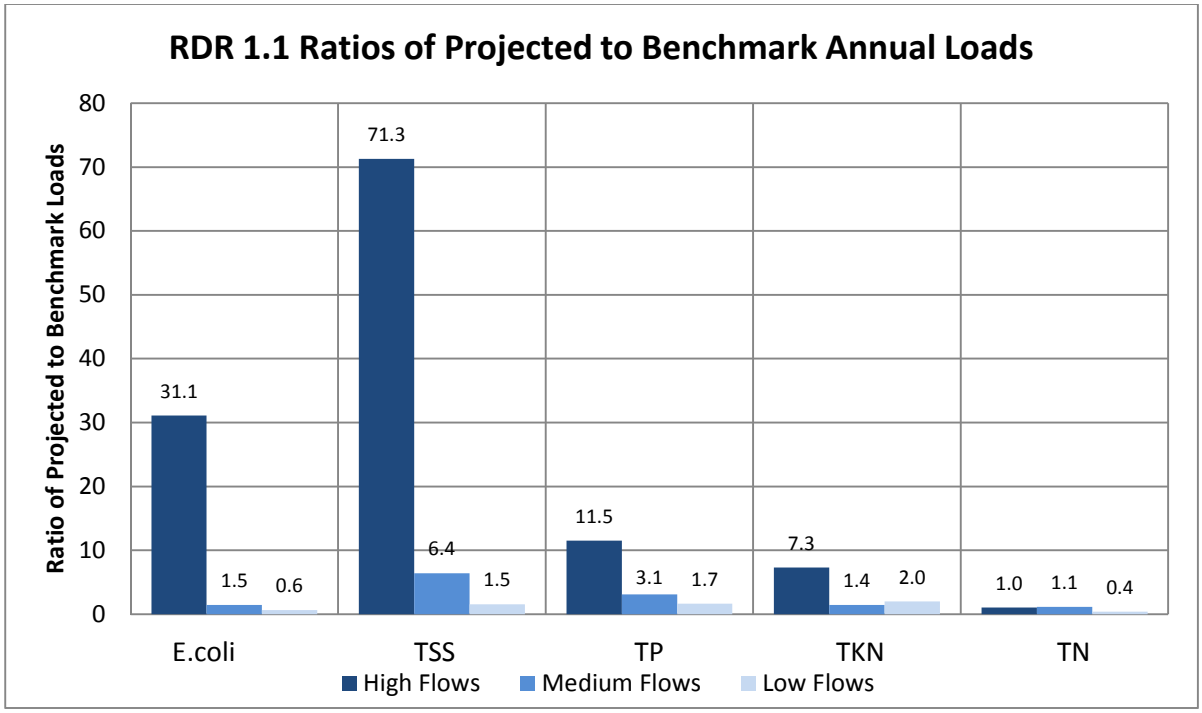
Site: **RDR 1.1** (continued)





NOTE: Ratios greater than 1 are above the benchmark limit set by KDOW benchmarks and ratios less than 1 are below the benchmark limit.

Site: **RDR 1.1** (continued)

CALCULATED ANNUAL LOADS

Flow Category	TOTAL BENCHMARK LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	1.2E+13	77,255	852	3,195	3,195	533
Medium Flows	1.5E+12	9,703	107	402	402	67
Low Flows	3.9E+10	261	2.88	10.82	10.82	1.80
TOTAL	1.3E+13	87,220	962	3,607	3,607	601

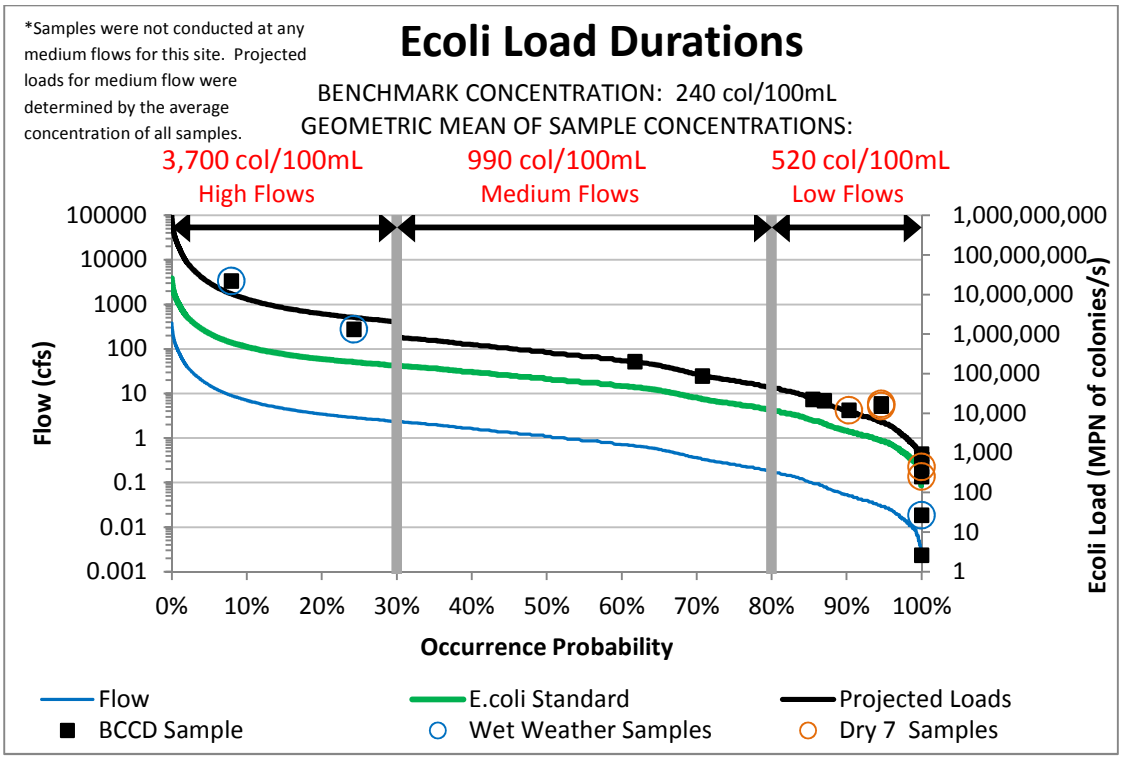
Flow Category	TOTAL PROJECTED LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	5.9E+13	229,635	1,678	5,344	3,490	320
Medium Flows	4.1E+12	5,354	162	442	134	40
Low Flows	5.4E+10	270	4.45	14.62	4.38	1.44
TOTAL	6.3E+13	235,259	1,845	5,800	3,628	361

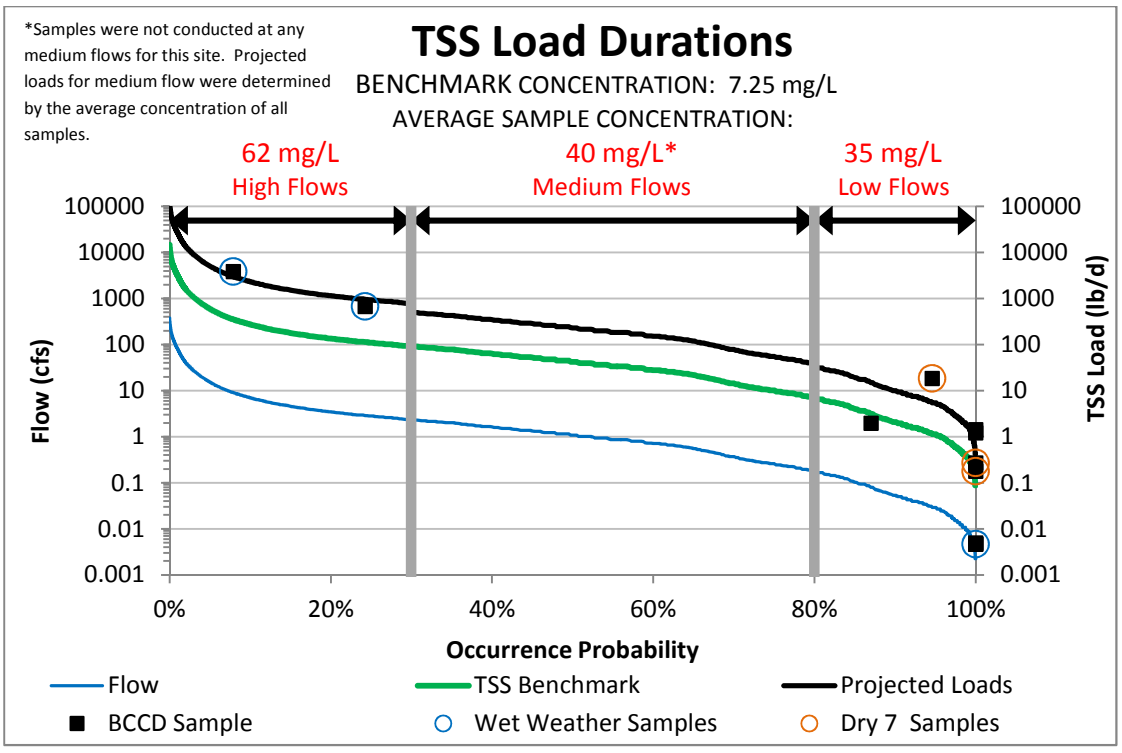
Flow Category	PERCENT DIFFERENCE: ((projected-target)/projected)*100					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/year)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	80%	66%	49%	40%	8%	-67%
Medium Flows	65%	-81%	34%	9%	-200%	-67%
Low Flows	27%	3%	35%	26%	-147%	-25%
TOTAL	79%	63%	48%	38%	1%	-66%

NOTE: The percent difference presented in the above table represents the percent load reduction needed to meet the KDOW water quality benchmark or standard. Negative numbers indicate the projected load is below the target for the pollutant of concern.

Flow Category	**CALCULATED POLLUTANT YIELDS: total projected load/drainage area**					
	E. coli Yield	TSS Yield	TP Yield	TKN Yield	TN Yield	Ammonia-N
	(col/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)
High Flows	2.86E+10	112.3	0.8	2.6	1.7	0.2
Medium Flows	2.02E+09	2.6	0.079	0.2	0.1	0.0
Low Flows	2.64E+07	0.1	0.002	0.0	0.0	0.0
TOTAL	3.07E+10	115.1	0.9	2.8	1.8	0.2

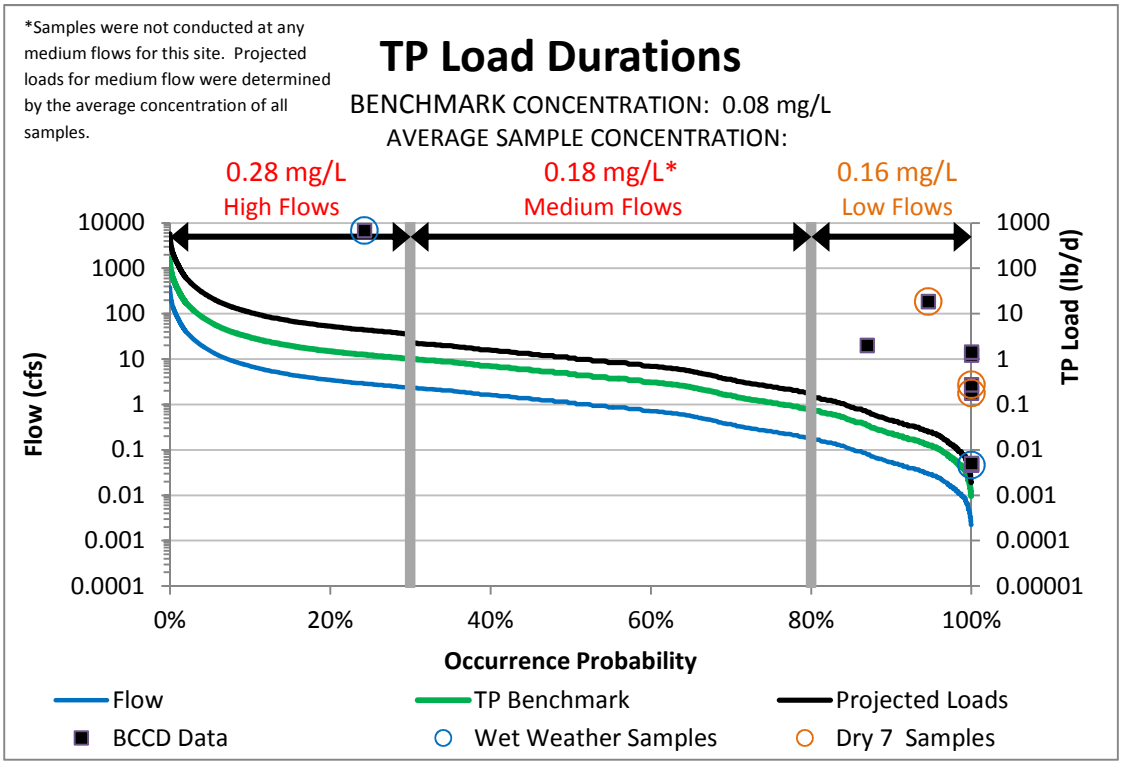
Site: LOB 0.5

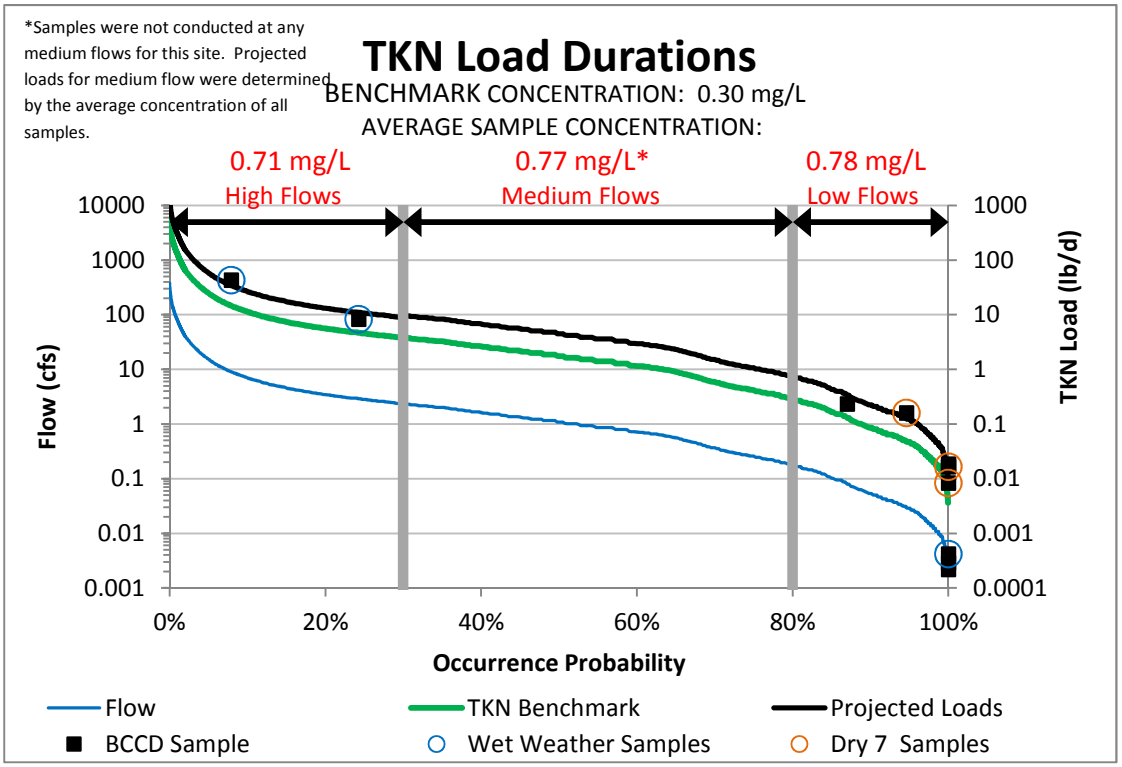




Average Sample Concentration Text:			
> 2x Benchmark	1-2x Benchmark	< Benchmark	

Site: **LOB 0.5** (continued)





Average Sample Concentration Text:			
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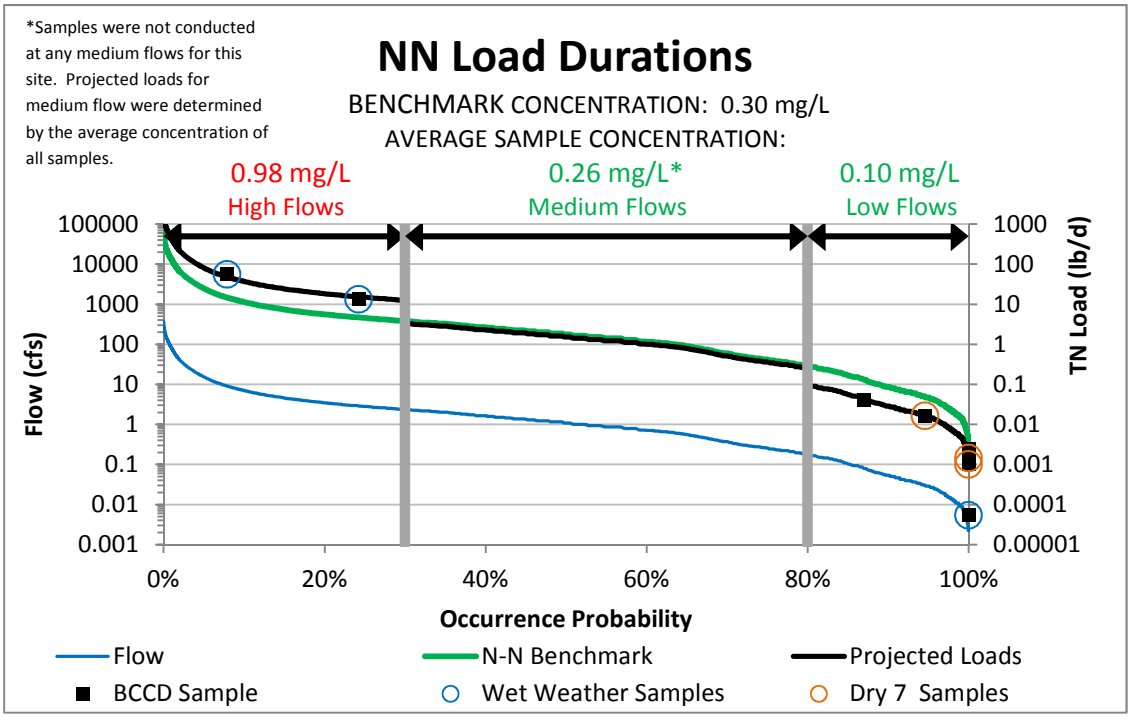
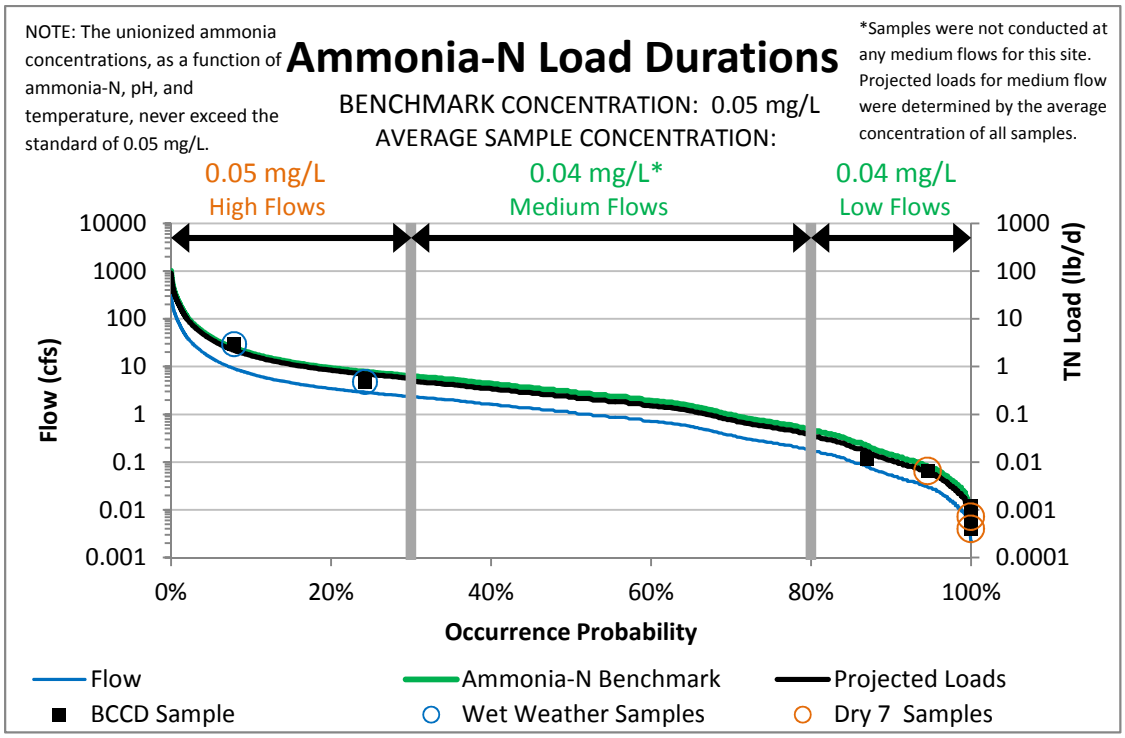
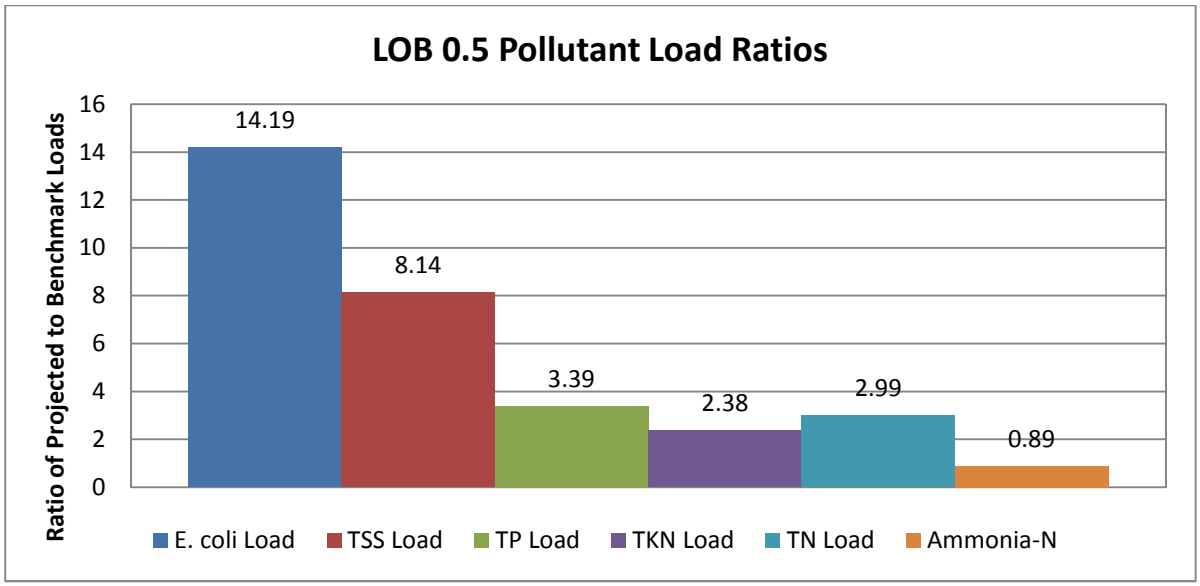
Site: **LOB 0.5** (continued)

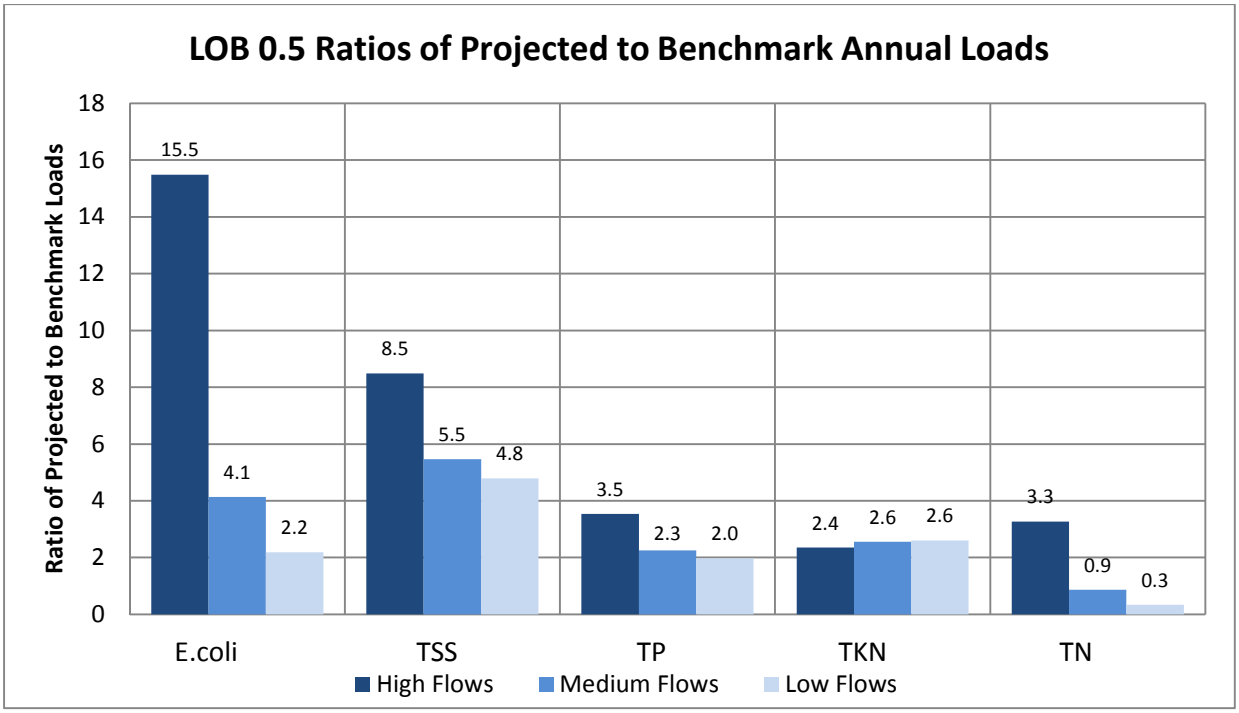




Average Sample Concentration Text:		
> 2x Benchmark	1-2x Benchmark	< Benchmark

Site: **LOB 0.5** (continued)





NOTE: Ratios greater than 1 are above the benchmark limit set by KDOW benchmarks and ratios less than 1 are below the benchmark limit.

Site: **LOB 0.5** (continued)

CALCULATED ANNUAL LOADS

Flow Category	TOTAL BENCHMARK LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	8.5E+12	56,786	626	2,349	2,349	391
Medium Flows	1.1E+12	7,132	79	295	295	49
Low Flows	2.9E+10	192	2.12	7.95	7.95	1.33
TOTAL	9.6E+12	64,110	707	2,652	2,652	442

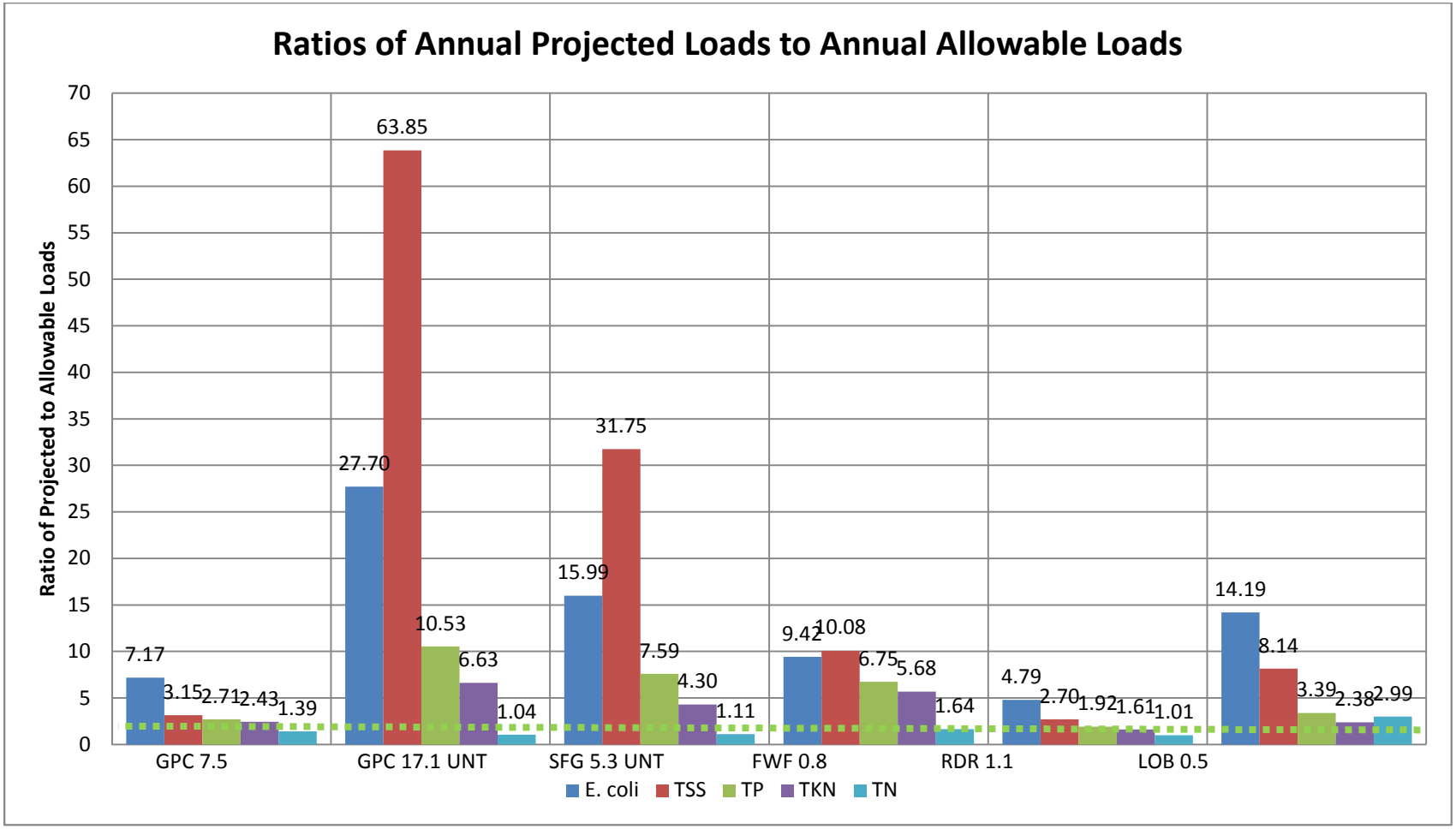
Flow Category	TOTAL PROJECTED LOAD PER YEAR					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	1.3E+14	482,091	2,217	5,526	7,680	352
Medium Flows	4.4E+12	38,983	177	755	256	38
Low Flows	6.3E+10	921	4.17	20.72	2.65	1.00
TOTAL	1.4E+14	521,995	2,398	6,302	7,938	392

Flow Category	PERCENT DIFFERENCE: ((projected-target)/projected)*100					
	E. coli Load	TSS Load	TP Load	TKN Load	TN Load	Ammonia-N
	(col/year)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)
High Flows	94%	88%	72%	57%	69%	-11%
Medium Flows	76%	82%	56%	61%	-15%	-28%
Low Flows	54%	79%	49%	62%	-200%	-32%
TOTAL	93%	88%	71%	58%	67%	-13%

NOTE: The percent difference presented in the above table represents the percent load reduction needed to meet the KDOW water quality benchmark or standard. Negative numbers indicate the projected load is below the target for the pollutant of concern.

Flow Category	**CALCULATED POLLUTANT YIELDS: total projected load/drainage area**					
	E. coli Yield	TSS Yield	TP Yield	TKN Yield	TN Yield	Ammonia-N
	(col/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)	(lb/yr/ac)
High Flows	7.61E+10	277.8	1.3	3.2	4.4	0.2
Medium Flows	2.55E+09	22.5	0.102	0.4	0.1	0.0
Low Flows	3.62E+07	0.5	0.002	0.0	0.0	0.0
TOTAL	7.87E+10	300.8	1.4	3.6	4.6	0.2

Summary of All Sites



APPENDIX 4-D

Pollutant Load Methodology

Gunpowder Creek Watershed Plan

Prepared by the

Gunpowder Creek Watershed Initiative

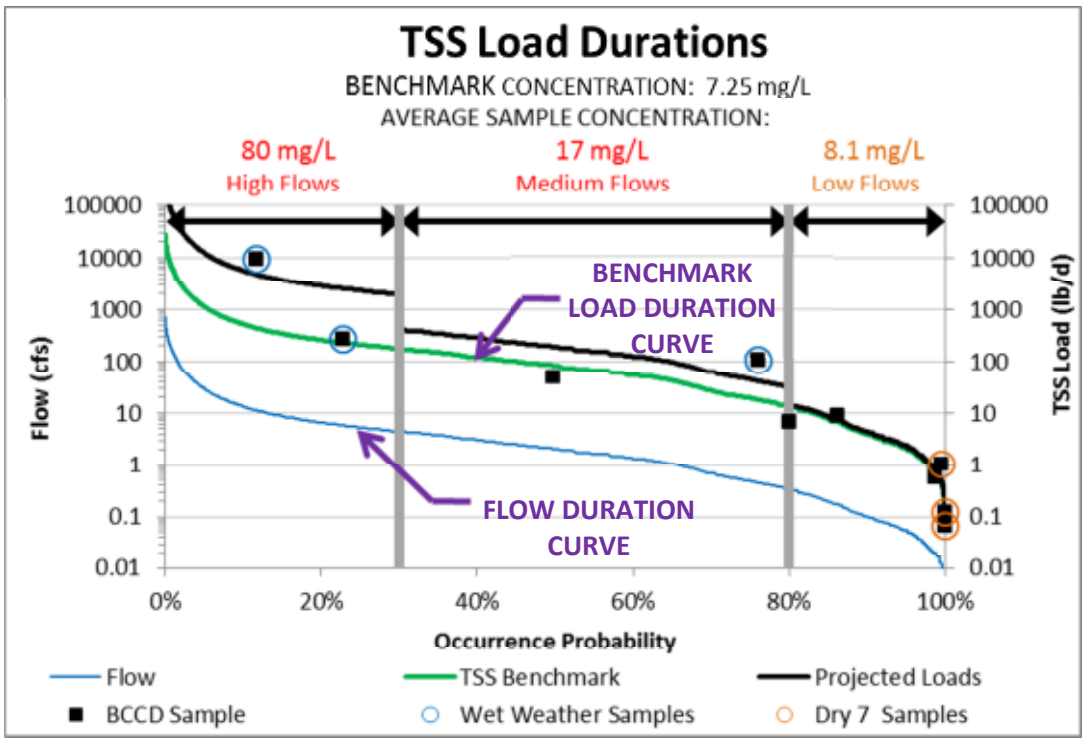
Pollutant load duration curves were used to analyze the relationship between exceedances in water quality benchmarks and flow conditions (e.g. high flow vs. low flow conditions and wet weather vs. dry weather conditions), as well as estimate overall pollutant loads and yields. The methodology used to develop the load duration curves and calculate annual pollutant loads is documented herein. Pollutant loads were calculated utilizing two independent methods and checked by separate reviewers. Therefore, several levels of quality control have been built into the calculations. The first, a step by step method with each flow (steps 1-9 below) is more complex and was utilized to generate the load duration figures. The second method, which involved an averaging approach (step 10 below), served as an independent verification of the first method. The results of both methods were equivalent. While both methods are included herein, the GCWI suggests that KDOW review the averaging approach (step 10). Reference the FWF 0.8 - Load Duration Curves_final.xlsx spreadsheet for the example calculations discussed throughout this document.

1. Instantaneous unit rates of pollutant loads are calculated by multiplying the stream flow at the time of the sample (column BL) by the measured pollutant concentration (column BF). See Column BO of the spreadsheet for this calculation:

   Example TSS load calculation from the wet sampling event on 6/20/2011 (cell BO-10) at site FWF 0.8:

   $$152\frac{mg}{L} \times 11.38\ \frac{ft^3}{s} \times 28.3168\frac{L}{ft^3} \times 86{,}400\frac{sec}{day} \times \frac{1\ lb}{453{,}592\ mg} = 9{,}330\ \frac{lb}{day}$$

2. The duration curve, which shows how long a given flow occurred in a given year, is called a flow duration curve. Each site had its own flow duration curve scaled from a local USGS gage, Gage 03277075 and based on linear regression relationships that were discussed in Section 3.2.4c of the Watershed Plan. The USGS gage flow is included in column E and the scaled flow is calculated in column G. This duration curve is illustrated by the blue line in the load duration figures (columns AJ through AX). The figure below presents an example.



3. Instantaneous benchmark loads for the measured water quality parameters were calculated by multiplying the KDOW-provided benchmark value (row 7 - columns K through P) by the scaled flow values (column G); the green line in the figure above represents this load for Total Suspended Solids (TSS). The calculation below presents an example calculation (see cell L-12) for instantaneous TSS benchmark pollutant load at the 0.00055% occurrence interval. The instantaneous benchmark loads for each flow value are calculated for the parameters in columns K through P.

$$7.25\ \frac{mg}{L} \times 719\ \frac{ft^3}{sec} \times 28.3168 \frac{L}{ft^3} \times 86{,}400 \frac{sec}{day} \times \frac{1\ lb}{453{,}592\ mg} = 28{,}116\ \frac{lb}{day}$$

4. Annual benchmark loads were then determined by summing the instantaneous *annual* benchmark loads calculated by multiplying the instantaneous benchmark load (determined in step 3) by the difference in occurrence probability by 365 days/year. The calculation below presents an example for the instantaneous annual TSS benchmark load at the 0.00055% occurrence interval (cell X-12).

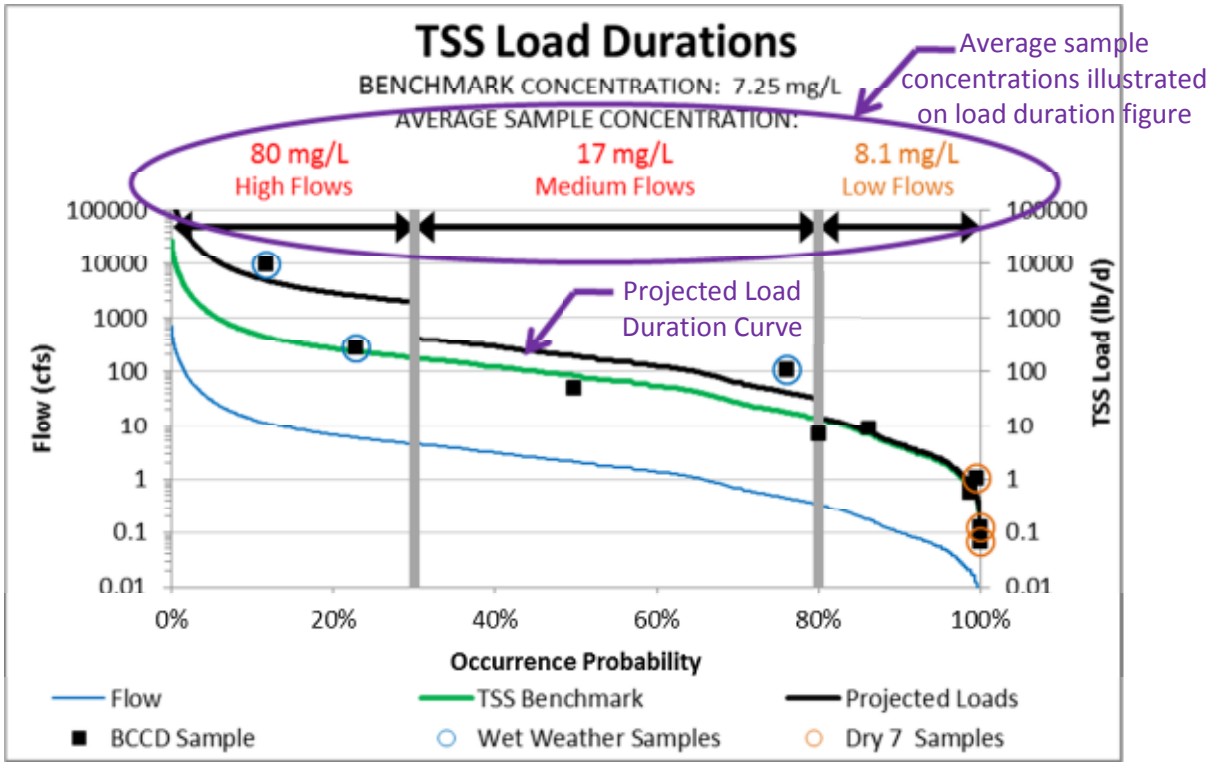
$$28{,}116\ \frac{lb}{day} \times (0.00055\% - 0\%) \times 365\ \frac{days}{year} = 57\ \frac{lb}{year}$$

The annual benchmark load is then determined by summing all of the instantaneous annual benchmark loads. Reference row 7 cells W through AB for this calculation.

5. In this data analysis, samples were divided into bins (i.e., groups) of high flows (occurring 0-30% of the time), medium flows (occurring 30%-80% of the time), and low flows (occurring >80% of the time). The bins were divided at the 30th and 80th percentile flows to facilitate quasi-equally spaced groupings with the goal of having at least a couple of samples in each group and no groups with zero samples. Reference the figure above for the three bins.

6. Because the resources do not exist to constantly measure pollutant concentrations at every sample location for 24 hours a day, 365 days per year, load duration methodologies typically include an averaging step. For this analysis, all concentrations within a given bin (discussed above in step 5) were averaged to calculate the mean concentration for the bin. In the case of E.coli, the geometric mean was used for each bin, as is customary. The concentrations are categorized by the appropriate bins in columns CI through CK. The average concentration values per bin per parameter are included in the table starting in cell CN-40. Reference the table below for an example of TSS concentrations categorized by bin and averaged. Average concentrations are also included in the duration curve figures. Concentrations that are colored red are greater than twice the benchmark level, those colored orange are greater than the benchmark level – but within 1 to 2 times greater, and those colored in green are less than the benchmark level.

						COLUMNS CI THROUGH CK →		
						CONCENTRATIONS (mg/L) CATEGORIZED BY BIN:		
Sample date	Parameter	Result	Units	Flow (cfs)	Occurrence Probability	Bin 1 (0-30%)	Bin 2 (30-80%)	Bin 3 (>80%)
06/20/11	TSS	152	mg/L	11.3778	11.75%	152.0		
06/24/11	TSS	8.67	mg/L	5.8346	22.8%	8.7		
07/07/11	TSS	4.36	mg/L	2.0688	49.8%		4.4	
07/29/11	TSS	9.33	mg/L	0.1732	86.3%			9.3
08/04/11	TSS	42.4	mg/L	0.4524	76.0%		42.4	
08/18/11	TSS	3.75	mg/L	0.3284	80.0%		3.8	
06/22/12	TSS	4.5	mg/L	0.0232	98.76%			4.5
06/28/12	TSS	4.74	mg/L	0.0026	99.99%			4.7
07/10/12	TSS	10.1	mg/L	0.0023	99.99%			10.1
07/23/12	TSS	6.09	mg/L	0.0246	98.76%			6.1
08/07/12	TSS	13.7	mg/L	0.0138	99.6%			13.7
(average concentrations for each bin and parameter are included in the table starting in cell CN-40)								
AVERAGE FOR TSS:						80.34	16.84	8.08



7. The average concentration for each bin was then divided by the benchmark concentration to determine the ratio of the sample concentration to the benchmark concentration. This calculation was determined by bins for each parameter in the table beginning in cell CN-10. For example, the high flow ratio for TSS was calculated by the following equation:

$$80.34\frac{mg}{L}/7.25\ \frac{mg}{L} = 11.08$$

This indicates that during high flows (occurring 0-30% of the time), the projected TSS pollutant load is about 11 times greater than the benchmark load. Numbers less than 1.0 represent pollutant loads that are less than the benchmark load.

8. The instantaneous projected pollutant load was calculated (columns Q-V) by multiplying the instantaneous benchmark pollutant load by the ratio. The calculation below presents an example of this calculation for the instantaneous projected TSS load at the 0.00055% occurrence interval (cell R-12). This instantaneous projected pollutant load is represented by the black line in the figure on the previous page. The projected pollutant loads in the first bin is based on the high flow ratio (11.08 – cell CN-10), the projected pollutant loads in the middle bin is based on the medium flow ratio (2.32 – cell CO-10), and the projected pollutant loads in the last bin is based on the low flow ratio (1.11 – cell CP-10).

$$28{,}116\ \frac{lb}{day} \times 11.08\ = 311{,}500\ \frac{lb}{day}$$

9. Using the same procedure as described in step 4, annual projected loads were determined by summing the instantaneous *annual* projected loads. Instantaneous *annual* projected loads were calculated by multiplying the instantaneous projected load (determined in step 8) by the difference in occurrence probability by 365 days/year. The calculation below presents an example for the instantaneous annual TSS benchmark load at the 0.00055% occurrence interval (cell AD-12).

$$311{,}550\ \frac{lb}{day} \times (0.00055\% - 0\%) \times 365\ \frac{days}{year} = 630\ \frac{lb}{year}$$

The annual projected load is then determined by summing all of the instantaneous annual projected loads. Reference row 7 cells AC through AH for this calculation.

10. INDEPENDENT CHECK OF THE PROJECTED LOAD CALCULATIONS:
The projected load calculations discussed above were also independently checked, beginning in column DC of the spreadsheet. This method involved calculating an average concentration within each bin and multiplying that by the average flow for the bin and the duration of time that occurs within that bin. The following steps were taken to independently check the load calculations.

    a. Determine an average flow for each bin (column DH rows 5 through 8):
        a. The flow durations scaled to the site are included in column DF beginning in row 9, where the flows were converted to cubic feet per day.
        b. Next, the number of days of occurrence for each flow was calculated (column DG) by multiplying the difference in the recurrence intervals by 365 days/year.
        c. The total volume of flow (beginning in cell DH-12) for each recurrence interval is then calculated by multiplying the flow (cubic feet per day – column DF) by the number of days of each recurrence interval (days – column DG).
        d. The total days of occurrence for each bin was summed based on the bins (high flows: 0-30%; medium flows: 30-80%; and low flows: > 80% (column DE rows 6 through 9)). This can also be calculated by multiplying the bin interval by 365 days per year.
        For example, the number of days in each bin is calculated below:

$$High\ Flow:\ 30\% \times 365 = 110\ days$$
$$Medium\ Flow:\ 50\% \times 365 = 183\ days$$
$$Low\ Flow:\ 20\% \times 365 = 73\ days$$

        e. The total volume for each bin was also summed based on the bins (column DF rows 6 through 9).
        f. The average flow for each bin was determined by dividing the total volume by the days in the bin (cubic feet per day - column DG rows 6 through 9). This was then converted to cubic feet per second (column DH rows 6 through 9).

b. Calculate the projected loads for each bin (columns DJ, DM, DP, etc.):
    a. The average concentration from each bin and parameter (as computed in step 6) was copied to columns DI, DL, DO, etc.
    b. The projected load (columns DJ, DM, DP, etc.) for each bin was calculated by multiplying the average concentration (mg/L) by the average flow (cfs) by the total number of days in the bin and a conversion factor. The calculation below presents an example of the annual TSS load for the high flow bin (cell DM-6)

$$80.34\frac{mg}{L} \times 25.28\frac{ft^3}{sec} \times 28.3168\frac{L}{ft^3} \times 86{,}400\frac{sec}{day} \times \frac{1\ lb}{453{,}592\ mg} \times 110\frac{days\ in\ bin}{year}$$
$$= 1{,}200{,}000\frac{lb}{year}$$

c. The projected loads for each bin were then summed to obtain a total projected annual load.

In addition to pollutant loads, yields were also calculated in order to standardize the data by accounting for differences in geographic size between the sub-watersheds. The pollutant yield was determined by dividing each load by the total area of the sub-watershed. These calculations are in columns DK, DN, DQ, etc. Pollutant yields were initially calculated in the *Summary Table* tab of the spreadsheet, and checked in this 'Independent Check' portion of the spreadsheet.

All load duration curve figures, associated annual watershed pollutant loads, and percent load reductions necessary to meet the water quality benchmark are included in the Watershed Plan: Appendix 4-C.

APPENDIX 4-F

Gunpowder Creek Watershed Plan
Benchmark Recommendations
Provided by KDOW

Gunpowder Creek Watershed Plan

Prepared by the
Gunpowder Creek Watershed Initiative

Gunpowder Creek Watershed Plan
Benchmark Recommendations for Non-Nutrient Parameters
Kentucky Division of Water
2/2/12

Consult water quality standards for parameters that have a numeric standard (e.g., pH, dissolved oxygen, unionized ammonia).

In general, for non-nutrient parameters that do not have numeric standards, use the 75th percentile of combined Bluegrass bioregion reference for data screening and prioritization. Individually, ecoregion 71d (Outer Bluegrass) is similar with respect to non-nutrient parameters to the Bluegrass bioregion as a whole (71d, 71k Hills of the Bluegrass, and 71l Inner Bluegrass); therefore, the combined summary statistics provide the best estimate of regional expectations based on reference conditions with the following qualifications/exceptions:

> For TSS and Turbidity, use these reference benchmarks only to compare normal April-October flow conditions and not high flow events or winter samples. The reference stream data came exclusively from biology sampling visits which are conducted only during stable flow conditions during these months. New monitoring data collected for the watershed plan project may identify streams where suspended sediment issues are minimal; if so, then high flow sample events from those streams could be used to derive a high flow screening benchmark.
>
> For Unionized Ammonia, use the WQS of 0.05mg/L as the main benchmark for screening. However, there may be cases where there is a concern for chronic effects to sensitive mussels at lower concentrations of unionized ammonia, especially at higher temperature and pH. If Ammonia-N at a site is routinely higher than 0.1 mg/L, then consult with the KDOW Nonpoint Source Section Technical Advisor (TA) to review the data for that site for potential chronic ammonia issues.

Benchmarks for data screening and prioritization may be lower than those to be used ultimately as targets for reduction in the watershed plan, since reference conditions may be well below reductions necessary to restore uses. Targets for reduction should take into consideration the extent and magnitude of problems as well as achievability. Consult the TA for assistance.

Ecoregional Reference summary

	Ecoregion	Number samples assessed	MIN	MAX	MED	**75th Percentile**	90th Percentile
Ammonia-N (mg/L)	71d	44	<0.025	0.064	0.025-0.050	**0.025-0.050**	0.025-0.050
	BG	117	<0.025	0.069	0.025-0.050	**0.025-0.050**	0.025-0.050
Unionized Ammonia (mg/L)	71d	14	<0.001	0.004	<0.001	**0-0.001**	0.001-0.003
	BG	29	<0.001	0.004-0.007	0.001	**0.001-0.002**	0.002-0.003

	Ecoregion	Number samples assessed	MIN	MAX	MED	**75th Percentile**	90th Percentile
Sulfate (mg/L)	71d	34	10.0	91.7	32.7	**51.0**	64.9
	BG	76	5	112	41.3	**61.05**	81.9
Specific Conductance (µS/cm)	71d	42	141	700	491	**522.5**	606
	BG	108	141	735	459	**509**	581
Alkalinity (mg/L as $CaCO_3$)	71d	31	63.7	256	209	**228**	246
	BG	70	63.7	281	201.5	**220**	240.6
TSS (mg/L)	71d	32	<1.5	43.5	4.0	**7.25**	16.0
	BG	73	<1.5	43.5	4.5	**10**	18.4
Turbidity (NTU)	71d	18	0.6	26.9	3.7	**8.3**	14.2
	BG	44	0.6	26.9	4.2	**8.7**	12.2

Gunpowder Creek Watershed Plan
Benchmark Recommendations for Nutrient Parameters
Kentucky Division of Water
2/2/12

Nutrient benchmarks given here represent the best information available to the Kentucky Division of Water (KDOW) at this time. They are estimates of typical or average in-stream concentrations below which it is unlikely that nutrients are a cause of observed impairments. As such, they are useful in identifying sub-basins with potential nutrient issues when setting priorities for further monitoring or for development of load reduction strategies. In making these recommendations we have considered regional and watershed-specific nutrient expectations, regional-scale patterns in biological effects, and the specific indicators of nutrient enrichment observed in the watershed. These benchmarks may be more stringent than targets to be used ultimately as management endpoints; watershed-specific characteristics, practical considerations, and insight gained from early phase monitoring might suggest alternate values for that purpose. The Watershed Group may wish to discuss with KDOW alternative benchmarks and/or targets based on more detailed local information or consultation with experts familiar with the watershed. A summary of candidate benchmarks is given here along with a final set of recommendations to provide more assistance in interpreting nutrient data.

Ecoregional Reference Reach and watershed reference candidate benchmarks:

Reference Reaches represent the least-impacted conditions for aquatic life available in the respective ecoregions. The Gunpowder Creek watershed is entirely within ecoregion 71d (Outer Bluegrass) and within the larger Bluegrass bioregion. The significance of the regional placement of the watershed is that the phosphorus content of the formations in the Outer Bluegrass are high relative to many ecoregions across the state, but not as high as other parts of the Bluegrass bioregion. Nitrate concentrations also may be influenced by the geologic setting. There are twelve Reference Reaches in 71d. A summary of the nutrient data from these streams (42 samples) is given below.

Segments within the focus watershed or closely comparable watersheds where uses are fully supported can be used as "watershed reference". These need not be Reference Reaches designated by KDOW, as long as they have been assessed as being fully supporting of the most sensitive use, in this case aquatic life, and the assessment has a high level of confidence. Watershed reference data can be useful if watershed-specific characteristics are important in predicting the effects of nutrient enrichment. Eight streams in the general vicinity of the Gunpowder Creek watershed had high-confidence assessments of full aquatic life use support and nutrient data, with a total of 22 combined samples (see summary below). For both sets of samples, the 75th percentile is a conservative estimate of the upper range that minimizes the influence of unusually high values, especially when the number of samples is small.

	Sample set	Number Samples	MIN	MAX	MED	**75th percentile**	90th percentile
TP(mg/L)	71d Ref Rch	42	<0.010	0.249	0.046	**0.075**	0.108
	Watershed ref	22	0.024	0.116	0.069	**0.079**	0.099
NN(mg/L)	71d Ref Rch	44	<0.010	1.390	0.193	**0.343**	0.693
	Watershed ref	22	<0.010	0.704	0.118	**0.288**	0.360
TKN(mg/L)	71d Ref Rch	43	<0.200	1.230	<0.200	**0.301**	0.439
	Watershed ref	22	<0.200	0.533	0.202	**0.329**	0.411
TN(mg/L)	71d Ref Rch	43	<0.200	1.550	0.420	**0.640**	0.965
	Watershed ref	22	<0.200	0.936	0.411	**0.596**	0.674

Effects-based (empirical) candidate benchmarks:

The entire watershed falls within the Bluegrass Bioregion and is not near a boundary. The benchmarks from a KDOW draft bioregional nutrient benchmarks report for the Bluegrass Bioregion are **TP 0.1 mg/L, TN 1.2 mg/L**; however, it is noted that background nutrient concentrations vary widely within the Bluegrass (as discussed above) and the relationships between nutrients and biological integrity are difficult to detect, compared to other bioregions. It is especially important in the Bluegrass to modify bioregional benchmarks using information from the local watershed and similar nearby watersheds.

Literature values

TP 0.1 mg/L is often cited as an upper threshold for preventing nuisance algae growth, which is one of the indicators of impairment observed in the Gunpowder Creek watershed. The figure is near the upper range found in 71d Reference Reaches and in streams observed to be fully supporting aquatic life use in the more specific area near this watershed. Literature guidelines for the boundary between oligotrophic and mesotrophic conditions are TP 0.025 mg/L and TN 0.700 mg/L. The boundary between mesotrophic and eutrophic conditions are given as TP 0.075 mg/L and 1.5 mg/L. Reference Reaches and watershed reference data summarized above places those streams near the mesotrophic boundary in terms of TN and near the eutrophic boundary in terms of TP. Maintaining or restoring levels near these boundaries may minimize nuisance algae problems and the effects on aquatic life.

Final benchmark recommendations:

Total P	0.08 mg/L
TKN	0.3 mg/L
Nitrate-Nitrite-N	0.3 mg/L
Total N	0.6 mg/L