Section 5-6
Penjajawoc Stream (Penjajawoc Stream Team)

Refer to Chapter 4 of this document for information about sampling methods, sampling sites, and quality assurance.

Overview

In the fall of 2007, the City of Bangor and the Maine DEP VRMP Program organized a Volunteer Monitoring Team to monitor water quality in Penjajawoc Stream. Penjajawoc Stream is a small urban stream located in Bangor and Veazie, Maine. The Penjajawoc has a watershed area of 8.57 square miles, with headwaters in a vast marsh system north of Bangor. The stream then flows through the Bangor Mall before passing under highway I-95, then past Eastern Maine Community College, a vocational college, the Dorothea Dix Mental Health Center complex, and past a number of auto dealerships before it passes into residential area and the Penobscot River. Two principal tributaries, Meadow Brook and Cemetery Brook, join the stream in the lower watershed. The Penjajawoc is 5.2 miles long, while the tributaries- Meadow and Cemetery Brooks are 1.5 and 2.2 miles respectively. The Penjajawoc and Meadow Brook are listed as impaired due to urban Non-point Source Pollution, hydraulic alterations due to development, and habitat degradation. Specific impacts include dissolved oxygen is seasonally low, water is seasonally too warm, and aquatic communities are impaired. Bacterial contamination has been documented, but it is still unclear at this time if human or wildlife is the dominant source. The statutory water class of the Penjajawoc and Meadow Brook are Class B. As recently as 2009 a DEP biomonitoring assessment and a more inclusive assessment in 2008 showed that all sites failed to attain Class B standards.

The purpose of the Volunteer Monitoring Team is to assess water quality and to monitor progress as the City of Bangor makes stormwater retrofits in order to improve water quality. Eventually, the goal is for these streams to meet their water quality classification standards. The Penjajawoc Sampling and Analysis Plan states that the objectives of monitoring are to (1) develop baseline data; (2) provide information on current watershed conditions; and (3) monitor progress during the restoration process.

Methods

Since the first monitoring in the fall of 2007, the Penjajawoc Volunteer Monitoring Team volunteers have monitored seven historical stations on the main stem and one station each on the lower reaches of Meadow and Cemetery Brooks. In 2010, due to attrition of volunteers, only three main stem sites and the two tributary sites were monitored. In the spring and fall, stream sampling was timed to coincide with stormwater episodes. Specific conductance (or total dissolved solids (TDS)), water temperature, and turbidity were measured in the field. In the summer, volunteers took baseflow measurements of water temperature, specific conductance, and dissolved oxygen. Occasional summer samples were analyzed for E. coli bacteria. All of

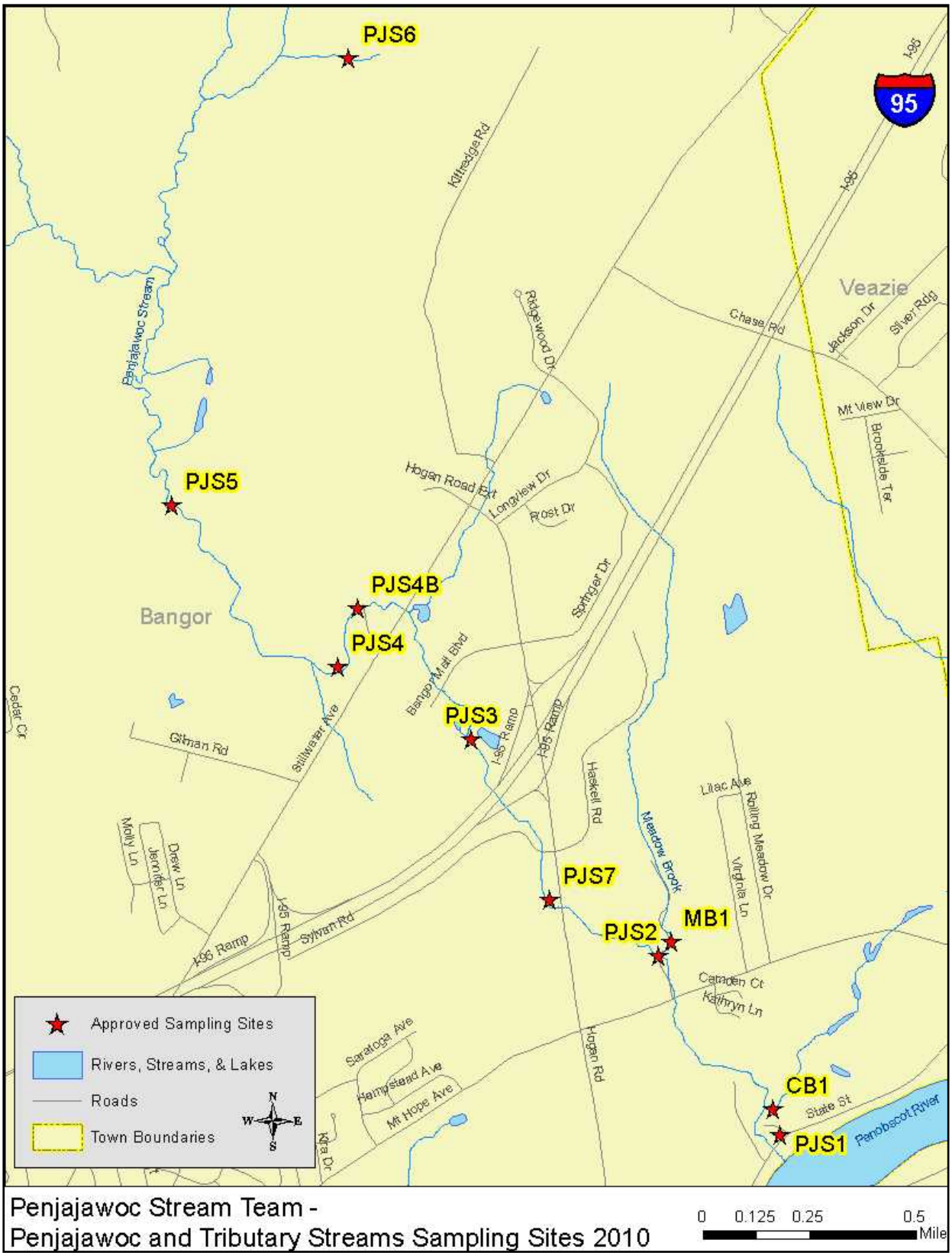
the Penjajawoc Stream Team sites are VRMP approved sites. Table 1 provides a list of the sites and Figure 1 is a map of sampling site locations.

Table 1: Sampling Sites

VRMP Site ID	Organization Site Code	Sample Location	Class
Penjajawoc Stream-PJS1-VRMP	PJS1	Above Route 2 bridge on Young St	B
Penjajawoc Stream-PJS2-VRMP	PJS2	Evergreen Woods above driveway bridge	B
Penjajawoc Stream-PJS4b-VRMP	PJS4b	Behind 33 Penn Plaza	B
Meadow Brook-MB1-VRMP	MB1	Above confluence with Penjajawoc Stream	B
Cemetery Brook-CB1-VRMP	CB1	Above confluence with Penjajawoc Stream	B

Monitoring was conducted from February 25 through December 14. Spring and fall samples were timed to catch stormwater events. Summer samples were essentially once a month to twice a month during baseflow conditions. At each site, the monitors made direct measurements of water temperature and dissolved oxygen using a LaMotte all-liquid Winkler titration kit. Conductivity was directly measured at the freshwater sites using an Oakton EC 11+ Testr conductivity pen (or some volunteers had Oakton TDS Testr 11 pens, TDS was converted to specific conductance for reporting). Grab samples were collected for E. Coli bacteria or turbidity analysis at the Bangor DEP office. DEP used the IDEXX system for E coli and a Hach 2100 P meter for assessing turbidity.

Figure 1: Map of Sampling Sites



Results

Dissolved Oxygen

Dissolved oxygen was measured irregularly at three sampling sites from June through September. Class B standards for dissolved oxygen are a minimum of 7 mg/l (milligrams/liter) or 75% saturation, whichever is higher. Table 2 and Table 3 provide a summary of dissolved oxygen concentration and % saturation for each site including minimum, maximum and average values.

Table 2: Dissolved Oxygen Concentration (mg/l) Summary

Site	Approved Site	# of Samples	Minimum Value	Maximum Value	Average
PJS1	Y	0			
PJS2	Y	4	4.25	8.6	7.3
PJS4b	Y	10	5.4	9.7	8.1
MB1	Y	4	3.8	8	6
CB1	Y	0			

Table 3: Dissolved Oxygen Saturation (%) Summary

Site	Approved Site	# of Samples	Minimum Value	Maximum Value	Average
PJS1	Y	0			
PJS2	Y	4	53	93	81
PJS4b	Y	10	64	88	80
MB1	Y	4	41	83	60
CB1	Y	0			

Dissolved oxygen concentrations measured at main stem and tributary sites ranged from 3.8 milligrams/liter to 9.7 mg/l. All sites with measurements for 2010 had some values below the Class B standard of 7.0 milligrams/liter. Dissolved oxygen percent saturation ranged from 53% to 93%. All sites with measurements for 2010 also had some values below the Class B standard of 75% saturation. All of the measurements below 75% saturation occurred in July. Four mg/L of oxygen is mentioned in fisheries literature as a threshold for survival for many fish and invertebrates. Dissolved oxygen is strongly influenced by flow conditions. During high flow conditions, more oxygen is added to the river from the atmosphere, as the water is moving faster and there is more opportunity for mixing. If summer flows are higher or lower than normal, then this will affect the dissolved oxygen.

Water Temperature

Temperature was measured about a dozen times at three sampling sites. Monitoring occurred from February through December. Maine's Regulations Relating to Temperature (06-096 CMR Chapter 582) require that discharge of pollutants not raise the temperature of any river and

stream above the EPA criteria for indigenous species (23°C maximum and 19°C weekly average) or 0.3°C (0.5°F) above the temperature that would naturally occur outside a mixing zone established by the Board of Environmental Protection. Pollutant is defined in statute as many things including dirt, excess heat, and toxic chemicals.

Table 4 provides a summary of temperature values for each site including minimum, maximum and average values.

Table 4: Temperature (˚ Celsius)

Site	Approved Site	# of Samples	Minimum Value	Maximum Value	Average
PJS1	Y	0			
PJS2	Y	12	0	27	11.1
PJS4b	Y	13	1	24	12.5
MB1	Y	11	0	17	8
CB1	Y	0			

Temperatures measured at three Penjajawoc Stream sites ranged from 0˚C to 27˚C. Meadow Brook site MB1 was consistently colder than mainstem sites. The lower mainstem site PJS2 was the warmest with temperatures as high as 27ºC. The warmest days of the year were in early July and early September. July and August rainfall totals were more than one inch below normal precipitation for those months.

Specific Conductance

Specific conductance was measured about a dozen times at three sites and only once at two sites. Monitoring occurred from February through December. Specific conductance is a measure of the amount of dissolved materials in the water (and it is interconvertable with total dissolved solids, or TDS). While there are no numerical standards, a relationship exists between conductivity and chloride which does have numerical criteria. In general, streams located in urban areas tend to have high specific conductance due to polluted urban stormwater runoff. This may also in large part be due to salt buildup in surface and groundwater from road maintenance practices. Table 5 provides a summary of specific conductance values for each site including minimum, maximum and average values.

Table 5: Specific Conductance (micro-Siemens/centimeter) Summary

Site	Approved Site	# of Samples	Minimum Value	Maximum Value	Average
PJS1	Y	1	165	165	165
PJS2	Y	12	184	1540	835
PJS4b	Y	13	89	1615	758
MB1	Y	11	311	1720	946
CB1	Y	1	130	130	130

Meadow Brook has the highest average specific conductance. Lab tests have confirmed that sodium chloride (road salt) is the dominant dissolved substance. There are weeks at a time in the spring when both chronic and acute State water quality standards for chloride are exceeded due to road salt contamination. Because the minimum value is also high, it is apparent that groundwater has been contaminated by road salt. Based on measurements in the Penjajawoc Marsh from previous years, the normal specific conductance for this watershed was probably around 115 uS before there was major development in the middle and lower watersheds. Cemetery Brook has the lowest average specific conductance. This watershed is dominated by the Mount Hope Cemetery and has the highest total forest cover. It also has the least impermeable cover (buildings and roads) and appears to have very little contamination from road salt.

Bacteria

E. coli bacteria were measured infrequently in February and March during stormwater flow events. Most if not all samples were taken during baseflow conditions. While these bacteria are not usually pathogenic, their presence indicates fecal contamination and potential pathogens.

Class B criteria for bacteria are as follows: "Between May 15th and Sept 30th, E. Coli of human and domestic origin shall not exceed a geometric mean of 64 colonies per 100 ml (milliliters) or an instantaneous level of 236/100 ml." Table 6 provides a summary of bacteria values for each site including minimum, maximum and geometric means. Geometric means are used instead of averages because measures like bacteria often have a few very large values that strongly influence the mean and make it a poor predictor.

Table 6: Bacteria Most Probable Number (MPN per 100 ml sample) Summary

Site	Approved Site	# of Samples	Minimum Value	Maximum Value	Geometric Mean
PJS1	Y	1	28	28	28
PJS2	Y	3	28	387	152
PJS4b	Y	1	15	15	15
MB1	Y	3	6	115	36
CB1	Y	1	31	31	31

In 2010, only one of the Penjajawoc at Evergreen Woods samples appears to have exceeded the statutory standard. Actually, we have no way of knowing if the bacteria were from human origins, domestic animals, or from wildlife. Furthermore, the number of samples is too few to make any statistically meaningful conclusions.

Turbidity

Turbidity was primarily measured in the late winter and early spring (February and March) or in the fall (October to December) during high flows, or at any other time when cloudiness was

observed in the water. Maine has no statutory criteria for turbidity, but streams are supposed to support native wildlife, including native fishes. The impacts of turbidity are measured by a combination of intensity (measured in NTU) and duration (hours, days or weeks). Negative impacts on aquatic organisms are expected when the intensity is greater than 10 NTU and the conditions last for weeks, or if the intensity is higher than about 100 NTU for many hours at a time. Table 7 gives the number of samples, minimum and maximum values, and averages for turbidity for all 2010 samples.

Table 7: Turbidity Summary in NTU

Site	Approved Site	# of Samples	Minimum Value	Maximum Value	Average
PJS1	Y	1	21	21	21
PJS2	Y	11	6	134	56
PJS4b	Y	4	2	17	8
MB1	Y	12	9	794	303
CB1	Y	1	25	25	25

Our data is from volunteer grab samples and does not provide information about the duration of the problem. However, we believe that the observed turbidities are high enough, occur over a long enough period, and are repeated frequently enough to be harmful for aquatic plants and animals.

Discussion and Recommendations

There are numerous sources of pollution and other stresses to the Penjajawoc sites monitored by the Penjajawoc Volunteer Monitoring Team that could potentially have an impact on water quality. Some of those sources of pollution and stress may include:

- Nonpoint source pollution (e.g., eroded soil, fertilizers, pesticides, heavy metals, petroleum residues, road salt, septic systems, wildlife and pet feces) and polluted stormwater originating from urban
- Impervious surfaces (e.g., streets, parking lots, driveways, rooftops), agriculture, and forestry
- Ponds and impoundments (which often create more pond-like aquatic habitat conditions that may have higher water temperatures and lower dissolved oxygen concentrations than free-flowing waters)
- Natural effects of wetlands (such as contributing waters to a stream/river that have low dissolved oxygen levels due to the decomposition of large amounts of organic matter, respiration of abundant plant matter, and low re-aeration rates that is characteristic of many wetlands).

Some of the objectives of the Penjajawoc Volunteer Monitoring Team have been achieved to date. Since 2008, the first full year of monitoring, the VRMP program has established a good baseline and has been able to accurately characterize the current water quality conditions. A

number of problems have been identified. The remaining mission of the Monitoring Team is to document changes as the stormwater collection system is up-graded and modernized.

The following are recommendations for future monitoring:

- Monitoring should include some early morning (before 8:00 am) sampling to document potential dissolved oxygen problems. Over a 24 hour period, the lowest readings occur in the early morning and highest readings in mid to late afternoon. This occurs because oxygen is used up during the night due to plant respiration and during the day, plant life is photosynthesizing. This is particularly important during the summer months of July to early September when temperatures are warmest and dissolved oxygen tends to be at the lowest levels.
- If very high specific conductance values are found again, the monitors may want to do some specific conductance readings in the river above the high values to see if a source can be found.
- Further study of the high bacteria may be warranted.
- The Volunteer Monitoring Team can do some macroinvertebrate monitoring to see if indicator species, such as stoneflies, will establish themselves. The Izaak Walton League Save our Streams Program has some appropriate protocols for volunteer groups.

Appendix A. 2010 water quality data for "Approved" and "Non-Approved" sites. Non-Approved sites do not yet meet official VRMP sample location criteria and/or require further inspection and review.
* Sampling depths are only reported for Tier 1 VRMP sites.
** "N" = normal environmental sample ; "D" = field duplicate; "D.O." = dissolved oxygen; "Spec. Cond" = specific conductance; "TDS" = total dissolved solids"
"TSS" = total suspended solids

Organization Site Code	Stream	Site	Date	Time	Flow	Sample Strategy	Stage Depth	Water Temp (DEG C)	Spec. Cond. (US/CM)	TDS	Chloride (MG/L)	DO %Sat	DO (MG/L)	Turb (NTU)	Inferred TSS	E. coli Bacteria (MPN/ 100 ml)	Rain (in) in last 7 days	Water Appear.	Notes
Penjajawoc Stream & Tributaries - City of Bangor & Volunteer Monitoring Team (Approved Sites)																			
CB-1	Cemetery Br	Young St	3/24/2010	4:30	Storm-water	Event	Medium		130	92	29			25	26	30.5	rain and snow	day after big storm	
MB-1	Meadow Br	Evergreen Woods	2/25/2010	9:00	Storm-water	Event	Medium	0.5	1068	755	275			763	725	114.5	rain and snow	1 inch of rain overnight	split sample
MB-1	Meadow Br	Evergreen Woods	2/25/2010	9:00	Storm-water	Event	Medium							794	754	95.9	rain and snow	turbid after about 1 inch of rain	split sample
MB-1	Meadow Br	Evergreen Woods	2/25/2010	9:00	Storm-water	Event	Medium							771	733		rain and snow	turbid after about 1 inch of rain	split sample
MB-1	Meadow Br	Evergreen Woods	2/26/2010	17:15	Storm-water	Event	High	0	593	420	151			135	130		rain	turbid and muddy	after 2 inches rain
MB-1	Meadow Br	Evergreen Woods	2/26/2010	17:15	Storm-water	Event	High							138	133				split sample
MB-1	Meadow Br	Evergreen Woods	3/23/2010	9:25	Storm-water	Event	Medium	4.2	1720	1216	447			528	502	66.3	rain	muddy	true duplicates
MB-1	Meadow Br	Evergreen Woods	3/23/2010	9:25	Storm-water	Event	Medium							519	494				true duplicates
MB-1	Meadow Br	Evergreen Woods	3/23/2010	17:30	Storm-water	Event	High	4	452	320	113			683	649		rain	muddy brown	sample taken just after storm
MB-1	Meadow Br	Evergreen Woods	3/23/2010	17:30	Storm-water	Event	High							710	675				split sample
MB-1	Meadow Br	Evergreen Woods	3/24/2010	8:30	Storm-water	Event	High	3	537	380	136			72	70	6.3		day after big storm	
MB-1	Meadow Br	Evergreen Woods	3/24/2010	8:30	Storm water	Event	High							77	75				split sample
MB-1	Meadow Br	Evergreen Woods	7/11/2010	11:25	Base-flow	Weekly	Low	17	1243	880	322	41	4				cloudy and light rain		
MB-1	Meadow Br	Evergreen Woods	7/29/2010	16:00	Base-flow	Weekly	Low	16	1040	735	268	81	8						
MB-1	Meadow Br	Evergreen Woods	7/29/2010	8:30	Base-flow	Weekly	Low	13.5	1554	1100	403	37	3.8						
MB-1	Meadow Br	Evergreen Woods	8/26/2010	11:30	Base-flow	Weekly	Medium	17	1229	870	318	83	8				rain in last 24 hrs		
MB-1	Meadow Br	Evergreen Woods	10/2/2010	9:30	Storm-water	Event	High							13	15		after 1.3 inches rain in		
MB-1	Meadow Br	Evergreen Woods	10/15/2010	9:30	Storm-water	Event	High							29	30		after 1 inches rain in Bangor		
MB-1	Meadow Br	Evergreen Woods	10/16/2010	9:20	Storm-water	Event	High							9	11		the day after large storm		
MB-1	Meadow Br	Evergreen Woods	11/5/2020	8:30	Storm-water	Event	High							30	31		after 2 inches rain		

Organization Site Code	Stream	Site	Date	Time	Flow	Sample Strategy	Stage Depth	Water Temp (DEG C)	Spec. Cond. (US/CM)	TDS	Chloride (MG/L)	DO %Sat	DO (MG/L)	Turb (NTU)	Inferred TSS	E. coli Bacteria (MPN/ 100 ml)	Rain (in) in last 7 days	Water Appear.	Notes
MB-1	Meadow Br	Evergreen Woods	11/8/2010	8:20	Storm-water	Event	Very High							98	95		after 2 inches rain		
MB-1	Meadow Br	Evergreen Woods	11/9/2010	7:25	Storm-water	Event	High	7.5	353	250	87			16	17		looks clear today, the day		
MB-1	Meadow Br	Evergreen Woods	12/13/2010	16:05	Storm-water	Event	Very Hi	5.5	311	220	76			63	62		during heavy weather, > 2		
PJS-1	mainstem	Young St	3/24/2010	4:30	Storm-water	Event	Medium		165	117	38			21	22	27.5	rain and snow	day after big storm	
PJS-2	mainstem	Evergreen Woods	2/25/2010	9:00	Storm-water	Event	Medium	2.9	1280	905	331			115	111	387.3	rain and snow	1 inch of rain overnight	
PJS-2	mainstem	Evergreen Woods	2/25/2010	9:00	Storm-water	Event	Medium							107	104	235.9	rain and snow	turbid after about 1 inch of rain	split sample
PJS-2	mainstem	Evergreen Woods	2/25/2010	9:00	Storm-water	Event	Medium							120	116		rain and snow	turbid after about 1 inch of rain	split sample
PJS-2	mainstem	Evergreen Woods	2/26/2010	17:00	Storm-water	Event	High	0	452	320	113			16	17		rain	turbid and muddy, 0.66	after 2 inches rain
PJS-2	mainstem	Evergreen Woods	2/26/2010	17:00	Storm-water	Event	High							19	20				split sample
PJS-2	mainstem	Evergreen Woods	3/23/2010	9:30	Storm-water	Event	Medium	5.3	1161	821	300			127	123	325.5	rain	muddy	true duplicates
PJS-2	mainstem	Evergreen Woods	3/23/2010	9:30	Storm-water	Event	Medium							134	129	272.2			true duplicates
PJS-2	mainstem	Evergreen Woods	3/23/2010	17:20	Storm-water	Event	High	4.5	466	330	117			115	111		rain	light brown and muddy, very high	sample taken just after storm
PJS-2	mainstem	Evergreen Woods	3/23/2010	17:20	Storm-water	Event	High							121	117				split sample
PJS-2	mainstem	Evergreen Woods	3/24/2010	8:45	Storm-water	Event	High	4.5	382	270	95			12	14	27.9		day after big storm	
PJS-2	mainstem	Evergreen Woods	3/24/2010	8:45	Storm-water	Event	High							13	15				split sample
PJS-2	mainstem	Evergreen Woods	7/11/2010	11:25	Baseflow	Weekly	Low	23	636	450	162	93	8				cloudy and light rain		
PJS-2	mainstem	Evergreen Woods	7/16/2010	8:50	Base-flow	Weekly	Low	22.4	1453	1027	377								bug collection day
PJS-2	mainstem	Evergreen Woods	7/29/2010	15:45	Base-flow	Weekly	Low	27	1040	735	268	53	4.25						
PJS-2	mainstem	Evergreen Woods	8/12/2010	8:30	Base-flow	Weekly	Low	16	1908	1350	496	85	8.4						
PJS-2	mainstem	Evergreen Woods	8/26/2010	11:45	Base-flow	Weekly	Medium	19	791	560	203	93	8.6				cloudy, light rain in last 24	air temp 70 F	
PJS-2	mainstem	Evergreen Woods	10/2/2010	9:15	Storm water	Event	High							8	10		after 1.3 inches rain in		
PJS-2	mainstem	Evergreen Woods	10/15/2010	9:30	Storm-water	Event	High							15	16		after 1 inches rain in Bangor		
PJS-2	mainstem	Evergreen Woods	10/16/2010	9:30	Storm-water	Event	High							6	8		the day after large storm		
PJS-2	mainstem	Evergreen Woods	11/5/2020	8:30	Storm-water	Event	High							15	16		after 2 inches rain		

Organization Site Code	Stream	Site	Date	Time	Flow	Sample Strategy	Stage Depth	Water Temp (DEG C)	Spec. Cond. (US/CM)	TDS	Chloride (MG/L)	DO %Sat	DO (MG/L)	Turb (NTU)	Inferred TSS	E. coli Bacteria (MPN/ 100 ml)	Rain (in) in last 7 days	Water Appear.	Notes
PJS-2	mainstem	Evergreen Woods	11/8/2010	8:20	Storm-water	Event	Very High							37	37		after 2 inches rain		
PJS-2	mainstem	Evergreen Woods	11/9/2010	7:25	Storm-water	Event	High	5.5	184	130	43			8	10		looks clear today, the day		
PJS-2	mainstem	Evergreen Woods	12/13/2010	16:15	Storm-water	Event	Very Hi	3	268	190	65			20	21		during heavy weather, > 2		
PJS-4b	mainstem	33 Penn Plaza	2/26/2010	9:58	Storm-water	Event	High	1	230	163	55			5	7		rain	clear	after 2 inches rain
PJS-4b	mainstem	33 Penn Plaza	3/23/2010	14:35	Storm-water	Event	High	6	250	177	60			14	15	14.5	rain	milky 1.44 inches of rain by 4:30	true duplicates
PJS-4b	mainstem	34 Penn Plaza	3/23/2010	14:35	Storm-water	Event	High							17	18	15.8			true duplicates
PJS-4b	mainstem	33 Penn Plaza	6/26/2010	10:01	Base-flow	Weekly	Low	19	500	354	126	80	7.4				light rain		
PJS-4b	mainstem	33 Penn Plaza	7/4/2010	10:55	Base-flow	Weekly	Low	18	654	462	167	87	8.2				clear and dry		
PJS-4b	mainstem	33 Penn Plaza	7/10/2010	14:45	Base-flow	Weekly	Low	24	225	159	54	64	5.4						
PJS-4b	mainstem	33 Penn Plaza	7/29/2010	9:45	Base-flow	Weekly	Low	18	930	658	239	78	7.4				school of fish noted		
PJS-4b	mainstem	33 Penn Plaza	8/19/2010	7:52	Base-flow	Weekly	Low	12.5	1365	965	353	79	8.4						
PJS-4b	mainstem	33 Penn Plaza	8/25/2010	9:30	Base-flow	Weekly	Low	13	122	86	27	88	9.3				cloudy		
PJS-4b	mainstem	33 Penn Plaza	8/31/2010	8:17	Base-flow	Weekly	Low	12.5	1300	919	336	78	8.3						
PJS-4b	mainstem	33 Penn Plaza	9/2/2010	7:45	Base-flow	Weekly	Low	13	1615	1142	419	78	8.2				clear		
PJS-4b	mainstem	33 Penn Plaza	9/9/2010	9:40	Base-flow	Weekly	Low	14	1260	891	326	83	8.5				cloudy, light rain in last 24		
PJS-4b	mainstem	33 Penn Plaza	9/16/2010	8:45	Base-flow	Weekly	Low	10.5	1313	928	340	87	9.7						
PJS-4b	mainstem	33 Penn Plaza	10/2/2010	9:00	Storm-water	Event	High							2	4		after 1.3 inches rain in		
PJS-4b	mainstem	33 Penn Plaza	10/16/2010	9:07	Storm-water	Event	High							2	4		the day after large storm		
PJS-4b	mainstem	33 Penn Plaza	12/14/2010	9:35	Storm-water	Event	Very Hi	1	89		18			7	9		after 3.2 inches rain		