Appendix A: Water Quality Data Report – Juanita Creek Stormwater Retrofit Project

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King County
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EXECUTIVE SUMMARY

As part of the Juanita Creek Stormwater Retrofit planning project, a water quality monitoring study was designed to assess current baseflow and stormwater quality in Juanita Creek and support the development of a watershed hydrologic and water quality model. Water quality samples were collected during seven storm events and three base flow events over a period of 14 months – October 2008 to November 2009 from eight stations. Over the same time period, continuous (15-minute) monitoring of stream flow was conducted at six sites and four of these sites also recorded continuous water temperature.

Evaluation of previous monitoring data by the Washington State Department of Ecology has resulted in listing Juanita Creek as having impaired beneficial uses for aquatic life based on data for dissolved oxygen and water temperature, and impairment of beneficial uses for humans based on data for fecal coliform bacteria – an indicator of the potential presence of human pathogens. Data collected for the Juanita Creek Stormwater Retrofit planning project are consistent with those listings. However, this study also found levels of pH, copper and zinc that exceed state water quality criteria for the protection of aquatic life.

Dissolved oxygen (DO) concentrations were below the applicable state criterion of 9.5 mg/L during both base and storm events. Twenty-six of the 52 samples collected from the baseflow events and 64 of the 142 samples from storm events had DO values below 9.5 mg/L. The wetland sites, 4GI (wetland inlet) and 4GO (wetland outlet), had the lowest DO concentrations during baseflow events. Dissolved Oxygen concentrations during sampled storms were typically lower at more locations than during baseflow events. All of the Storm 6 (10/16-17/2009) event samples had DO levels below the criterion with concentrations ranging from 0.7 to 3.8 mg/L. It is unknown at this time if the data collected during Storm 6 was due to an equipment problem or a flushing occurrence that happens at the first fall storm.

The water temperature data collected as part of this study are a combination of grab samples and continuous sensor probes at stream flow gauge locations. The temperature criteria are based on the 7-day average of the daily maximum temperature. At the four sites with continuous temperature data the number of days that the ore Salmonid Rearing criterion of 16.0 °C was exceeded ranged from 35 to 128 days. The largest number of days that the temperature criterion was exceeded was at Station 27J-6G on Upper Juanita Creek. The Supplemental Spawning criterion of 13.0 °C applies only to the mainstem of Juanita Creek. The temperatures measured on the mainstem of the creek exceeded this criterion for a total of 56 days. The grab (discreet) data was collected at all sites and supports the continuous temperature data.

The pH data for all baseflow and storm events were within the state criteria of greater than 6.5 and less than 8.5 except for five storm samples. Four samples were below the criterion of 6.5 at sites 5GF and 4GI. A result of 13.9 from site 5GF during Storm 6 appears to be anomalous when compared to the total dataset of 142 storm samples whose values ranged from 6.3 to 8.0.

Fecal coliform were detected in all baseflow and storm event samples. The state criteria are based on the protection of Extraordinary Primary Contact Recreation use. The criteria are that

the geometric mean of the samples from a particular location not exceed50 CFU/100 mL[1] and that not more than 10 percent of all the samples from a site exceed 100 colonies per 100 mL. The geometric mean of all baseflow samples was 64 CFU/100ml while the geometric mean of all storm event samples was 765 CFU/100ml. Both of these results are above the Extraordinary Primary Contact Recreation criterion of 50 CFU/100ml. Storm 5 (August 10-11, 2009) had the highest geometric mean of all sampled storms with 3,823 CFU/100ml and site 6G had the highest geometric mean of all sites with 2,479 CFU/100ml and a peak concentration at site 5GF of 23,000 CFU/100ml. For the baseflow sampling events, the June 20, 2009 event had the highest geometric mean value with 204 CFU/100ml and site 6G had the highest geometric mean of all sites with 622 CFU/100ml.

For dissolved metals (copper and zinc), no baseflow event samples exceeded either the acute or chronic criteria. However, of the 142 observed storm event dissolved copper concentrations measured during the study, two exceeded the acute criterion and 12 exceeded the chronic criterion. Similarly, six of the 142 measured storm event dissolved zinc concentrations exceeded the chronic and acute criteria. Moreover, the storm events and site locations with exceedances for dissolved zinc were different than the sites where exceedances of dissolved copper criteria were observed.

In general, the data collected were of sufficient quality to support the development of a watershed hydrologic and water quality model that can be used to evaluate the effectiveness of various stormwater retrofit strategies in improving water quality and quantity conditions in the Juanita Creek watershed.

[1] Fecal coliform concentrations are reported as numbers of colony forming units or CFU per 100 millilters (mL).

1.0. INTRODUCTION

King County Department of Natural Resources and Parks have entered into a partnership with City of Kirkland and Washington State Department of Transportation for a Washington State Ecology grant to investigate potential benefits of retrofitting the storm water system in the Juanita Creek basin. This basin is almost completely developed with residential and commercial land uses, and drains to Juanita Bay on the northeastern shore of Lake Washington (Figure 1).

Land use in the basin is comprised of mostly residential and commercial developments (including a major interstate freeway corridor, I-405), two relatively large forested wetlands, and one small lake (Totem Lake) receiving storm water runoff from a large portion of the commercial development in the eastern headwaters of the basin.

Evaluation of previous monitoring data by the Washington State Department of Ecology has resulted in listing Juanita Creek as having impaired beneficial uses for aquatic life and human recreational use. The listings for these impairments are based on data for dissolved oxygen (DO) and water temperature (aquatic life use impairment) and on data for fecal coliform bacteria[2] (human recreational use impairment). As part of the Stormwater Retrofit grant, watershed models will be developed to characterize the hydrologic regime and water quality for existing conditions and future conditions with retrofits targeted to improve Juanita Creek stream habitat and beneficial uses. This report describes the results of a water quality monitoring study that will be used to support the development and calibration of the watershed models and provide a snapshot of existing water quality conditions for a range of parameters over a number of locations within the basin.

1.1 Goals and Objectives

Monitoring of water quality conditions occurred over a 14 month period starting in October 2008 and ending in November 2009. The goal was to measure conditions during all four seasons during storm and non-storm (i.e. baseflow) events. This design was intended to capture the seasonal variability in concentrations for a number of constituents from variable size storms during different times of the year and during periods when streamflows were predominantly driven by shallow groundwater contributions (i.e., baseflow conditions).

Parameters analyzed in the field during baseflow and storm event sampling events included dissolved oxygen, pH, temperature, and specific conductance. Continuous (15-minute) temperature measurements were also made at a subset of the sampling sites. Samples collected in the field were also taken back to the laboratory for analysis of nutrients, alkalinity, biochemical oxygen demand, total and dissolved organic carbon, chlorophyll a, fecal coliform bacteria, and total and dissolved trace metals (copper and zinc). Nutrient analyses included ammonia nitrogen, nitrate plus nitrite nitrogen, total nitrogen, orthophosphate phosphorus, and total phosphorus. Stream gages were also established to continuously (15-minute interval) measure water levels (which were then converted to flow rates) and temperature.. Additionally, calcium and magnesium concentrations were measured so that hardness could be calculated for

[2] Fecal coliform bacteria are used as an indicator of the potential presence of human pathogens that include pathogenic bacteria and viruses.

use in the equations that accounts for the effect of hardness on dissolved metal toxicity. Further details of this study design can be found in the Quality Assurance Project Plan and Sampling and Analysis Plan developed as part of this grant (King County 2008).

The results of this study are used to meet the objectives of this grant by: 1) characterizing existing conditions and 2) provide the necessary level of spatial and temporal stream conditions to support development of a predictive watershed model to be used to evaluate benefits resulting from various stormwater retrofitting strategies.

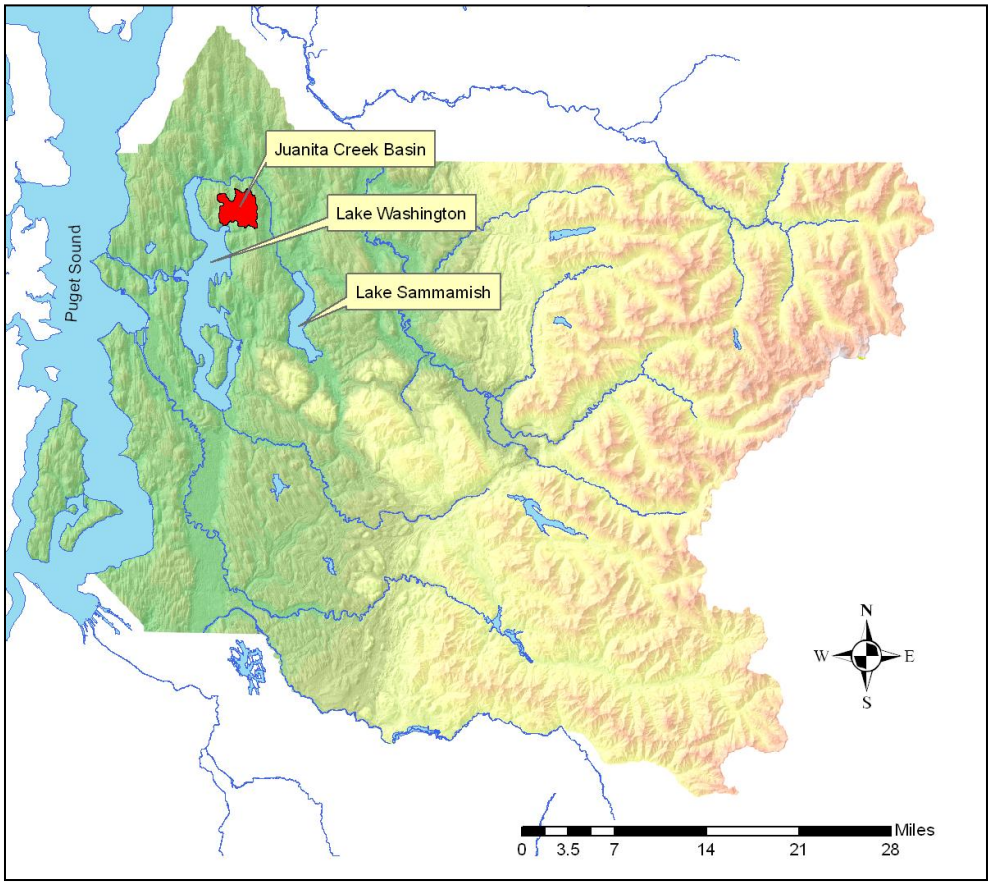

Figure 1. Map showing the location of the Juanita Creek basin in King County.

2.0. WATER QUALITY CRITERIA

Water quality criteria for surface waters are established to protect public health and maintain the public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife as defined by Washington Administrative Code (WAC) 173-201A. As defined by code, beneficial uses include maintaining the quality of potable water and water essential to farming activities, preserving aesthetic values, and providing adequate water quality for aquatic life (fish and wildlife).

The federal Clean Water Act, adopted in 1972, requires that all states restore their waters to be "fishable and swimmable." Section 303(d) of the Clean Water Act established a process to identify and clean up polluted waters. Every two years, all states are required to perform a *water quality assessment* of the quality of surface waters in the state, including all the rivers, lakes, and marine waters where data were available. As noted in Section 1.0, Juanita Creek has 303(d) listings for dissolved oxygen, water temperature, and fecal coliform.

The criteria that apply to Juanita Creek and that are used in this report are adopted by the state of Washington (WAC 173-201A-200) and are shown in Table 1.

Table 1. Water quality criteria for surface water in Washington State — WAC 173-201A.

Parameter	**Water Quality Criteria**	
	Core Rearing and Migration	Supplemental Spawning
Temperature[a]	16.0 °C	13.0 °C
Dissolved Oxygen[b]	9.5 mg/L	
pH	Range of 6.5 to 8.5	
	Extraordinary Primary Contact Recreation	
Fecal Coliform[c]	50 CFU/100 ml	
	Acute	Chronic
Ammonia[d]	24.1 mg/L	2.1 mg/L
Copper (dissolved)[e]	8.7 µg/L	9.3 µg/L
Zinc (dissolved)[e]	62.6 µg/L	85.6 µg/L

[a] = Temperature values shall not exceed these criteria based on the 7-day average of the daily maximum temperature. Supplemental Spawning criterion applies to the period from September 15th to May 15thas defined in Waters Requiring Supplemental Spawning and Incubation Protection For Salmonid Species (Ecology, 2011).

[b] = Dissolved oxygen values shall not be less than this criterion.

[c] = Fecal coliform bacteria concentrations should not exceed a geometric mean value of 50 CFU/100 mL and no more than 10 percent of the samples should exceed 100 CFU/100 mL. Or if less than 10 samples, no sample shall exceed 100 CFU/100 mL.

[d] = Formula based criteria – numbers shown are based on salmonids present with temperature 15° C and pH of 7.0. see WAC 173-201A for formula.

[e] = Formula based criteria – numbers shown are based on average hardness of 49.1 mg/L for storm events used in the acute criteria and an average hardness of 79.0 mg/L for baseflow events for the chronic criteria. see WAC 173-201A for formulas.

Units: C: Celsius; µg/L: microgram per liter; mg/L: milligrams per liter; CFU/100ml: colony forming units per 100 milliliters

3.0. STUDY DESIGN AND METHODS

Data were collected at a number of locations (eight in total) during storm and non-storm events which can be grouped into three categories: 1) continuously recording instruments during the entire study period, 2) parameters that were measured in the field, and 3) lab analyses performed on grab samples taken at each of the monitoring stations. Samples were collected during seven storm events over the course of two wet seasons and three base flow events within the same water year over a period of 14 months.

3.1.1 Sampling Locations

Locations of sample collections were located on all five major tributaries near the confluence with Juanita Creek main stem, and near the mouth of the basin itself. These six locations have an associated continuously measuring flow gauge site nearby (Table 2 and Figure 2). Two additional water quality sampling locations were added to assess a significantly large wetland that receives runoff from a commercial business district (i.e. shopping mall) via a small lake and neighboring high density residential development (Table 2 and Figure 2).

3.1.1.1 Continuous Temperature

Four of the six gauge locations had continuous (15-minute) temperature recorders (Table 2). Temperature data collection started in late October 2008 for the three upper Juanita Creek tributaries sites. Juanita Creek site (27a) near the mouth is an existing monitoring site and has had temperature and flow measured since 2003.

3.1.2 Sampling Criteria

Criteria for initiating sampling during storm and baseflow events are described below.

3.1.2.1 Storm Events

Sampling events for a storm were determined using a few considerations; 1) was the lab available for receiving samples collected, 2) when was the last storm sample collected, and 3) was the forecast predicting a storm of 0.25 inches (or greater) in 24 hours. When all three conditions were met and the storm forecast remained at 0.25 inches or greater, sampling would begin at the onset of rainfall. However, since the total amount of rainfall during the sampled storm could not be known until sampling was completed; two storms did not ultimately result in more than 0.25 inches of rainfall. Samples were collected and used in those situations. During the storm event, the intention was to collect three grab samples representing the beginning, middle, and end of the storm. However, some storms were either too short in duration to collect the third sample and/or technical difficulties with equipment reduced the number of samples.

3.1.2.2 Baseflow Events

Baseflow sampling targeted periods during which no precipitation had occurred within at least 3 days. Baseflow events were scheduled events that could have been delayed if these antecedent conditions changed. Three sampling events were planned to occur; one sampling event in each of three seasons: fall, winter, and summer.

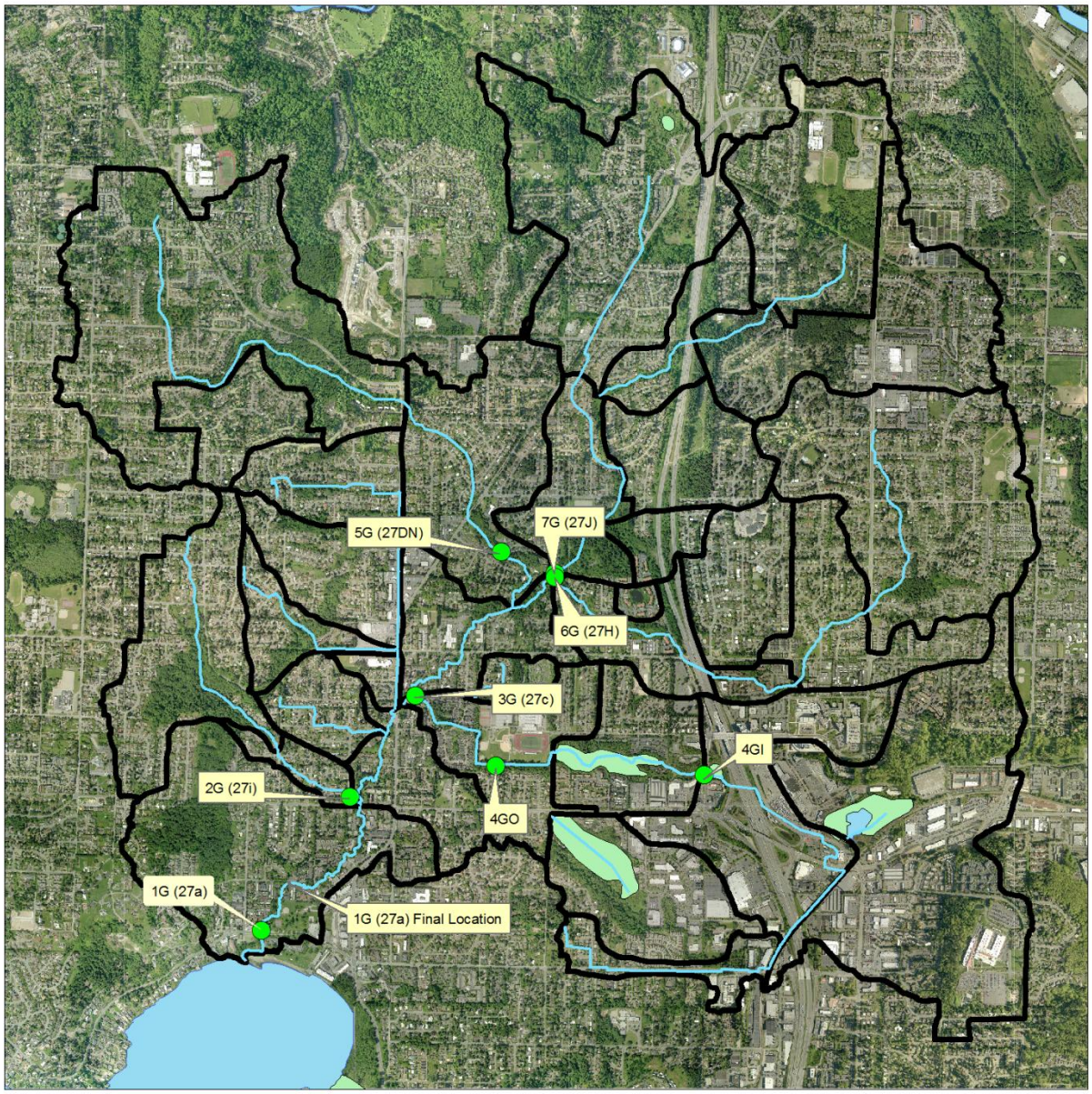

Figure 2. Map showing water quality and stream gauging locations within Juanita Creek Basin.

Note: The eight water quality sites are labeled. The six gauge locations are also designated with the site id in parenthesis with an example given: 1G (27a) for water quality site — 1G at or near gauge — 27a.

Table 2. Monitoring locations for water quality sampling and stream gauging.

Locator	Site Description	Gauge Sites	
		Flow	**Temperature**
J446_1G	Juanita Creek, at mouth	27a	27a
J446_2G	Lower Juanita trib - west	27i	No temperature
J446_3G	Lower Juanita trib - east	27c	No temperature
J446_4GI	Wetland Entrance	No flow gauge	No temperature
J446_4GO	Wetland Exit	No flow gauge	No temperature
J446_5GF	Upper Juanita - west trib	27dn	27dn
J446_6G	Upper Juanita - east trib	27h	27h
J446_7G	Upper Juanita - central trib	27j	27j

Baseflow samples were collected twice in one day at the eight sampling sites. Once in the morning (goal of within 1-hour of sunrise), and once in the early evening (target 5:pm)—such that if there were any consistent indications of potential diurnal variation present, this timing of sample collection might capture some aspect of it.

3.1.3 Sampling Methods

Sampling methods included the use of in situ probes capable of making instantaneous readings within the water column in the field, and grab samples that were collected and then transported to the King County Environmental Laboratory (KCEL) for analysis. With either method, consistent sample handling procedures were necessary to maintain sample integrity and provide data that is as defensible and as high a quality as possible under the sampling conditions. Details of the sampling methods used are provided in King County (2008).

3.1.3.1 Field Measurements

Field measurements for temperature, dissolved oxygen, specific conductance, and pH using Hydrolab sondes was be done according to KCEL SOP # 205v4 (Field Measurement using an Attended Hydrolab – (see King County 2008).

3.1.3.2 Grab Samples

Samples were collected from the thalweg, within free-flowing stream sections, and away from channel boundaries. Where access was from a bridge or roadway because of loss of access, the sample was collected from the upstream side. These procedures are described in KCEL Standard Operating Procedure 214v3 (see King County 2008).

Field filtration was done for dissolved metals and nutrients. Filtration occurred within 15 minutes of sample collection.

4.0. RESULTS

This section summarizes the data collected from October 2008 through November 2009 – 14 month period. The results are summarized separately for baseflow and storm sampling events. An overall summary of the conditions experienced sampling events is provided (Summary of Events) and then results are summarized by the type of measurement (Field vs. Laboratory).

4.1 Summary of events

A total of three baseflow events and seven storm events were collected (Table 3). Figure 3 provides a graphical representation of the precipitation, flow and timing of sampling events.

4.1.1 Baseflow events

The baseflow events were conducted on October 28, 2008, January 20, 2009 and June 10, 2009. A summary of these events are presented in Table 3. These represent different time periods (fall, winter, spring/summer) as outlined in King County (2008). The criteria outlined in section 3.1.2.2 were met before each base flow event.

The collection of the samples were taken over two time periods during the same day with the initial set of samples during the morning and the second set of samples were taken in the late afternoon. Each event was to have one field replicate collected, although this was not always the case as described below. In total, 51 samples were collected during baseflow events (Table 3).

4.1.2 Storm events

Storm samples were collected from seven events from February through November 2009. Table 3 presents a summary of the storm events and their sample collection details.

Three of these events did not collect three rounds of samples as outlined in the QAPP (King County 2008). Storm 1 only had one round of samples with no field replicate due to the lack of sufficient precipitation. This storm did not track as predicted with less rainfall occurring within the basin. Storms 2 and 4 only had two rounds of sample collection for similar reasons. In total, 142 samples were collected during storm events (Table 3).

4.2 Field Measurements

Field measurements for temperature, dissolved oxygen, specific conductance, and pH were done using calibrated Hydrolab sondes. Temperature was also measured continuously at four of the six gauge locations.

4.2.1 Baseflow Events

The baseline data of field parameters do show some variability depending on the parameter and the season of sample collection (Table 4, Table 5 and Appendix 1). Washington State does have surface water quality criteria for three of the four field parameters collected, Table 1.

Table 3. Summary of baseflow and storm sampling events and sample collection details.

Events	Collect Date	Samples Collected^	Sample Duration^{o}	Rainfall total (in)$^{\bullet}$	Max flow (cfs)*
Base 1	10/28/2008	2 rounds - 0 FREPs (16)	4 hours	0.00	2.9
Base 2	1/20/2009	2 rounds - 2 FREPs (18)	4 hours	0.00	6.5
Base 3	6/10/2009	2 rounds - 1 FREPs (17)	4 hours	0.00	3.4
Storm 1	2/25/2009	1 round - 0 FREPs (8)	3.5 hours	0.14	29.7
Storm 2	3/14/2009	2 rounds - 1 FREPs (17)	6 hours	0.06	21.5
Storm 3	5/04-5/05/2009	3 rounds - 2 FREPs (26)	12 hours	1.08	100.6
Storm 4	5/13-5/14/2009	2 rounds - 2 FREPs (18)	7 hours	0.11	17.3
Storm 5	8/10-8/11/2009	3 rounds - 2 FREPs (26)	12 hours	0.40	18.1
Storm 6	10/16-10/17/2009	3 rounds - 2 FREPs (26)	10.5 hours	0.30	43.8
Storm 7	11/16-11/17/2009	3 rounds - 1 FREPs (25)	12.5 hours	0.92	71.4

^ = refers to total number of samples collected during an event in parenthesis. Storm events were planned to have 3 rounds with 2 field replicates (FREPs) with a total of 26 samples. Baseflow events were scheduled to have 2 rounds of samples with 1 field replicate for a total of 17 samples.

^{o} = refers to total time during sample collection.

$^{\bullet}$ = refers to total rainfall during sample collection.

***** = refers to maximum flow measured at gauge 27a (mouth of Juanita Creek) during the sample duration.

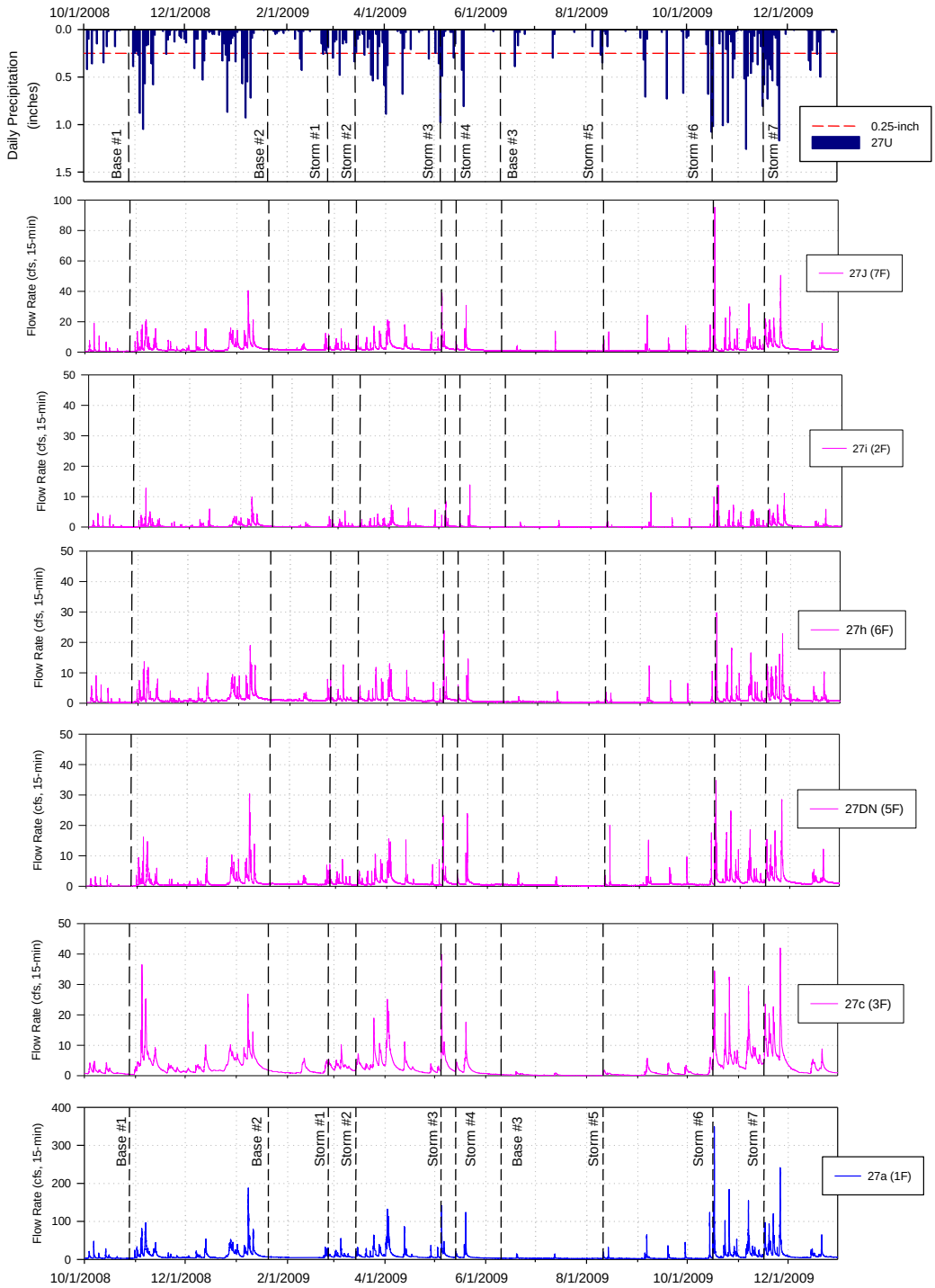

Figure 3. Summary of daily accumulated precipitation, 15-minute flow rates, and timing of sampling events.

Note: Gage flow data are 15 minute intervals while precipitation are daily totals..

4.2.1.1 Dissolved Oxygen

Dissolved oxygen data collected during base events ranged from 0.7 to 14.2 mg/L with an average value of 9.1 mg/L. All sites had at least one measured DO level below the state criterion of 9.5 mg/L (Table 5 and Table 1). The DO data from all sites show a pattern of greatest values during the winter event (01/20/2009) and the lowest values during the spring/summer event (06/10/2009). Almost all of the DO data from the spring/summer base event were below the 9.5 mg/L criterion. DO concentrations measured at Station 4GI were all below 4.0 mg/L. In total, 27 of the 52 baseflow event samples had DO values below the state criterion of 9.5 mg/L (Table 5, Table 1, and Appendix 1).

4.2.1.2 Temperature

Temperature data were collected by grab (discreet) and continuous methods. The state criterion for stream temperature is based on a 7-day average of daily maximum temperatures (7-DADMax) (Table 1). Continuous temperature data were collected at four of the six gauge sites (Table 2). Continuous temperature data collection started at the three upper tributary gauge sites in late October 2008 and continuous temperature data has been collected at the the gauge site at the mouth since 2003. At the four sites with continuous temperature data the number of days that the Core Salmonid Rearing criterion of 16.0 °C was exceeded ranged from 35 to 128 days (Table 6 and Figure 4). The largest number of days that the temperature criterion was exceeded was a Station 27J-6G on Upper Juanita Creek (Figure 4).

Juanita Creek also has a Supplemental Spawning temperature criterion for the mainstem of 13° C assessed from September 15th until May 15th (Ecology, 2011). Two periods of assessment were done during this 14 month study. They are: 9/15/2008 to 05/15/2009 and 9/15/2009 to 11/30/2009. The Supplemental Spawning criterion does not apply to the upper tributaries of Juanita Creek, but these stations were included in this assessment due to their potential influence on the mainstem reach of the creek. During the first period, 9/15/2008 to 05/15/2009, two sites (27a and 27h) had 7-DADMax that exceeded the standard of 13 °C (Table 6 and Figure 4). During the second period of assessment from 9/15/2009 to 11/30/2009, all four sites had at least 18 days over the standard with site 27h (6G) having the most (29 days) (Table 6 and Figure 4).

The grab (discreet) data was collected at all sites and supports the continuous temperature data findings. The temperature data collected during base events ranged from 2.5 to 19.7 °C with an average value of 9.8 °C. This temperature data also showed a pattern which is opposite of the dissolve oxygen with lowest values occurring the winter event and highest values during the spring/summer event (Table 5). This pattern is consistent with the seasonal variation observed in the continuous temperature data. Lower temperatures in the morning and higher temperatures in the evening sample (see Table 5) are also consistent with the diel variability observed in the continuous temperature data. Every sample collected during the afternoon round during the spring/summer base event (06/10/2009) had temperatures over 16 °C (Table 5).

Table 4. Summary of base event water quality for all parameters. *State water quality criteria are presented in table 1.

PARMNAME	Avg-result	Min	Max	StDev	Total Samples	Detected	MDL	UNITS	threshold exceed
Ammonia Nitrogen	0.04	0.01	0.34	0.07	51	41	0.005	mg/L	**0**
Biochemical Oxygen Demand	4.02	2.88	5.16	1.61	51	2	2.0	mg/L	N/A
Calcium, Total,	16,251.0	12,100	21,500	2,264.5	51	51	10	ug/L	N/A
Chlorophyll a	1.03	0.51	3.06	0.61	51	17	0.5	ug/L	N/A
Copper, Dissolved	0.82	0.33	2.67	0.38	51	50	0.1	ug/L	**0/0**
Copper, Total	1.05	0.39	2.57	0.57	51	51	0.1	ug/L	**0/0**
Dissolved Organic Carbon	4.19	1.93	7.39	1.25	51	51	0.5	mg/L	N/A
Fecal Coliform	276.31	1.00	5,000	722.0	51	51	>1	CFU/100ml	**51***
Hardness, Calc	79.0	50.7	109	17.2	51	51	0.066	mg CaCO3/L	N/A
Magnesium, Total	9,331.0	4,950	15,400	3,039.2	51	51	10	ug/L	N/A
Nitrite + Nitrate Nitrogen	1.00	0.02	2.53	0.70	51	50	0.01	mg/L	N/A
Orthophosphate Phosphorus	0.03	0.01	0.09	0.02	51	51	0.002	mg/L	N/A
Pheophytin a	1.86	1.60	2.12	0.25	51	4	1	ug/L	N/A
Total Alkalinity	79.0	50.40	108	16.08	51	51	1	mg CaCO3/L	N/A
Total Nitrogen	1.23	0.26	2.68	0.67	51	51	0.05	mg/L	N/A
Total Organic Carbon	4.45	1.77	8.84	1.49	51	51	0.5	mg/L	N/A
Total Phosphorus	0.059	0.02	0.17	0.03	51	51	0.005	mg/L	N/A
Total Suspended Solids	3.60	0.50	18.0	4.00	51	46	0.5	mg/L	N/A
Zinc, Dissolved	4.97	1.40	31.7	6.69	51	51	0.5	ug/L	**0/0**
Zinc, Total	5.91	1.50	30.8	6.80	51	51	0.5	ug/L	**0/0**
Field Parameters									
pH, Field	7.31	6.48	8.05	0.46	54	54	0.1	pH	**0**
Temperature, Field	9.82	2.49	19.73	4.86	54	53	0.1	deg C	**11**
Dissolved Oxygen, Field	9.06	0.71	14.20	3.30	54	54	0.5	mg/L	**27**
Specific Conductance	202.1	149	272	34.33	54	54	0.5	µS/cm	N/A

Table 5. A summary of field parameters collected during base events. Bold red refers to sample results over state criteria of water quality — WAC 173-201A.

Site	Event	flow (cfs)	Date	pH	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)*	Temperature (deg C)
1G	base 1	2.8	10/28/2008	7.3	210	10.6	9.0
		2.9		7.4	210	10.7	10.0
	base 2	6.5	1/20/2009	7.2	198	12.4	5.0
		6.5		7.2	198	12.4	5.0
		6.5		7.3	199	12.0	5.6
	base 3	3.4	6/10/2009	7.4	213	**8.8**	14.0
		3.4		7.5	214	**8.6**	17.2
2G	base 1	0.1	10/28/2008	7.9	272	11.5	8.8
		0.1		8.0	268	10.3	10.4
	base 2	0.2	1/20/2009	7.7	221	14.2	3.9
		0.2		7.9	223	12.7	4.8
	base 3	0.1	6/10/2009	8.1	254	9.6	13.9
		0.1		8.0	254	**8.9**	17.1
3G	base 1	0.5	10/28/2008	6.8	161	**9.3**	8.7
		0.5		6.8	161	**9.4**	8.7
		0.5		6.8	160	**9.4**	9.6
	base 2	1.8	1/20/2009	6.8	152	13.4	4.2
		1.7		6.9	153	11.6	5.2
	base 3	0.4	6/10/2009	6.9	169	**8.0**	14.4
		0.3		6.9	172	**7.6**	17.0
4GI	base 1	No Flow	10/28/2008	6.6	168	**1.4**	8.7
				6.6	197	**1.2**	9.9
	base 2		1/20/2009	6.5	157	**3.6**	4.0
				6.6	159	**3.3**	4.6
				6.6	160	**3.2**	4.6
	base 3		6/10/2009	6.7	180	**1.0**	16.8
				6.6	182	**0.7**	18.4
4GO	base 1	No Flow	10/28/2008	6.9	157	**7.6**	6.9
				6.9	157	**7.8**	7.9
	base 2		1/20/2009	6.8	149	10.3	2.5
				6.9	149	10.1	3.3
	base 3		6/10/2009	7.2	181	**5.7**	16.7

Site	Event	flow (cfs)	Date	pH	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)*	Temperature (deg C)
				7.2	182	**6.1**	19.7
				7.2	182	**6.2**	19.7
5GF	base 1	0.1	10/28/2008	7.7	253	11.1	8.0
		0.1		7.7	249	10.9	9.4
	base 2	0.9	1/20/2009	7.7	231	13.4	3.7
		1.0		7.7	232	12.8	4.6
	base 3	0.6	6/10/2009	7.7	252	**9.2**	13.6
		0.5		7.7	252	**9.0**	16.4
6G	base 1	0.3	10/28/2008	7.6	212	10.3	8.8
		0.4		7.6	192	9.6	10.8
	base 2	0.8	1/20/2009	7.5	205	11.9	6.1
		1.0		7.5	205	11.1	7.0
	base 3	0.4	6/10/2009	7.7	208	**9.0**	14.0
		0.4		7.8	208	**8.2**	19.7
J446_7G	base 1	0.7	10/28/2008	7.6	229	10.9	8.5
		0.6		7.6	227	10.0	10.0
		0.6		7.6	228	10.1	10.0
	base 2	1.9	1/20/2009	7.5	214	12.4	5.1
		1.9		7.6	214	11.6	5.9
	base 3	0.8	6/10/2009	7.8	226	**9.4**	13.0
		0.8		7.8	225	**9.4**	13.0
		0.8		7.8	228	**9.1**	16.2

"*" = refers to Washington State criterion for Dissolved Oxygen of 9.5 mg/L (see Table 1).

4.2.1.3 pH

The pH values of all samples collected during the baseflow events were within the state standard of 6.5 to 8.5 (Table 5 and Table 1).

4.2.1.4 Specific Conductance

Specific conductance data collected during baseflow events ranged from 149 to 272 µS/cm with an average value of 202 µS/cm. Typically, the lowest values were collected during the winter baseflow event (1/20/2009) and higher values in summer to early fall (Table 5).

Table 6. A summary of days over the temperature criteria.

Gauge sites	Site name	Date started	16°C Core Standard	13°C Spawning Standard^	
			10/01/2008 - 11/30/20009	9/15/2008- 5/15/2009	9/15/2009- 11/30/20009
27a (1G)	Juanita Creek - mouth	10/13/2003	89	36	23
27dn (5G)	Upper Juanita -west	10/28/2008	35*	0*	18
27h (6G)	Upper Juanita -central	10/23/2008	128*	26*	29
27j (7G)	Upper Juanita -east	10/24/2008	40*	0*	18

"^" = The supplement spawning standard for Juanita Creek is for main stem and does not apply to the upper tributaries. Data were assessed and compared for additional information.

"*" = These sites had data collection start in late October.

Note: Temperature values shall not exceed this criteria based on the 7-day average of daily maximum temperatures. Supplemental Spawning criteria is from September 15th to May 15th. see WAC 173-201A.

4.2.2 Storm Events

The storm data show some variability depending on the parameter and the storm event sampled **(**Table 7). All storm data including field parameters are presented in Table 8.

4.2.2.1 Dissolved Oxygen

Dissolved oxygen data collected during baseflow events ranged from 0.7 to 22.7 mg/L with an average value of 8.8 mg/L (Table 7). All samples from Storm 6 (10/16/2009) had DO data below the state criterion of 9.5 mg/L with no values above 4.0 mg/L (Figure 5 and Table 7). The DO data for the wetland sites, 4GI and 4GO, consistently had results below the state criterion. For storm samples, 64 of the 142 samples were below the state criterion of 9.5 mg/L (Table 8). DO concentrations during storms were the highest at site 2G. This is suspected to be the result of samples taken in a plunge-pool approximately 3-feet vertically below the invert of the culvert draining that sub basin.

4.2.2.2 Temperature

Temperature data collected during storm events ranged from 5.4 to 18.9 °C with an average value of 11.7 °C (Table 7). Temperature data from storm events reflected the time of year of the sample collection with winter storms being the coldest while spring/summer storm being the warmest (Figure 4). Twenty-five of the 26 samples collected during the Storm 5 event (08/10-11/2009) had temperature values over 16.0 °C (Table 8).

4.2.2.3 pH

The pH levels measured at all sites and storms were within the state criteria of greater than 6.5 and less than 8.5 except for 5 samples (Table 7 and Table 8). Four samples were below 6.5 while one sample was above 8.5. The result of 13.9 from site 5GF during Storm 6 appears to be anomalous when compared to the total dataset of 142 storm samples (Table 7) which ranged from 6.3 to 8.0.

4.2.2.4 Specific Conductance

Specific conductance data collected during storm events ranged from 33 to 217 µS/cm with an average value of 118 µS/cm (Table 7). The specific conductance data for a few sites (1G and 3G) did show a relationship of lower conductance with increasing stream flows (Figure 6). Site 1G, Juanita Creek at the mouth, has the maximum flows of any site measured and shows this association (Figure 6). This is due to the runoff of rain water with relatively low conductance (ionic strength) during storm events relative to the baseflow derived from groundwater that generally has higher conductance.

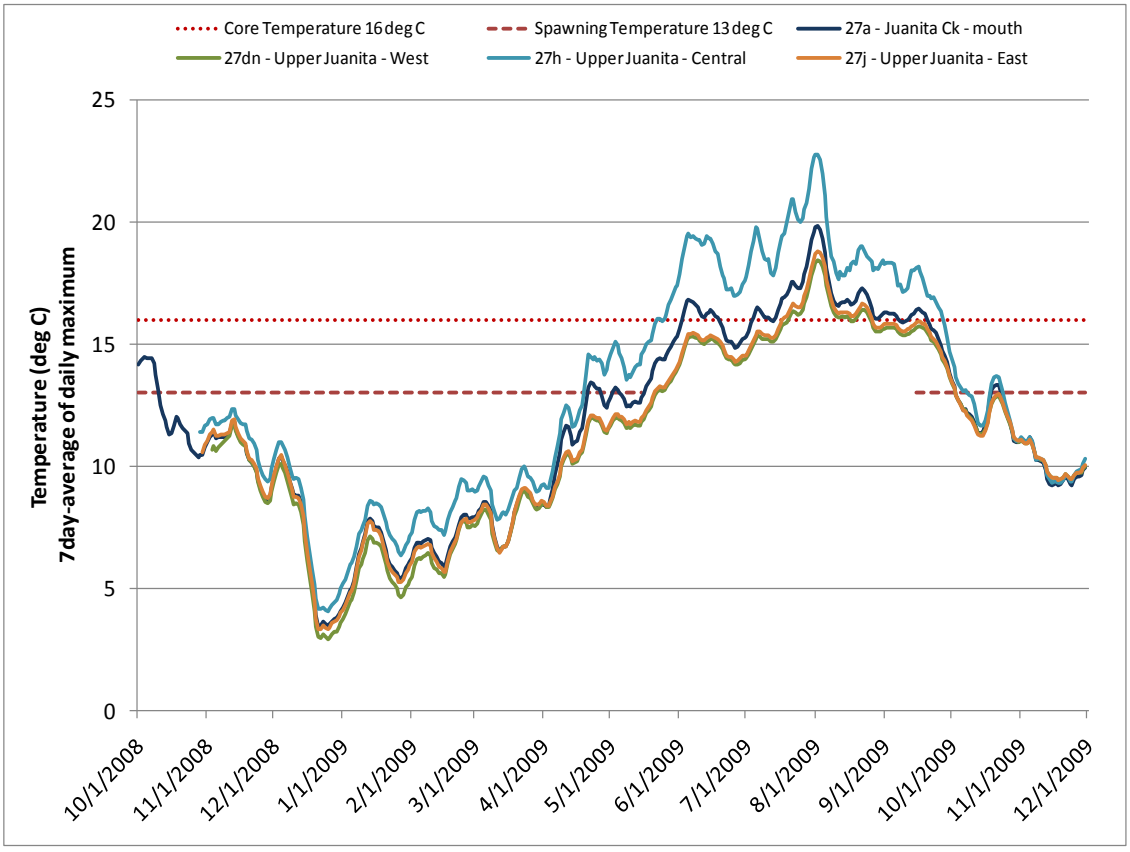

Figure 4. Temperature (7-day average of daily maximum) data for Juanita Creek.

Note: Temperature values shall not exceed the criterion based on the 7-day average of daily maximum temperatures. Spawning criterion is from September 15th to May 15th, see table 6.

Table 7. A summary of field parameters collected during storm events.

Parameter	Event	Average	Min	Max	StDev	Units
Specific Conductance	ALL	118.5	33	217	40.0	µS/cm
	storm 1	118.5	68	187	36.9	
	storm 2	155.2	127	202	20.1	
	storm 3	102.3	33	212	38.0	
	storm 4	134.5	96	177	21.1	
	storm 5	153.7	97	217	30.0	
	storm 6	93.1	44	162	34.2	
	storm 7	88.7	53	148	24.7	
Dissolved Oxygen	ALL	**8.8**	**0.7**	22.7	4.0	mg/L
	storm 1	11.0	**7.6**	12.1	1.6	
	storm 2	11.2	**7.6**	12.7	1.5	
	storm 3	9.8	**4.5**	12.0	2.1	
	storm 4	10.0	**3.3**	12.6	2.5	
	storm 5	**8.8**	**4.4**	11.5	2.1	
	storm 6	**2.4**	**0.7**	**3.7**	0.8	
	storm 7	11.4	**1.6**	22.7	4.8	
pH	ALL	7.1	**6.3**	**13.9**	0.65	*unitless*
	storm 1	7.3	7.0	7.7	0.27	
	storm 2	7.4	6.7	8.0	0.36	
	storm 3	6.9	6.5	7.2	0.22	
	storm 4	6.9	**6.4**	7.3	0.25	
	storm 5	7.3	6.7	7.6	0.25	
	storm 6	7.1	**6.3**	**13.9**	1.4	
	storm 7	7.0	6.6	7.5	0.21	
Temperature	ALL	11.7	5.4	18.9	3.3	deg C
	storm 1	7.2	6.8	7.7	0.31	
	storm 2	6.3	5.4	7.2	0.51	
	storm 3	11.4	10.2	12.2	0.59	
	storm 4	11.1	9.9	11.9	0.57	
	storm 5	17.0	15.8	18.9	0.76	
	storm 6	13.7	12.9	14.6	0.53	
	storm 7	10.0	7.2	11.0	0.69	

Note: Bold red refers to sample results over state water quality criteria

Table 8. Summary of storm event water quality for all parameters.

PARMNAME	Avg-result	Min	Max	StDev	Total Samples	Detected	MDL	UNITS	Exceedance Frequency *
Ammonia Nitrogen	0.09	0.0	1.3	0.17	142	135	0.005	mg/L	**0**
Biochemical Oxygen Demand	6.21	2.2	29.4	5.74	142	52	2	mg/L	N/A
Calcium, Total	10,668.7	4,280	20,800	3,128.9	142	142	10	ug/L	N/A
Chlorophyll a	4.98	0.7	27.4	5.16	142	91	0.5	ug/L	N/A
Copper, Dissolved	2.90	1.0	13.8	2.07	142	139	0.4	ug/L	**2/12**
Copper, Total	8.23	1.0	89.7	10.36	142	142	0.4	ug/L	
Dissolved Organic Carbon	7.81	3.3	40.1	4.43	142	142	0.5	mg/L	N/A
Fecal Coliform	2,144.3	5	23,000	3,569.7	142	142	>1	CFU/100ml	**142***
Hardness, Calc	49.06	17.7	98.2	15.26	142	142	0.066	mg CaCO3/L	N/A
Magnesium, Total	5,444.9	1,620	11,600	2,050	142	142	10	ug/L	N/A
Nitrite + Nitrate Nitrogen	0.56	0.0	2.2	0.46	142	142	0.1	mg/L	N/A
Orthophosphate Phosphorus	0.03	0.0	0.3	0.04	142	142	0.006	mg/L	N/A
Pheophytin a	7.72	1.2	25.4	6.13	142	33	1	ug/L	N/A
Total Alkalinity	44.01	13.2	85.3	15.15	142	142	1	mg CaCO3/L	N/A
Total Nitrogen	1.22	0.3	5.2	0.82	142	142	0.5	mg/L	N/A
Total Organic Carbon	12.18	3.8	54.4	9.28	142	142	0.5	mg/L	N/A
Total Phosphorus	0.15	0.0	1.1	0.15	142	142	0.005	mg/L	N/A
Total Suspended Solids	69.26	1.8	1,530.0	161.54	142	142	0.5	mg/L	N/A
Zinc, Dissolved	16.12	2.3	292.0	38.76	142	139	0.5	ug/L	**6/6**
Zinc, Total	40.85	4.2	341.0	52.38	142	142	0.5	ug/L	
Field Parameters									
pH, Field	7.11	6.3	13.9	0.65	146	146	0.1	No units	**5**
Temperature, Field	11.70	5.4	18.9	3.34	146	146	0.1	deg C	**25**
Dissolved Oxygen, Field	8.83	0.7	22.7	3.98	146	142	0.5	mg/L	**49**
Specific Conductance, Field	118.5	33	217	40.0	146	146	0.5	uS/cm	N/A

*State water quality criteria are presented in table 1. Dissolved metal data are presented as acute/chronic threshold.

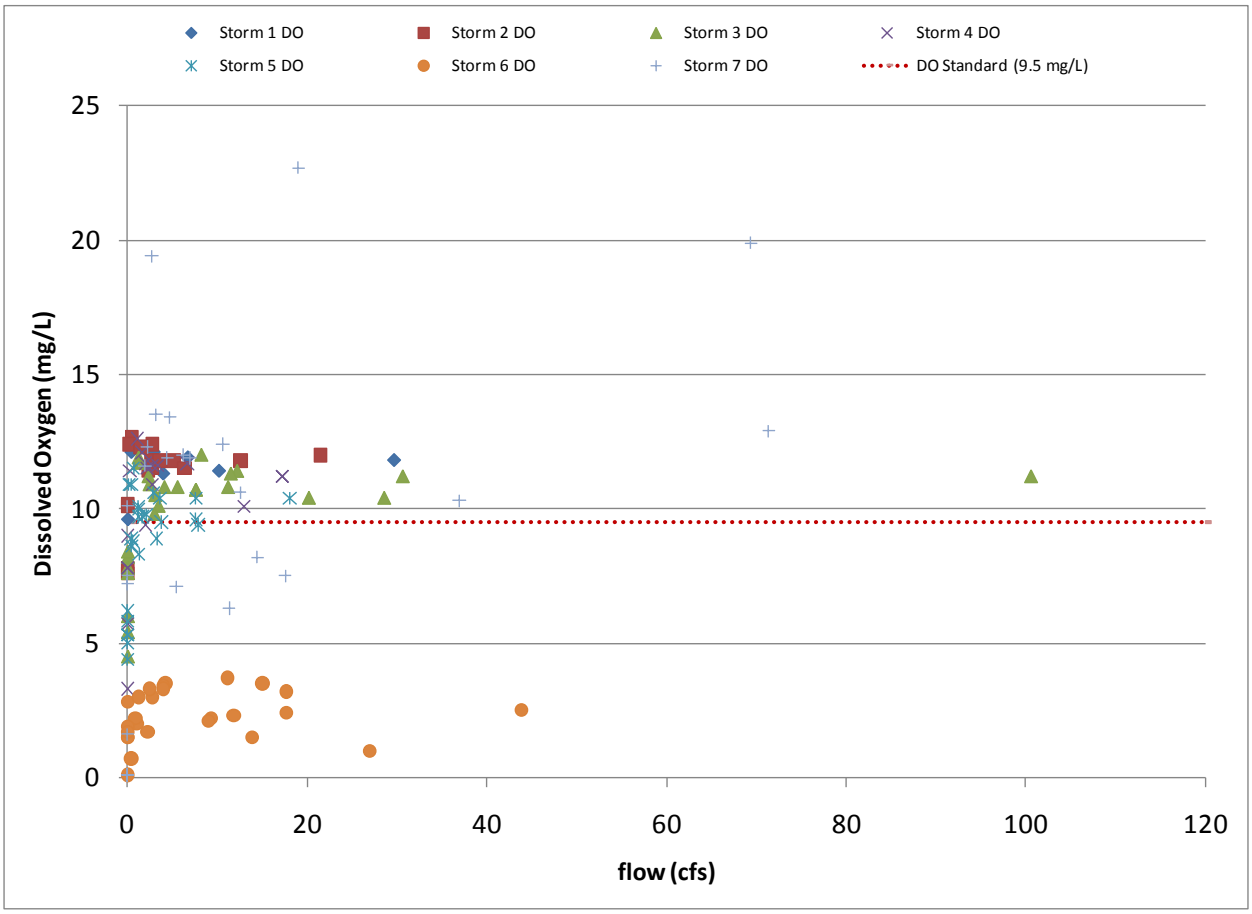

Figure 5. A scatter graph of dissolved oxygen and flow data for storm events.

Note: no flow measurements were taken at wetland sites (4GI and 4GO).

4.3 Lab Analysis

This section summarizes the data analyzed at the King County Environmental Laboratory for all samples collected. The method, detection limits and other laboratory analysis details can be found in the Sampling and Analysis plan, King County 2008.

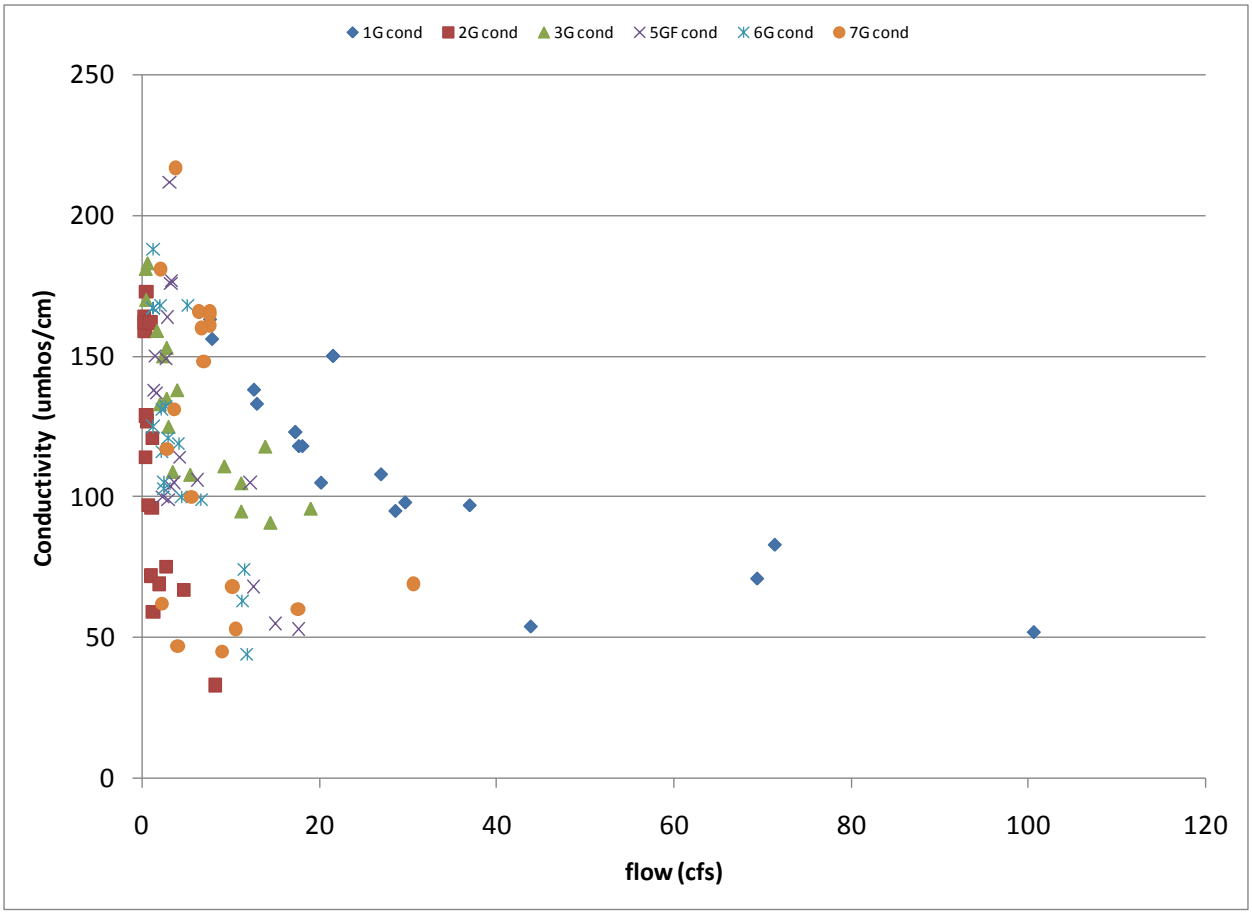

Figure 6. A scatter graph of specific conductance and flow data for storm events.

4.3.1 Conventional Parameters

Results for baseflow and storm event sampling for parameters analyzed in the laboratory are discussed below. All laboratory data are summarized in Table 4, Table 8, and Appendix 1.

4.3.1.1 Alkalinity

The baseflow event alkalinity ranged from 50.4 to 108 mg/L $CaCO_3$ and the storm event alkalinity ranged from 13.2 to 85.3 mg/L $CaCO_3$. The average values for the baseflow and storm events were 79.0 mg/L and 44.0 mg/L $CaCO_3$, respectively. Alkalinity values for all sites were lower for the storm samples than during baseflow events and this is likely caused by the increased runoff of rain water into the stream during storm events which has lower alkalinity (i.e., buffering capacity) than baseflow derived from groundwater during storm events. This is consistent with the specific conductance results presented above.

4.3.1.2 Total Suspended Solids

The baseflow event total suspended solids (TSS) values ranged from 0.5 to 18 mg/L and the storm event TSS values ranged from 1.8 to 1,530 mg/L. The average values for the base and storm events were 3.6 mg/L and 69.2 mg/L, respectively. Total suspended solids values for all sites were higher for the storm samples than during baseflow events except for site 4GI. This site

had similar values for both baseflow and storm events. The general increase in TSS values during storm events is likely caused by a combination of rainfall washoff from the land, resuspension and transport along the stream bed, and erosion and transport from the stream bank. However, the highest concentrations did not always occur at the highest observed flows for those sites with associated flow measurements (Figure 7).

4.3.1.3 Dissolved Organic Carbon

The baseflow event dissolved organic carbon (DOC) values ranged from 1.9 to 7.4 mg/L and the storm event DOC values ranged from 3.3 to 40.1 mg/L. The average values for the baseflow and storm events were 4.2 mg/L and 7.8 mg/L, respectively. Dissolved organic carbon values for all sites were higher for the storm samples than during baseflow events.

4.3.1.4 Total Organic Carbon

The baseflow event total organic carbon (TOC) values ranged from 1.8 to 8.8 mg/L and the storm event TOC values ranged from 3.8 to 54.4 mg/L. The average values for the base and storm events were 4.4 mg/L and 12.2 mg/L, respectively. Total organic carbon values for all sites were higher for the storm samples than during base events.

4.3.1.5 Biochemical Oxygen Demand

The baseflow event biochemical oxygen demand (BOD) values were all below the method detection limit of 2.0 mg/L, except for two samples with reported concentrations of 2.9 and 5.2 mg/L at Stations 4GI and 6G, respectively. The storm event BOD values ranged from below the laboratory method detection limit to 29.4 mg/L. Twenty-six of the 85 samples were below the method detection limit of 2.0 mg/L. Additionally, seven samples from Storm 2 were qualified with an "R" which refers not reported and text added stated 'No result available due to contamination of dilution water'. Each site had at least three storm samples above the detection limit and the average values for storm events were 2.7 mg/L and 9.5 mg/L. Biochemical oxygen demand values for the storm samples were higher than baseflow event samples for all sites.

4.3.1.6 Hardness

The baseflow event hardness values ranged from 50.7 to 109 mg/L and the storm event hardness values ranged from 17.7 to 98.2 mg/L. The average values for the baseflow and storm events were 79.0 mg/L and 49.1 mg/L, respectively. Hardness, like alkalinity, was lower for the storms than during base events for all sites.

4.3.1.7 Fecal Coliform

The baseflow event fecal coliform (FC) values ranged from 1 to 5,000 CFU/100 ml and the storm event FC values ranged from 5 to 23,000 CFU/100 ml. The geometric mean of all

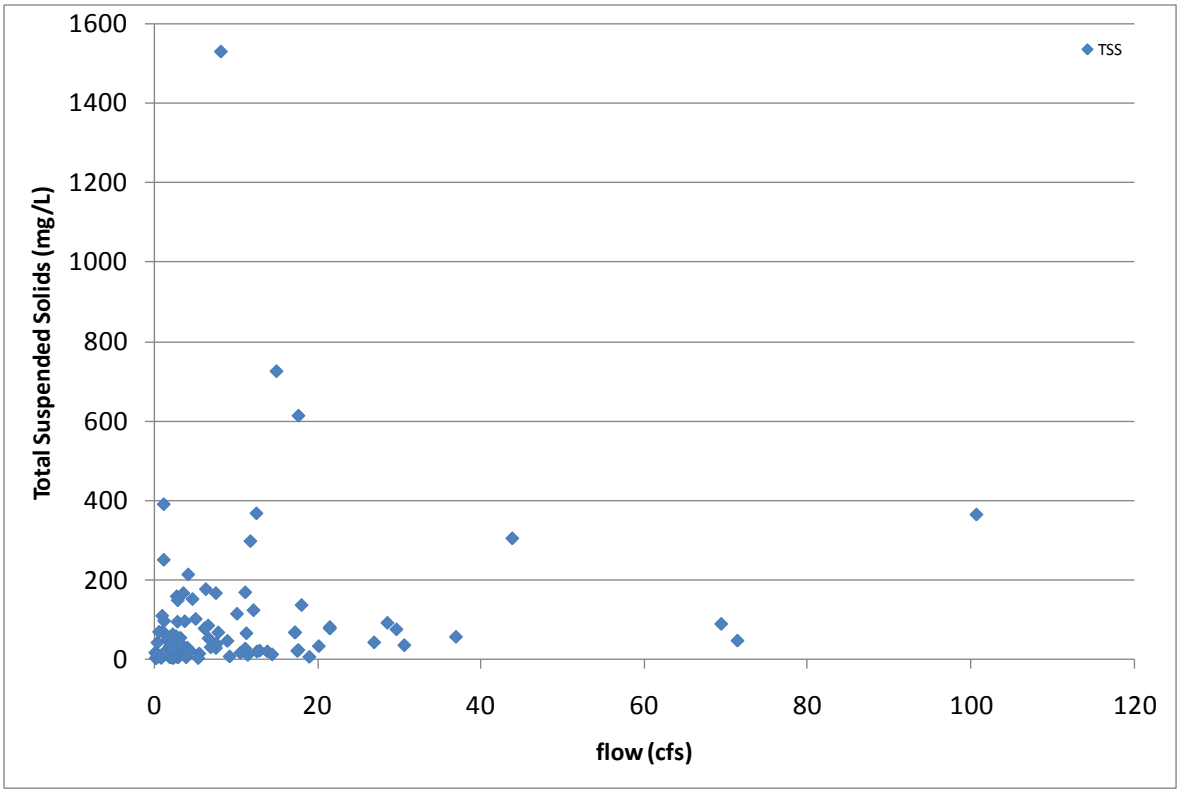

Figure 7. A graph of total suspended solids verses flow data for storm events.

baseflow event samples was 64 CFU/100 ml while the geometric mean of all storm event samples was 765 CFU/100 ml (Table 9). Both of these results are above the Extraordinary Primary Contact Recreation criterion of 50 CFU/100 ml

Table 9 shows the data by event and by site. The geometric mean values of all storm events and for each site during storm events exceeded the Ordinary Primary Contact Recreation of 100 CFU/100ml. The storm event 5 (08/10-11/2009) had the highest geometric mean of all storm events with 3,823 CFU/100 ml and site 6G had the highest geometric mean of all sites with 2,479 CFU/100ml, Table 9. For the baseflow events, Base 3 (06/20/2009) had the highest geometric mean value with 204 CFU/100ml and site 6G also had the highest geometric mean of all sites with 622 CFU/100ml, Table 9.

4.3.1.8 Chlorophyll a — Pheophytin a

The baseflow event values of chlorophyll and pheophytin ranged from 1 to 3 µg/L with the majority of the samples below the laboratory method detection limit. The number of samples below the limit of detection was 34 and 47 of 51 total samples for chlorophyll and pheophytin, respectively. For storm samples, the number of measured concentrations and the range of values increased for both parameters. Chlorophyll storm values ranged from 1 to 27 µg/L with an average value of 4.9 µg/L for 91 of 142 samples. The remaining samples (51) were below the limit of detection. Pheophytin storm values ranged from 1 to 25 µg/L with an average value of 7.7 µg/L for 33 of 142 samples while the remaining samples (109) were below the limit of detection.

Table 9. A summary of fecal coliform data (geometric means) from baseflow and storm sampling events.

Storm events		**Baseflow events**	
768		**65**	
Storm samples			
Event	Geometric mean	Site	Geometric mean
storm 1	**224**	J446_1G	**1,254**
storm 2	**197**	J446_2G	**808**
storm 3	**823**	J446_3G	**323**
storm 4	**688**	J446_4GI	**316**
storm 5	**3,823**	J446_4GO	**351**
storm 6	**1,322**	J446_5GF	**1,680**
storm 7	**385**	J446_6G	**2,479**
		J446_7G	**959**
Base flow samples			
Event	Geometric mean	Site	Geometric mean
base 1	**87**	J446_1G	**135**
base 2	17	J446_2G	47
base 3	**204**	J446_3G	17
		J446_4GI	10
		J446_4GO	15
		J446_5GF	**153**
		J446_6G	**622**
		J446_7G	**205**

Note: Data are geometric mean values over the state criterion are shown in bold.

4.3.1.9 Ammonia

The baseflow event ammonia values ranged from 0.01 to 0.34 mg/L and the storm event ammonia values ranged from 0.01 to 1.28 mg/L. The average values for the base and storm events are 0.04 mg/L and 0.09 mg/L, respectively. No samples exceeded the surface water criterion for ammonia.

4.3.1.10 Nitrate

The parameter analyzed was nitrate plus nitrite (identified as nitrate in the remainder of this report for convenience[3]). The baseflow event nitrate values ranged from 0.02 to 2.5 mg/L and

[3] Measured as nitrate plus nitrite nitrogen. Nitrite nitrogen concentrations are typically very low in well oxygenated ambient waters (Hem 1985) and are typically very near or below the analytical detection limit when specific measurements of nitrite nitrogen are made.

the storm event nitrate values ranged from 0.02 to 2.2 mg/L. The average values for the base and storm events are 1.0 mg/L and 0.6 mg/L, respectively. All sites except the wetland sites (4GI and 4GO) had lower average values during storm events relative to baseflow samples. Nitrate values from sites 4GI and 4GO were consistent for both storm and baseline events within the range of 0.1 to 0.2 mg/L.

4.3.1.11 Total N

The base event total nitrogen (TN) values ranged from 0.3 to 2.7 mg/L and the storm event TN values ranged from 0.3 to 5.2 mg/L. The average values for the base and storm events are 1.2 mg/L and 1.2 mg/L, respectively. The average and minimum values for both type of events were the same while the maximum values of storm event samples were greater than the baseflow events.

4.3.1.12 Orthophosphate Phosphorus

The baseflow event orthophosphate phosphorus (ortho P) values ranged from 0.008 to 0.09 mg/L and the storm event ortho P values ranged from 0.006 to 0.29 mg/L. The average values for the base and storm events are 0.03 mg/L and 0.03 mg/L, respectively. The average and minimum values for both types of events were similar while the maximum values measured during storm events were greater than the concentrations observed in baseflow events sampled.

4.3.1.13 Total Phosphorus

The baseflow event total phosphorus (TP) values ranged from 0.02 to 0.17 mg/L and the storm event TP values ranged from 0.02 to 1.08 mg/L. The average values for the base and storm events are 0.06 mg/L and 0.15 mg/L, respectively. All sites except for site 4GI had greater values during storm events than the base events. Site 4GI had similar values (average, minimum and maximum) for both storm and base events with a range of 0.02 to 0.18 mg/L.

4.3.2 Metals

The trace metals, copper and zinc, were analyzed as total and dissolved fractions.

4.3.2.1 Copper

Dissolved copper concentrations ranged from 0.33 to 2.67 µg/L for baseflow events and ranged from 0.95 to 13.8 µg/L for storm events. The average concentrations for base and storm events were 0.82 and 2.9 µg/L, respectively.

Total copper concentrations ranged from 0.39 to 2.57 µg/L for base events and ranged from 1.0 to 89.7 µg/L for storm events. The average concentrations for base and storm events were 1.1 and 8.2 µg/L, respectively.

No base event samples exceeded either the acute or chronic criteria (Table 10). Two of the 142 storm samples exceeded the acute criterion. These samples were from Storm 5 (08/20/2009) and occurred at sites 4GI and 5G. The chronic criterion was exceeded in 12 of the storm samples. Storm 5 and Site 4GI had the most samples over the standard - 9 and 6 samples, respectively. Storm 3 had two samples with values over the chronic criterion while Storm 7 only had one. The

other sites with sample values over the chronic criterion included 5GF and 6G with 2 samples each while sites 1G and 2G only had one sample.

4.3.2.2 Zinc

Dissolved zinc concentrations ranged from 1.4 to 31.7 µg/L for baseflow events and ranged from 2.3 to 292 µg/L for storm events. The average concentrations for base and storm events were 5.0 and 16.1 µg/L, respectively.

Total zinc concentrations ranged from 1.5 to 30.8 µg/L for base events and ranged from 4.2 to 341 µg/L for storm events. The average concentrations for base and storm events were 5.9 and 40.9 µg/L, respectively.

Dissolved zinc, like copper, did not have any baseflow event samples that exceeded either the acute or chronic criteria (Table 10). Six of the 142 storm samples exceeded the acute criterion . Each sample that exceeded the acute threshold also exceeded the chronic criterion. No other chronic standard exceedances occurred. The occurrence of these samples is different than those of copper. Storm 2 and site 1G had the most samples over the chronic criterion with 3 samples each. Storm 5 had two samples with values over the chronic criterion while Storm 7 only had one. The other sites with sample values over the chronic criterion included 4GI, 4GO and 5GF with one sample each.

Table 10. A summary of trace metal data collected during baseflow and storm events compared to the state acute and chronic criteria*. Number of samples over the criteria are shown in bold.

Dissolved Copper			**Dissolved Zinc**	
Base				
Acute	**Chronic**		**Acute**	**Chronic**
0	0	Event/Site	0	0
Storm				
Acute	**Chronic**		**Acute**	**Chronic**
2	**12**	Event/Site	**6**	**6**
0	0	Storm 1	0	0
0	0	Storm 2	**3**	3
0	**2**	Storm 3	0	0
0	0	Storm 4	0	0
2	**9**	Storm 5	**2**	**2**
0	0	Storm 6	0	0
0	**1**	Storm 7	**1**	**1**
0	**1**	J446_1G	**3**	**3**
0	**1**	J446_2G	0	0
0	0	J446_3G	0	0
1	**6**	J446_4GI	**1**	**1**
0	0	J446_4GO	**1**	**1**
1	**2**	J446_5GF	**1**	**1**
0	**2**	J446_6G	0	0
0	0	J446_7G	0	0

* = These criteria are formula based using the hardness of the sample. see WAC 173-201A for formulas. Average values can be found in Table 1.

5.0. SUMMARY

As part of the Juanita Creek Stormwater Retrofit planning project, a water quality monitoring study was designed to assess current baseflow and stormwater quality in Juanita Creek and support the development of a watershed hydrologic and water quality model. Water quality samples were collected during seven storm events and three base flow events over a period of 14 months – October 2008 to November 2009 from eight stations. Continuous (15-minute) monitoring of stream flow and water temperature was also conducted at six sites from October 2008 to December 2009.

The dissolved oxygen concentrations were below the state criteria of 9.5 mg/L during both base and storm events (Table 4 and Table 8). The wetland sites (4GI and 4GO) had the lowest DO concentrations during baseflow events. Low DO was observed at Station 4GI relative to the other locations sampled could be a result of very flat highly vegetated channels connecting between the wetland and Totem Lake upstream?. These types of water courses can have high levels of benthic oxygen demand which can be exacerbated by slow moving waters. One other sample collected at Station 3G was below the criterion (Table 5). The storm DO data had more sites with data below the state criterion (Table 8). All of Storm 6 (10/16-17/2009) event had DO data below the criterion with data ranging from 0.7 to 3.8 mg/L (Figure 5). It is unknown at this time if the data collected during Storm 6 was an equipment problem or a flushing occurrence that happens during the first fall storm. Other storm events had six of eight sites with low DO data. They include sites 3G, 4GI, 4GO, 5GF, 6G, 7G.

The water temperature data collected as part of this study were a combination of grab samples and continuously recording sensors. The temperature criteria are based on the 7-day average of daily maximum temperatures. All continuous temperature sites had temperatures that exceeded the criterion intended to protect salmonid rearing and migration (Table 6 and Figure 4). Site 27h (6G) had the highest temperatures and the most days over the standards. The grab (discreet) temperature data collected at all sites support the data collected at continuous sites.

The pH data for all baseflow and storm events were within the state criteria of greater than 6.5 and less than 8.5 except for 5 storm samples (Table 4, Table 7 and Table 8). Four samples were below 6.5 at sites 5GF and 4GI. The result of 13.9 from site 5GF during Storm 6 appears to be anomalous when compared to the total dataset of storm samples (142) (Table 7) which ranged from 6.3 to 8.0.

Fecal coliform were detected in all samples from baseflow and storm events. The geometric mean of all baseflow event samples was 64 CFU/100 ml while the geometric mean of all storm event samples was 765 CFU/100 ml, or approximately an order of magnitude greater during storm events (Table 9 and Appendix 1). Both of these results are above the Extraordinary Primary Contact Recreation criterion of 50 CFU/100 ml (Table 1 and Table 9). Storm 5 (08/10-11/2009) had the highest geometric mean of all storm events with 3,823 CFU/100 ml and site 6G had the highest geometric mean of all sites with 2,479 CFU/100 ml (Table 9). For the baseflow events, Base 3 (06/20/2009) had the highest geometric mean value with 204 CFU/100 ml and site 6G also had the highest geometric mean of all sites with 622 CFU/100 ml (Table 9).

For dissolved metals (copper and zinc), no baseflow event samples exceeded either the acute or chronic criteria (Table 4 and Table 10). For dissolved copper, two of the 142 storm samples exceeded the acute criterion. These samples were from Storm 5 (08/20/2009) and occurred at

sites 4GI and 5G. The chronic criterion was exceeded in 12 samples, with Storm 5 and Site 4GI having the most samples over this standard with 9 and 6 samples, respectively. Elevated copper levels measured at 4GI is consistent with the drainage area that includes major arterials and Interstate-405- copper from automobile brake pads is a potential source of copper in urban streams. Storm 3 had two samples with values over the chronic criterion while Storm 7 had one. The other sites with sample values over the chronic criterion included 5GF and 6G with two samples each while sites 1G and 2G only had one sample, Table 10.

For dissolved zinc, six of the 142 storm samples exceeded the acute criterion (Table 10). Each sample that exceeded the acute criterion also exceeded the chronic criterion. The occurrence of these standard exceedances is different than those for dissolved copper. Storm 2 and site 1G had the most samples over the criteria with 3 samples each (Table 10). Storm 5 had two samples with values over the chronic criterion while Storm 7 only had one. The other sites with sample values over the chronic criterion included 4GI, 4GO and 5GF with one sample each.

In general, the data collected were of sufficient quality to support the development of a watershed hydrologic and water quality model that can be used to evaluate the effectiveness of various stormwater retrofit strategies in improving water quality and quantity conditions in the Juanita Creek watershed.

6.0. REFERENCES

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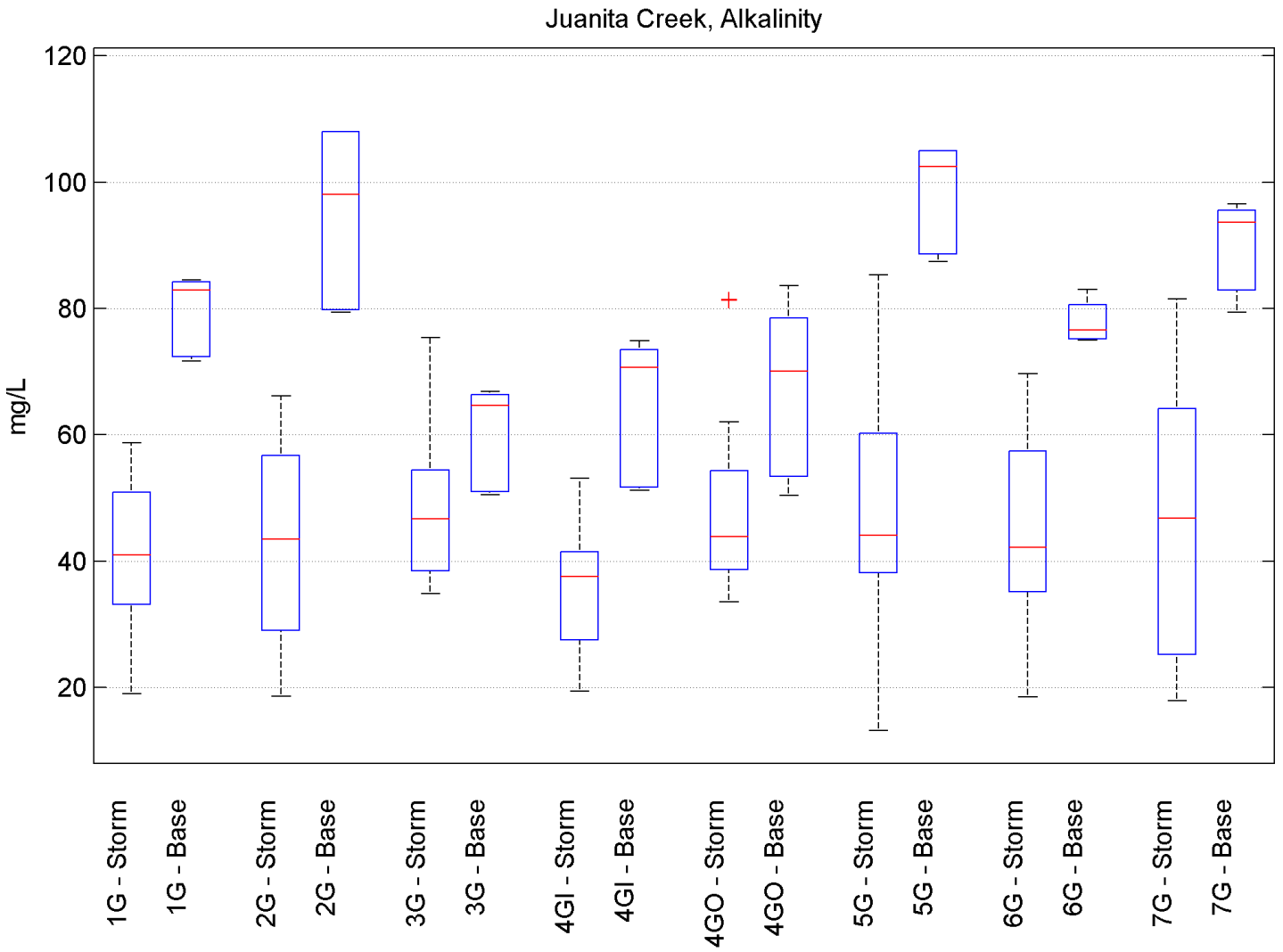
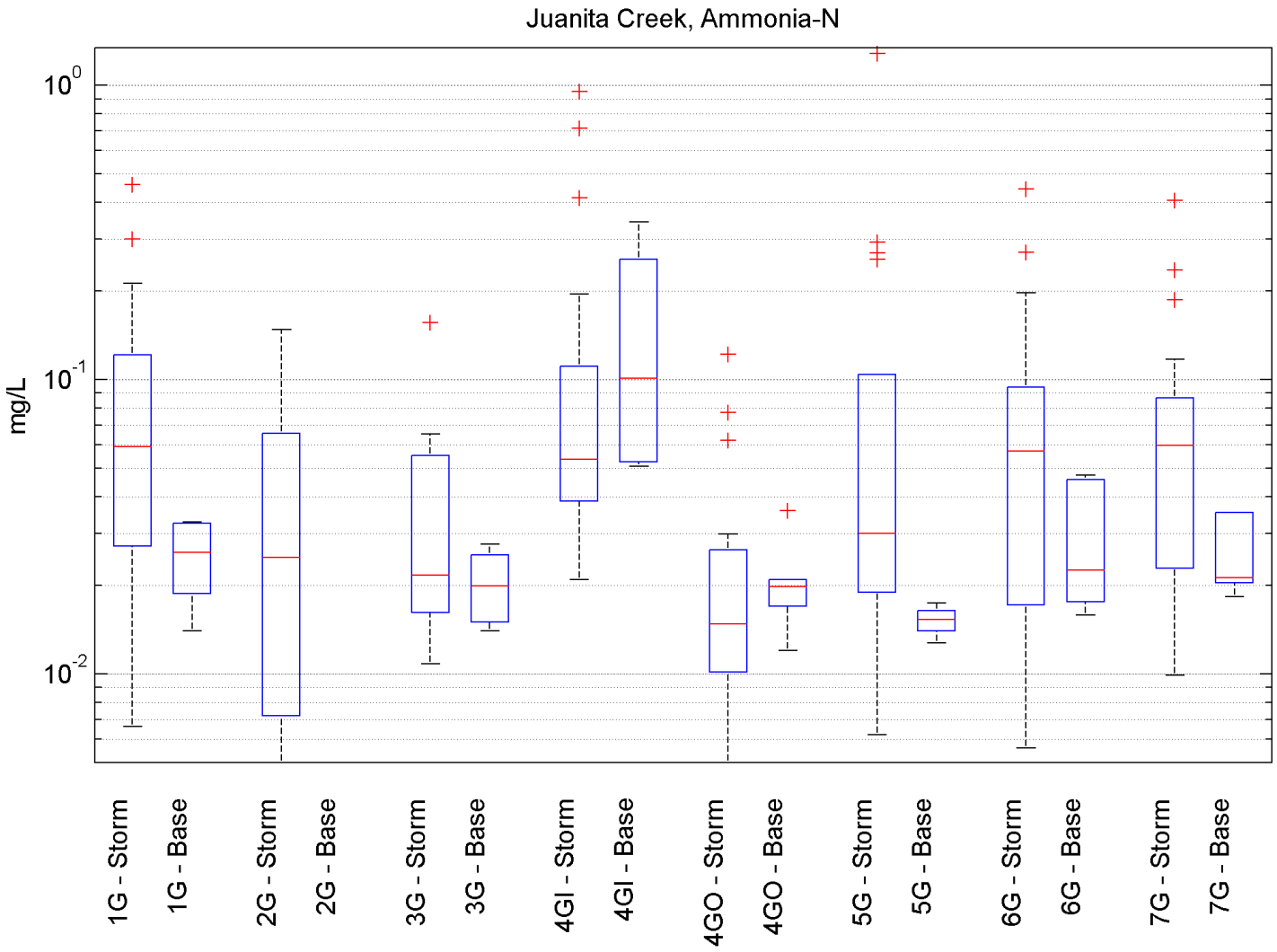
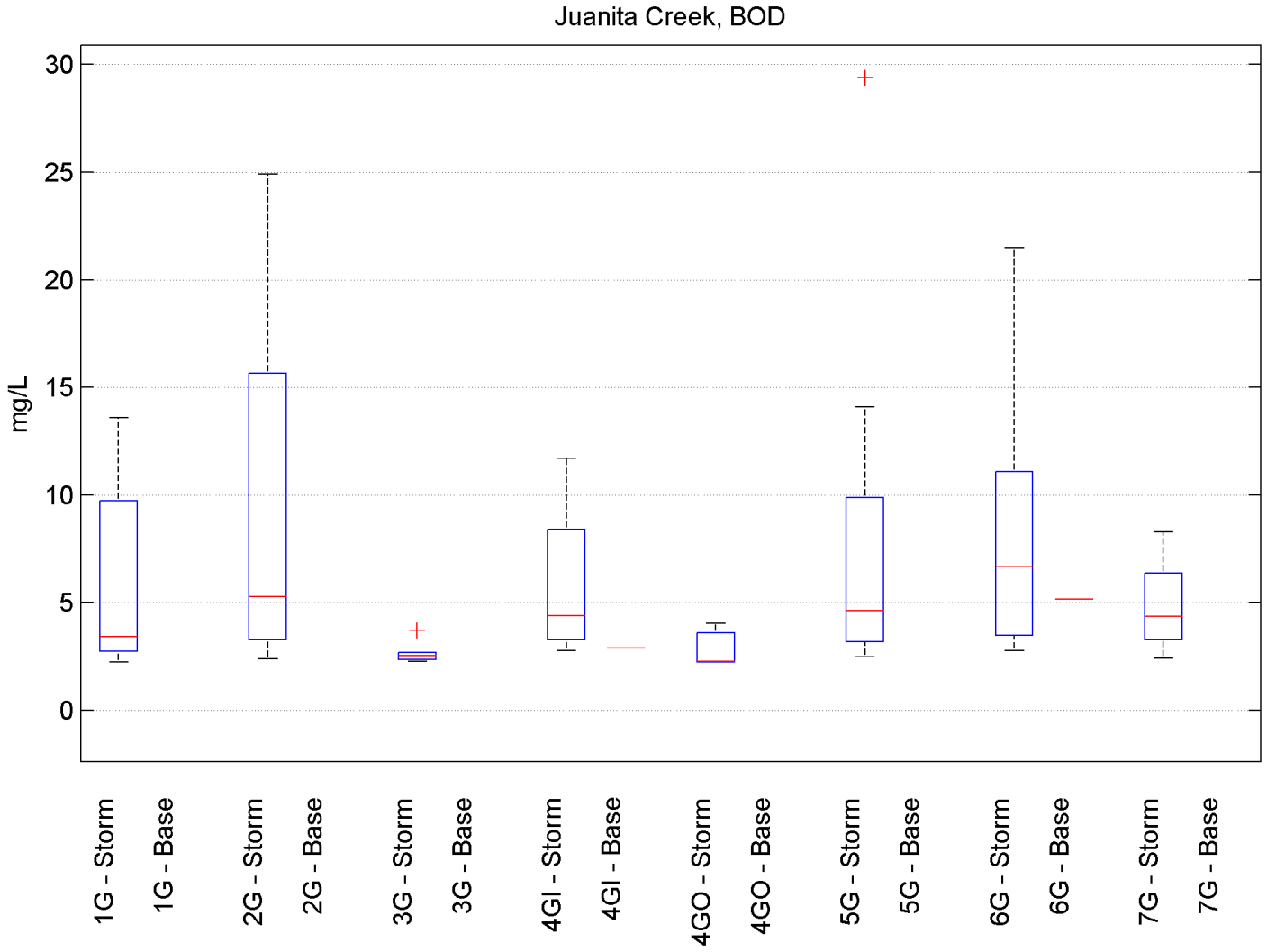
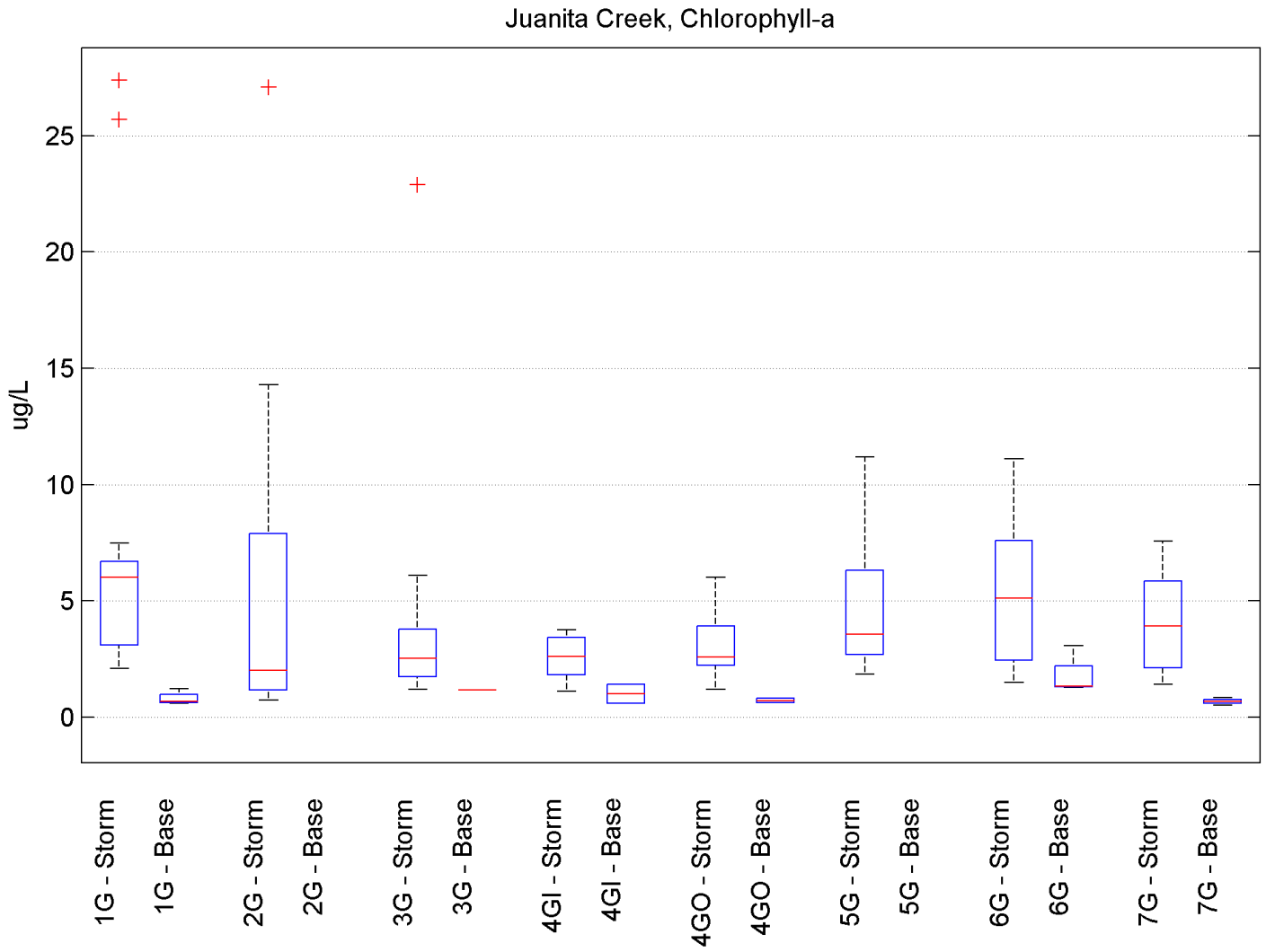
Appendix 1

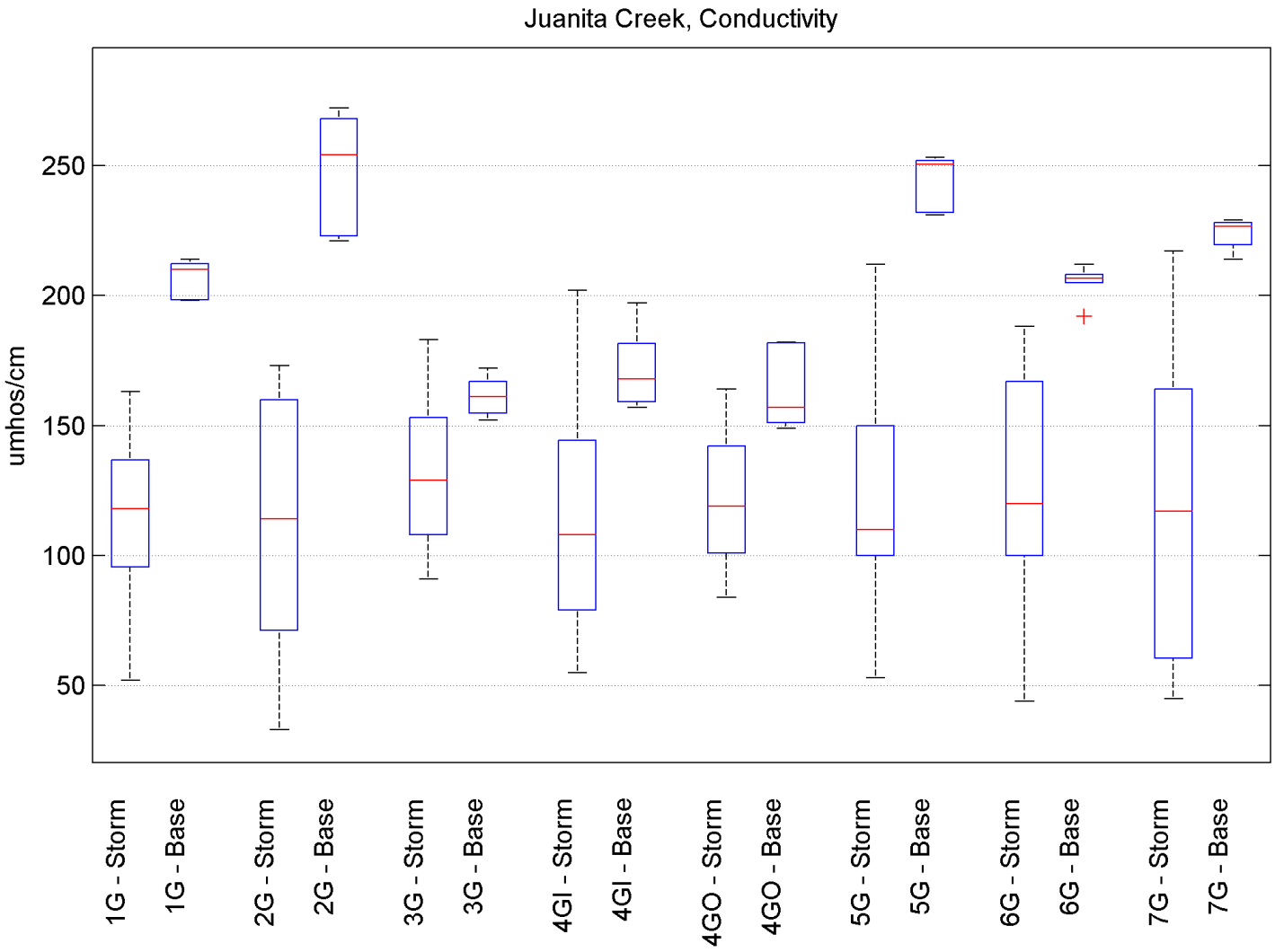
Boxplots of water quality parameters (base and storm)

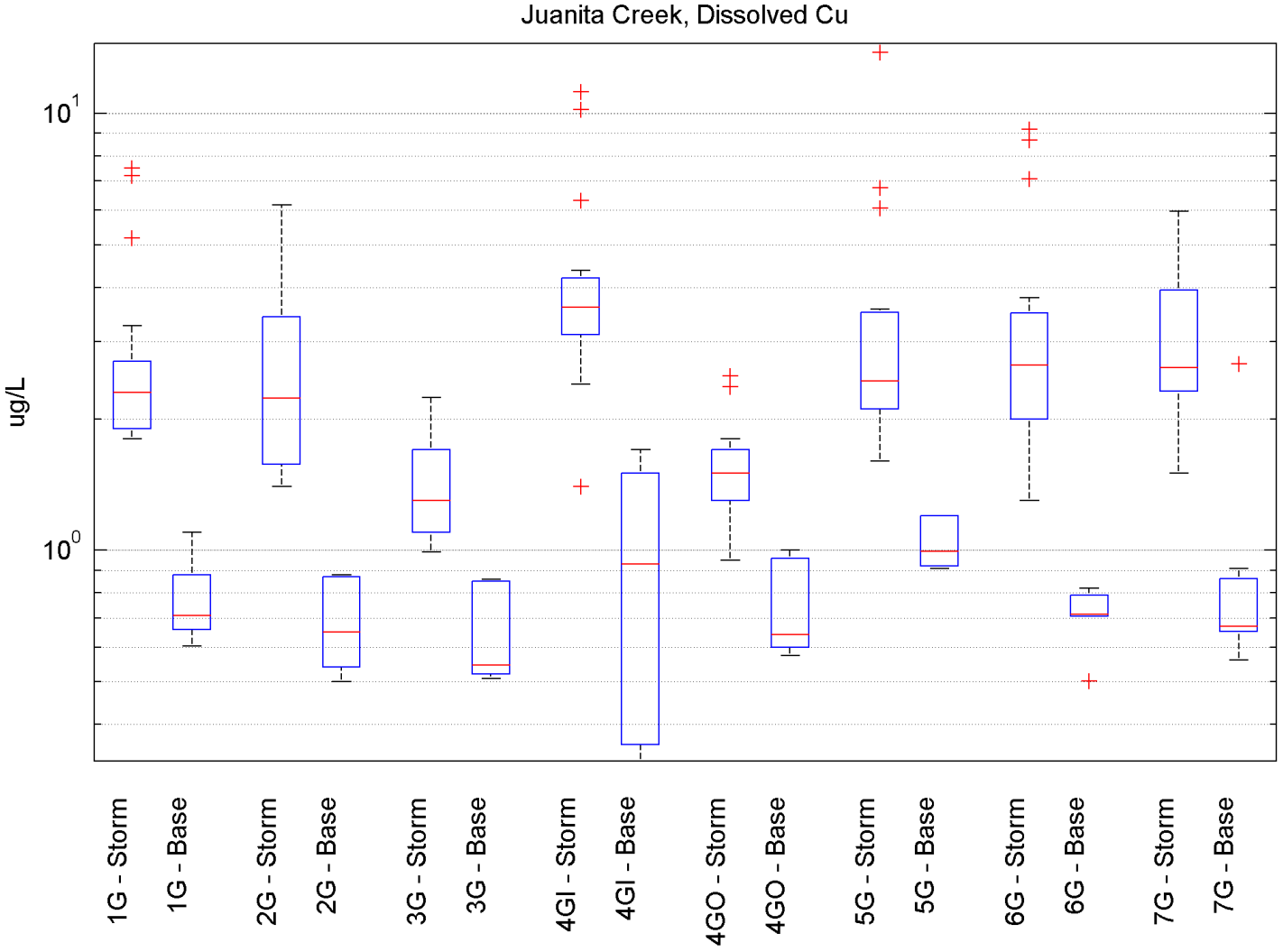

Juanita Creek, Alkalinity
mg/L
120
100
80
60
40
20
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

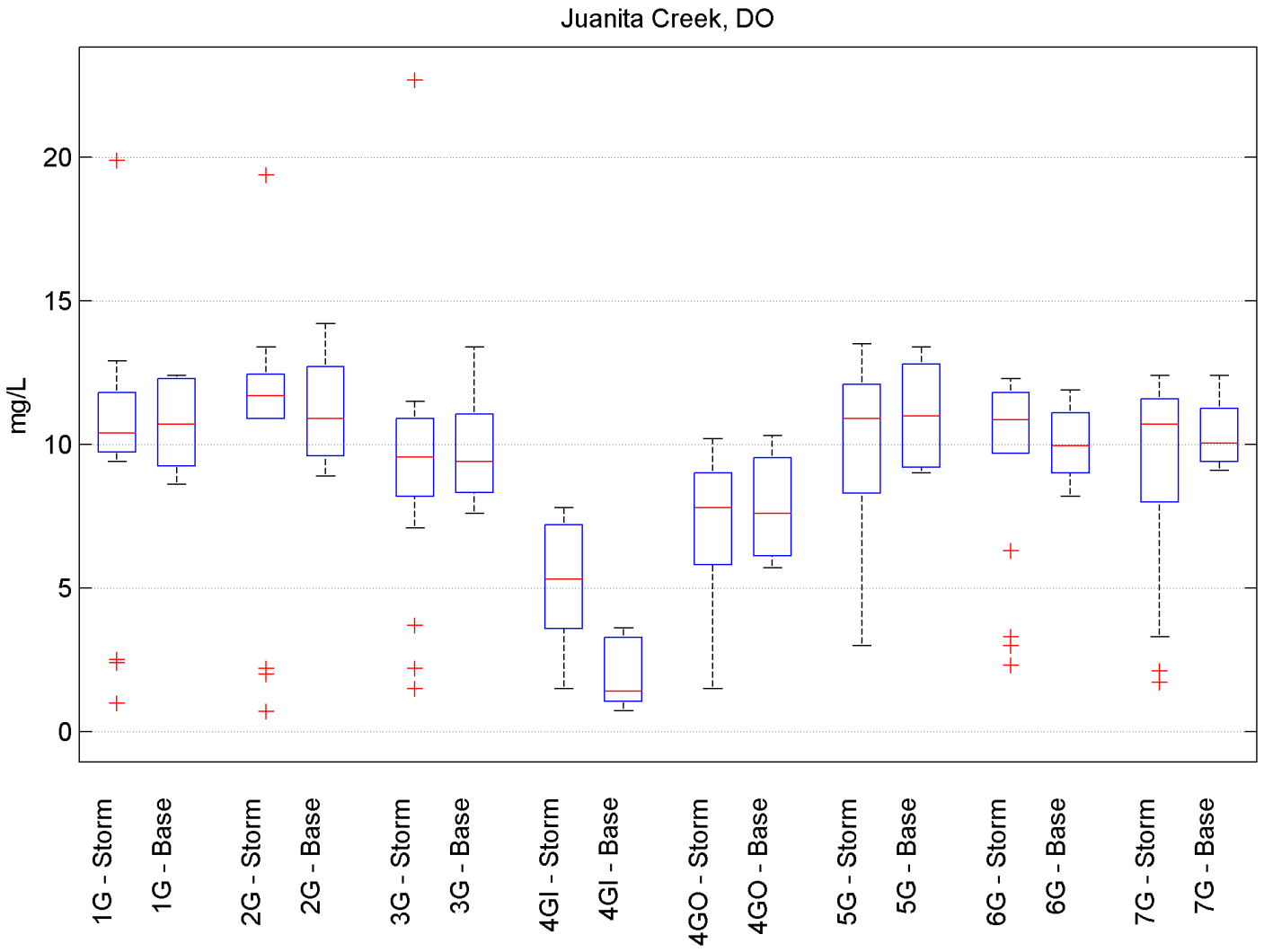

Juanita Creek, Ammonia-N
mg/L
10^{0}
10^{-1}
10^{-2}
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

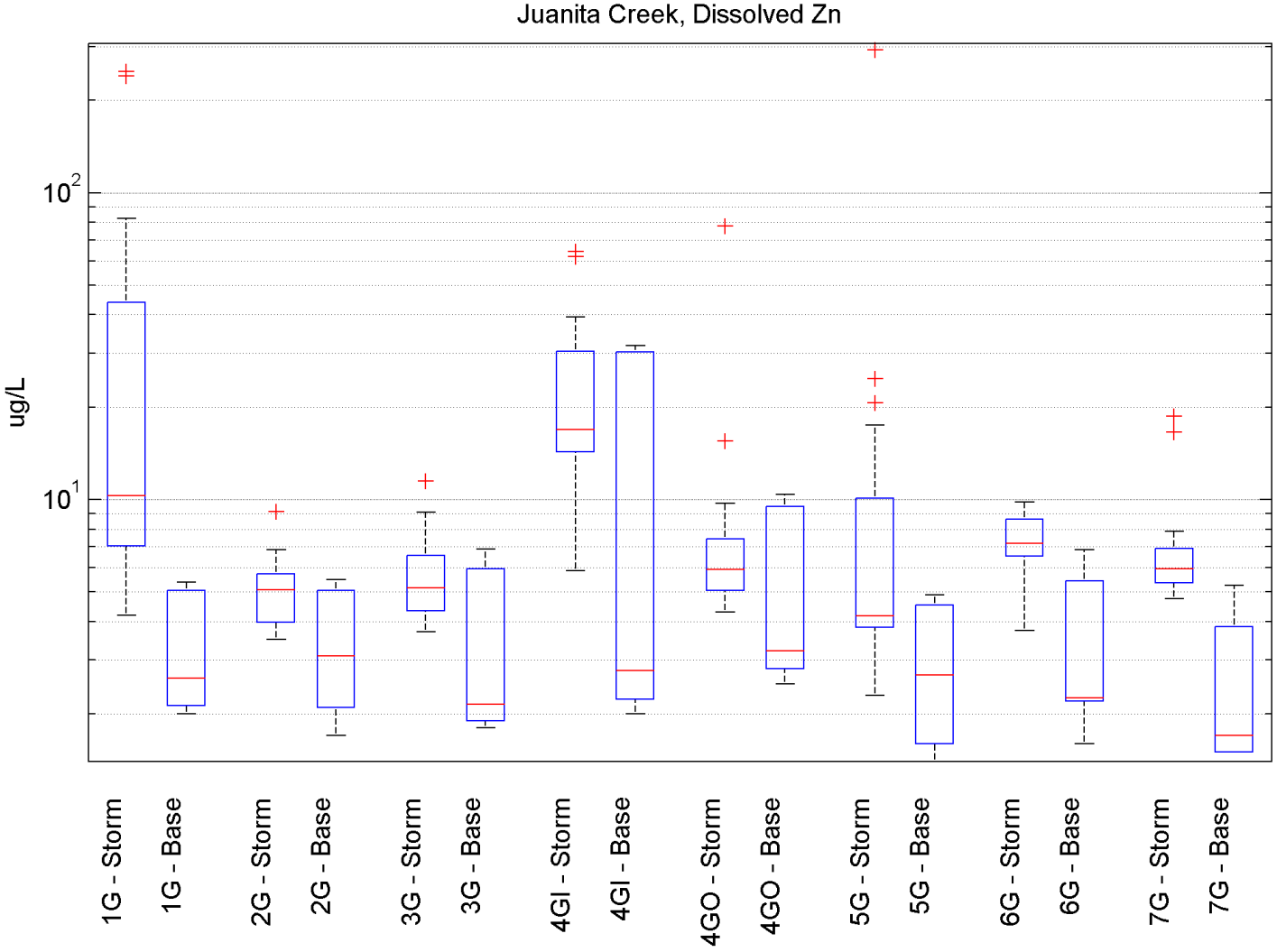

Juanita Creek, BOD
mg/L
30
25
20
15
10
5
0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

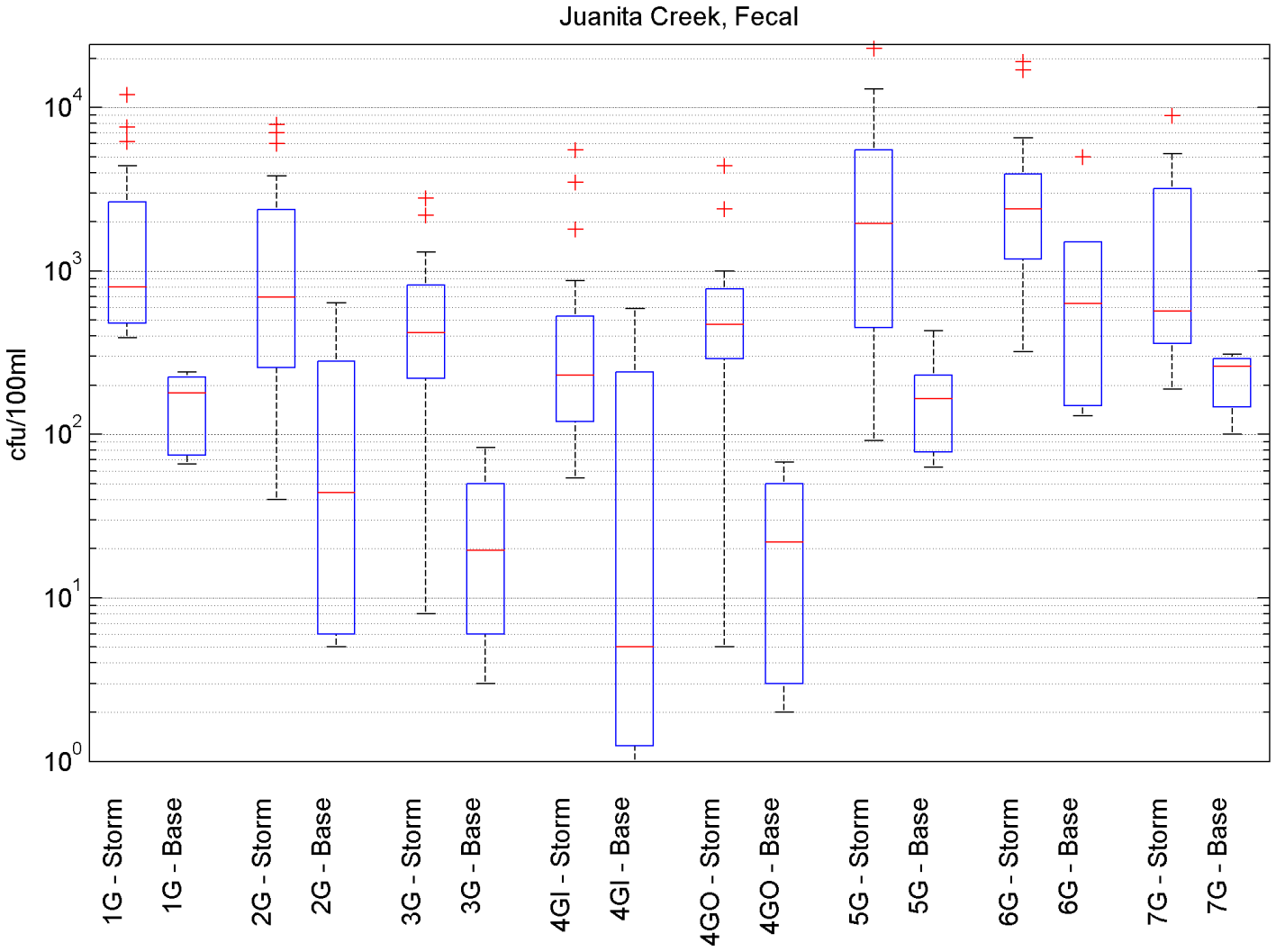

Juanita Creek, Chlorophyll-a
ug/L
25
20
15
10
5
0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

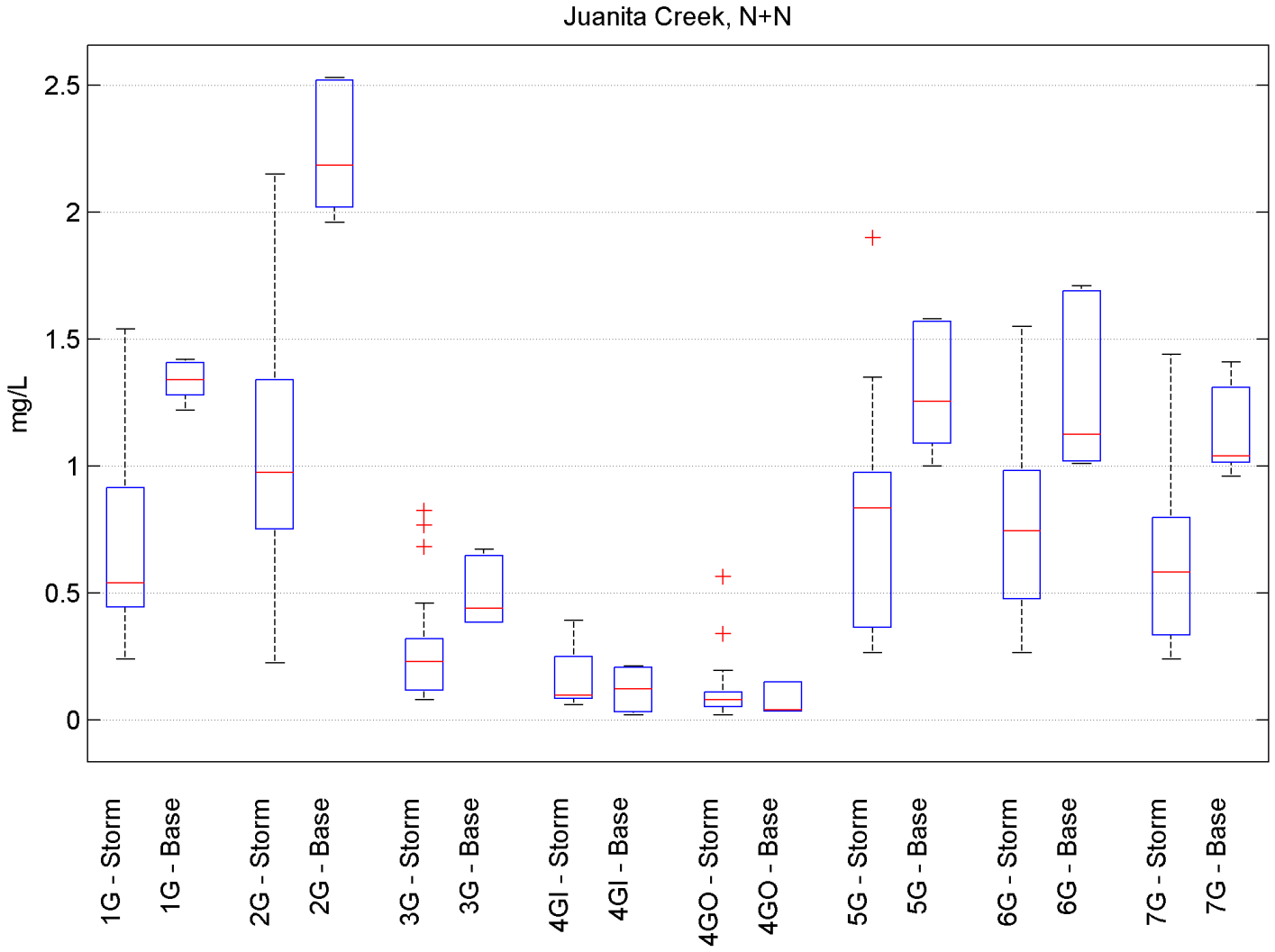

Juanita Creek, Conductivity
umhos/cm
250
200
150
100
50
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

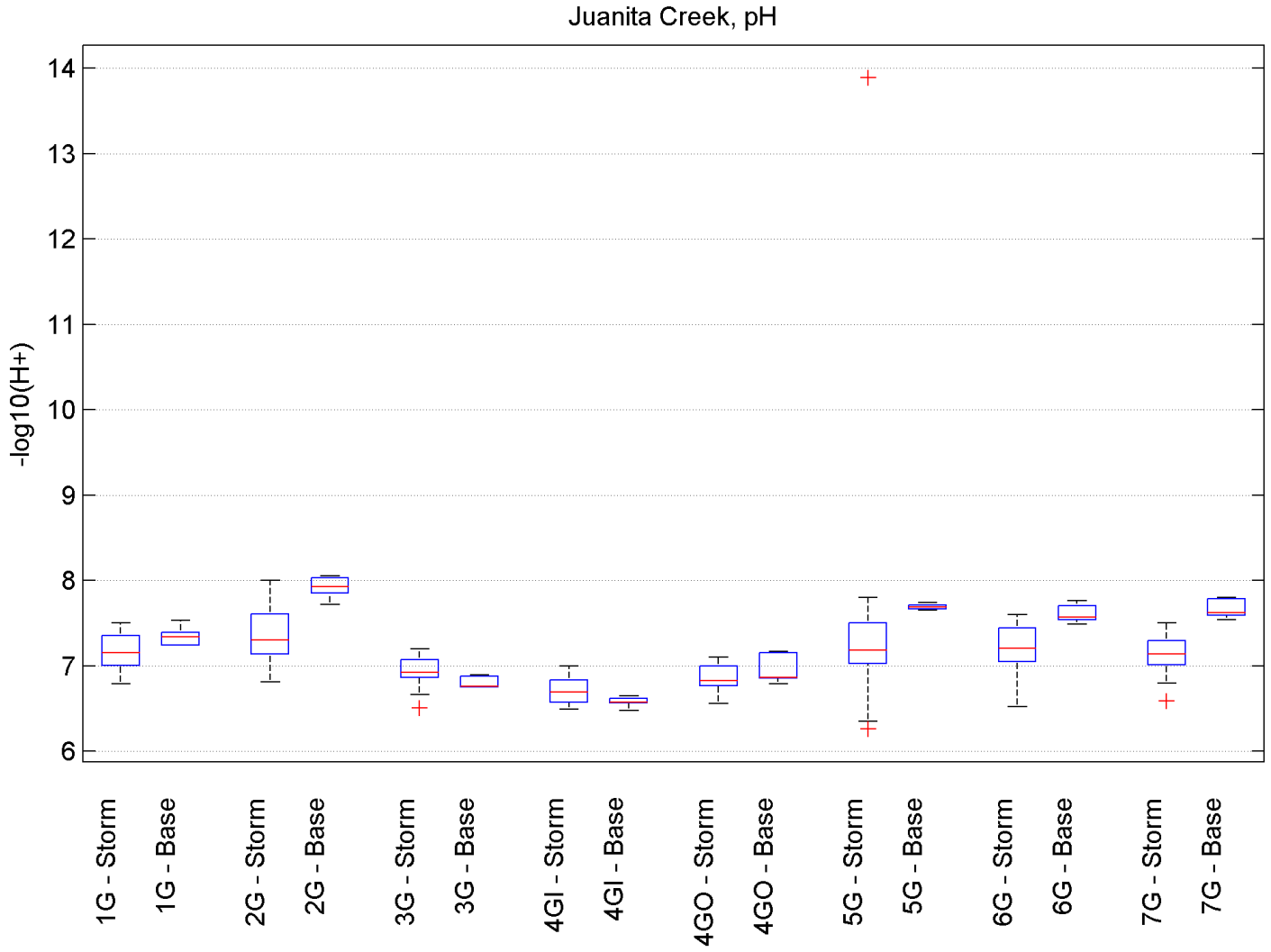

Juanita Creek, Dissolved Cu
ug/L
10^1
10^0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

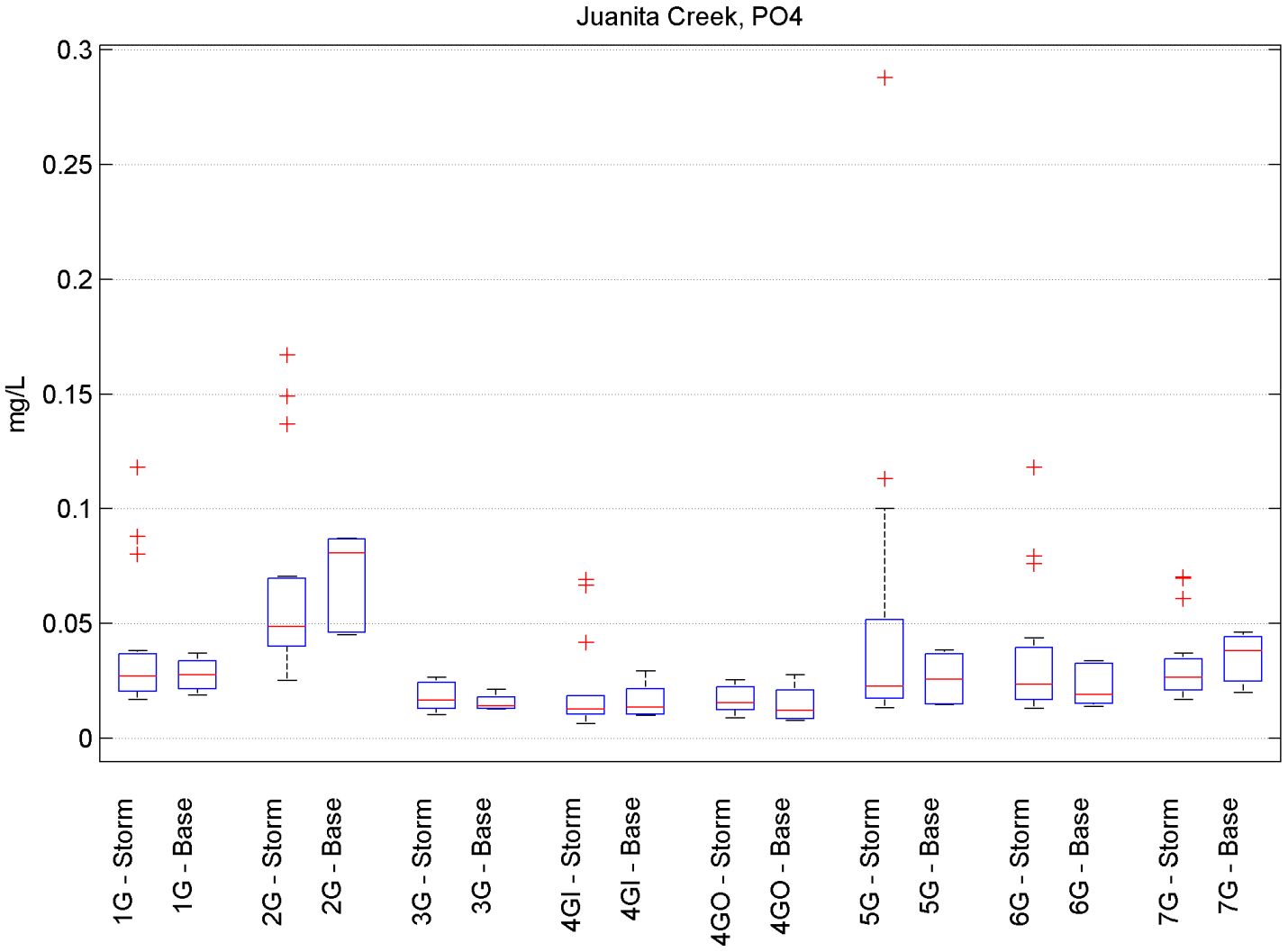

Juanita Creek, DO
mg/L
20
15
10
5
0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

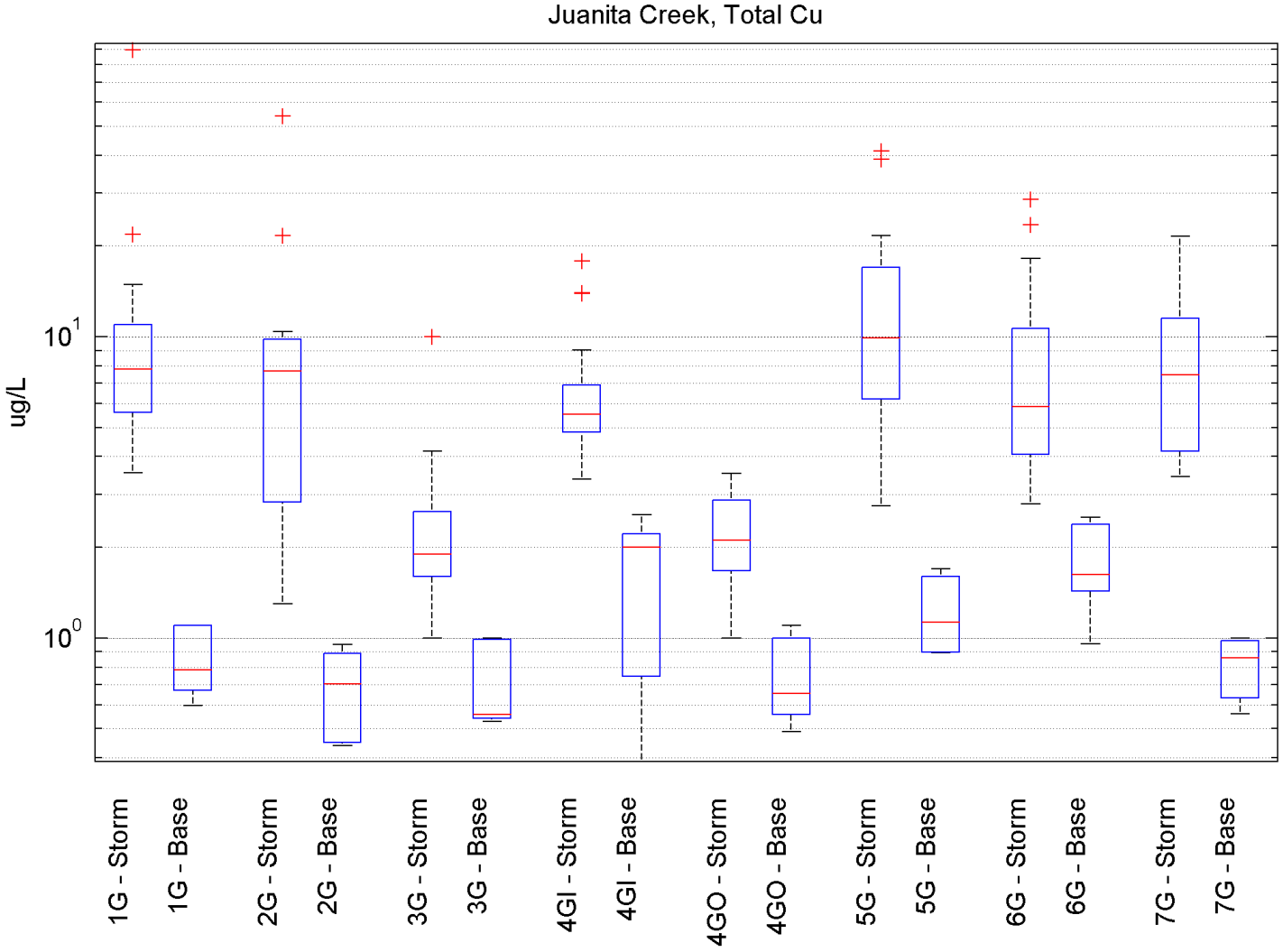

Juanita Creek, Dissolved Zn
ug/L
10^2
10^1
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

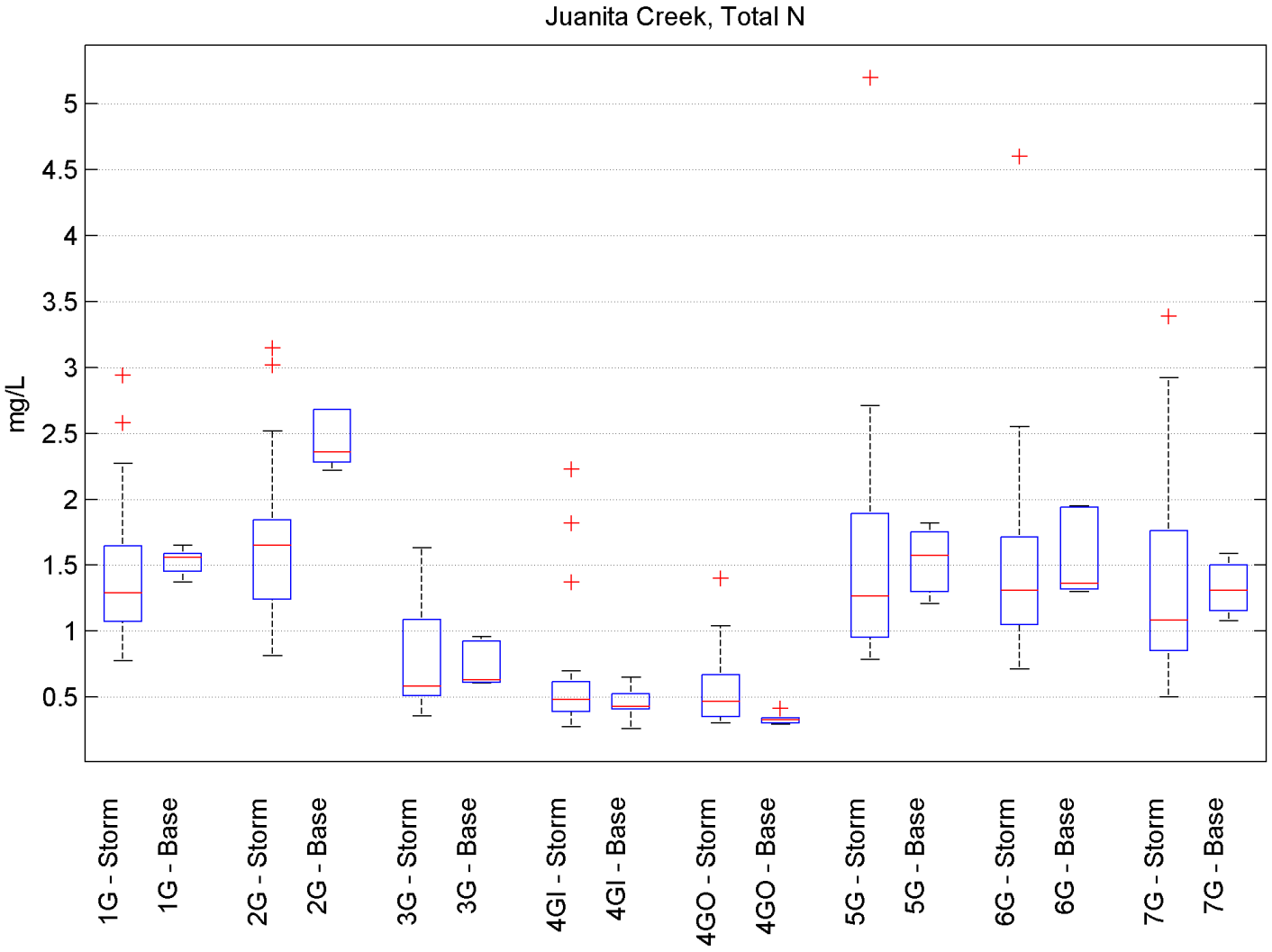

Juanita Creek, Fecal
cfu/100ml
10^4
10^3
10^2
10^1
10^0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

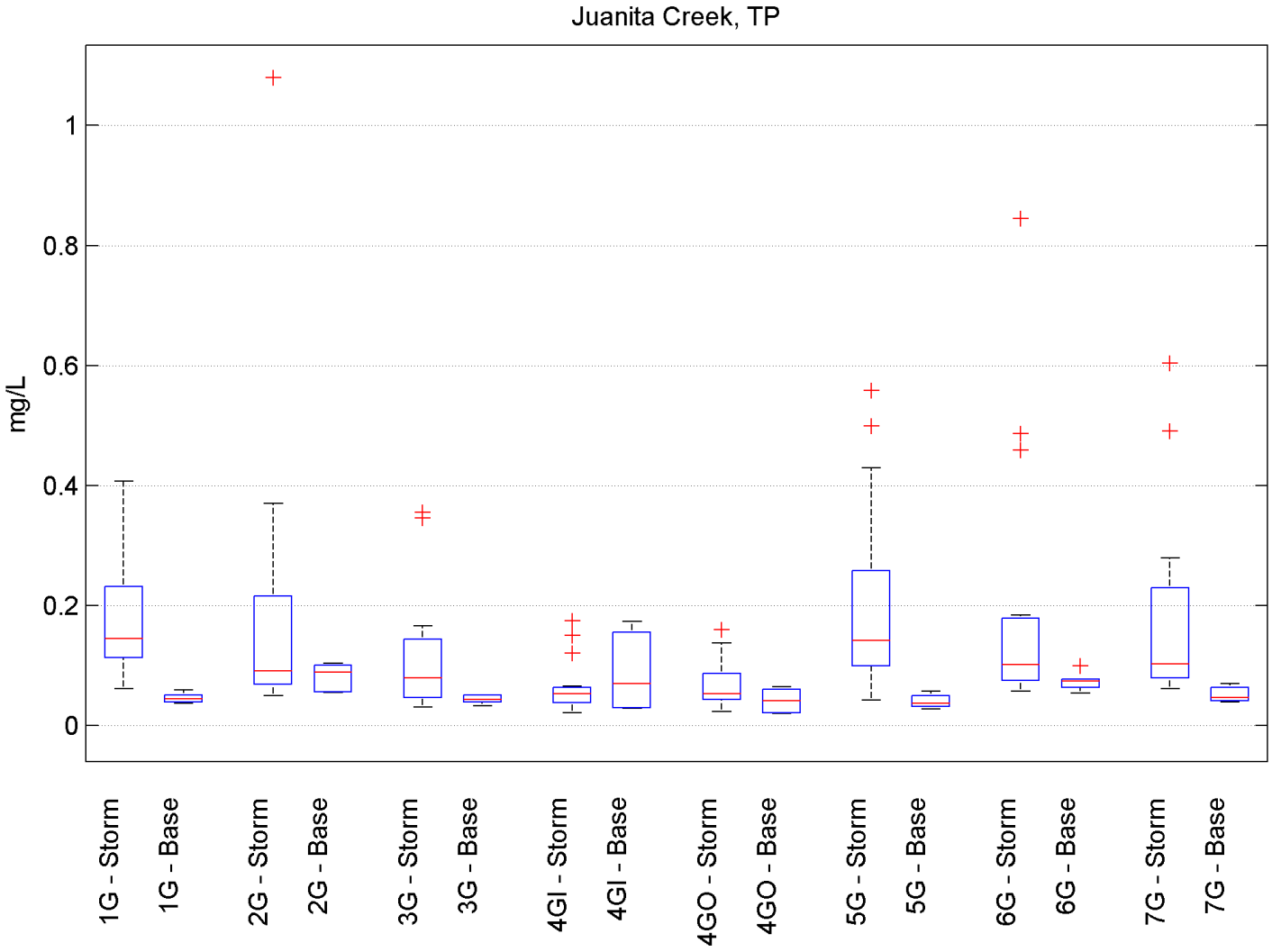

Juanita Creek, N+N
mg/L
2.5
2
1.5
1
0.5
0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

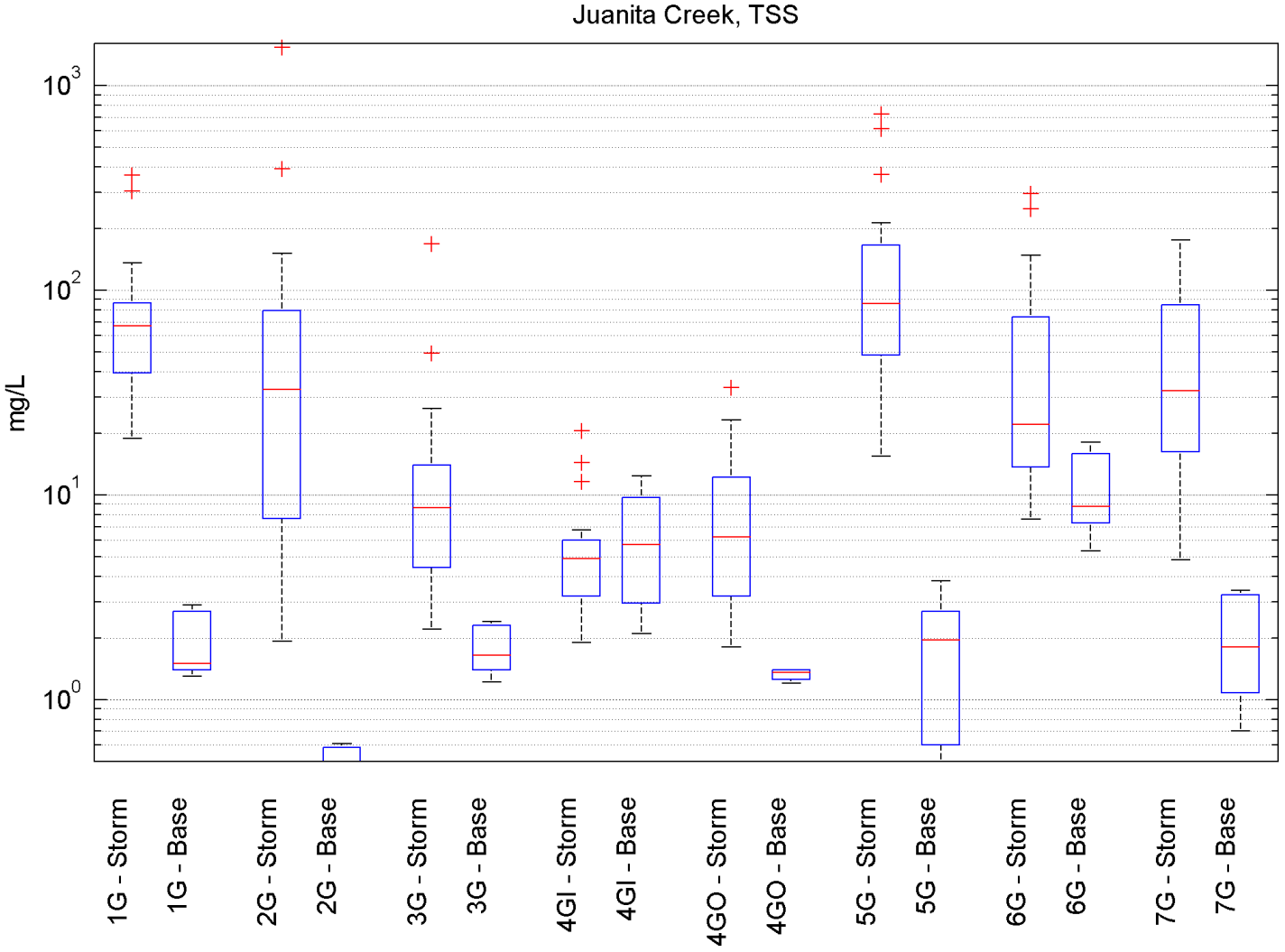

Juanita Creek, pH
-log10(H+)
14
13
12
11
10
9
8
7
6
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base

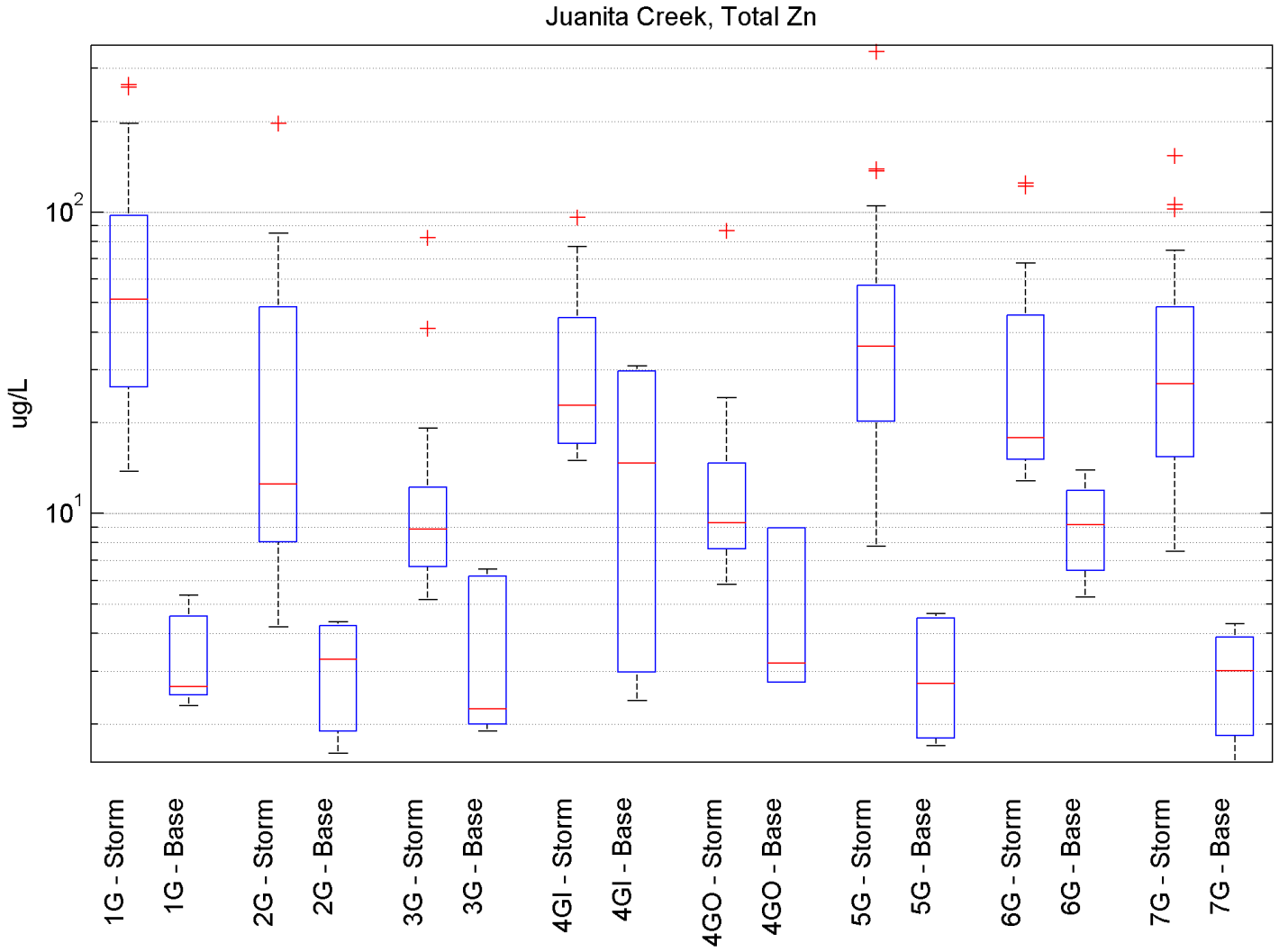

Juanita Creek, PO4
mg/L
0.3
0.25
0.2
0.15
0.1
0.05
0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base


Juanita Creek, Total Cu
ug/L
10^1
10^0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base


Juanita Creek, Total N
mg/L
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base


Juanita Creek, TP
mg/L
0
0.2
0.4
0.6
0.8
1
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base


Juanita Creek, TSS
mg/L
10^3
10^2
10^1
10^0
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base


Juanita Creek, Total Zn
ug/L
10^2
10^1
1G - Storm
1G - Base
2G - Storm
2G - Base
3G - Storm
3G - Base
4GI - Storm
4GI - Base
4GO - Storm
4GO - Base
5G - Storm
5G - Base
6G - Storm
6G - Base
7G - Storm
7G - Base