Technical Memorandum CN 325.2

BLACKSTONE RIVER WATERSHED
2008 BENTHIC MACROINVERTEBRATE BIOASSESSMENT

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INTRODUCTION

Biological monitoring is a useful means of detecting anthropogenic impacts to the aquatic community. Resident biota (e.g., benthic macroinvertebrates, fish, periphyton) in a water body are natural monitors of environmental quality and can reveal the effects of episodic and cumulative pollution and habitat alteration (Barbour et al. 1995, Plafkin et al. 1989).

As part of the Massachusetts Department of Environmental Protection/Division of Watershed Management's (MassDEP/DWM) 2008 Blackstone River Watershed assessment, aquatic benthic macroinvertebrate biomonitoring was conducted to evaluate the biological health of selected stream reaches that comprise both the tributaries and the mainstem to determine their status with respect to the support of the *Aquatic Life* use, as designated in the *Massachusetts Surface Water Quality Standards* (SWQS) (MassDEP 2006). These assessments form the basis for reporting and listing waters pursuant to sections 305(b) and 303(d) of the Clean Water Act (CWA). A total of fifteen stations were sampled to investigate the effects of potential point and nonpoint sources of pollution—both historical and current—on the aquatic invertebrate populations throughout the watershed. While specific monitoring locations and protocols governing sample collection and data analysis differed over time, MassDEP biologists had previously assessed some of the streams studied in 2008 (Fiorentino 2000, 2006). Repeated sampling at the same station allows for comparisons of the biological conditions over time. The 2008 sampling location descriptions, along with station identification numbers, sampling dates and biomonitoring history are presented in Table 1. A map of benthic sampling locations is provided in Figure 1.

To provide information for making *Aquatic Life* use-support determinations, macroinvertebrate communities present at biomonitoring stations in the Blackstone River Watershed were compared with the community occurring at a watershed reference station. The Mumford River (B0091) was used as the reference station in 1998, and again in 2003. It is also used as the reference for the 2008 Blackstone River Watershed Assessment. The Mumford River (B0091) has no NPDES discharges contributing to its flow, has one-percent impervious cover, and is second only to Tinkerville Brook (B0659) in the Human Disturbance Index (HDI) score (Meek 2013) (Table 2). While it is true that the reach habitat score (100 meters) is greater at the mainstem Blackstone station B0660, there are 33 NPDES discharges contributing to its flow. When the measurements reported in Table 2 are considered in their entirety, the Mumford River (B0091) is the best choice for a reference station.

METHODS

Macroinvertebrate Sampling - RBPIII

Macroinvertebrate sampling activities employed for the 2008 Blackstone River Watershed survey were conducted in accordance with the Sampling & Analysis Plan (SAP) for the Blackstone River Watershed (MassDEP 2008). The sampling procedures are described in the standard operating procedures *Water Quality Monitoring in Streams Using Aquatic Macroinvertebrates* (Nuzzo 2003), and are based on US EPA Rapid Bioassessment Protocols (RBPs) for wadeable streams and rivers (Plafkin et al. 1989). The macroinvertebrate collection procedure utilized kick-sampling, a method of sampling benthic organisms by kicking or disturbing bottom sediments and catching the dislodged organisms in a net as the current carries them downstream. Sampling was conducted by MassDEP/DWM biologists throughout a 100 m reach, in riffle/run areas with fast currents and rocky (cobble, pebble, and gravel) substrates—generally the most productive habitats, supporting the most diverse communities in the stream system. Ten kicks in squares approximately 0.46 m x 0.46 m were composited for a total sample area of about 2 m^2. Samples were labeled and preserved in the field with denatured 95% ethanol, then brought to the MassDEP/DWM lab for further processing.

Macroinvertebrate Sample Processing and Data Analysis

The macroinvertebrate sample processing and analysis procedures employed for the 2008 Blackstone River Watershed biomonitoring samples are described in the standard operating procedures (Nuzzo 2003). Macroinvertebrate sample processing entailed distributing whole samples in pans, randomly selecting grids within the pans, and sorting specimens from the other materials in the sample until

Table 1. List of biomonitoring stations sampled during the 2008 Blackstone River watershed survey, including station and unique identification numbers, drainage areas, sampling site descriptions, and sampling dates.

Stream Name	Unique ID	Latitude Longitude	Sampling Site Description	Sampling Date
Cook Allen Brook	B0656	42.117514 -71.719847	~100 meters downstream/northeast from Mendon Road crossing, upstream of Reservoir #4, Sutton	8-JUL-2008
Kettle Brook[1]	B0100	42.262389 -71.89673	~ 300 meters downstream/south from Earle Street, Leicester, MA	9-JUL-2008
Tinkerville Brook	B0659	42.016789 -71.719714	at driveway crossing ~100 meters downstream of Hemlock Street, Douglas	8-JUL-2008
Unnamed Tributary to Middle River[1]	B0101	42.259773 -71.847506	unnamed Middle River tributary ~300 meters downstream/south from June Street, Worcester, MA	9-JUL-2008
West River[1]	B0092	42.150106 -71.616387	~40 meters upstream/northwest from West River Street, Upton, MA	8-JUL-2008
Mumford River[R 1 2]	B0091	42.075581 -71.725336	~125 meters downstream/south from Manchaug Street, Douglas, MA	7-JUL-2008
Quinsigamond River	B0658	42.230201 -71.710902	at USGS gage #01110000, downstream of Hovey Pond outlet, west of Route 140, Grafton	9-JUL-2008
Mill River[1]	B0089	42.039301 -71.514262	~ 200 meters downstream/southeast from Park Street, Blackstone, MA	7-JUL-2008
Unnamed Tributary to Middle River[1]	B0098	42.234408 -71.838378	unnamed Middle River tributary ~500 meters downstream/northwest from Webster Street, Worcester, MA	9-JUL-2008
Mumford River	B0272	42.084396 -71.695288	~100 meters downstream/east from confluence with Gilboa Brook, Uxbridge, MA (~300 meters downstream/northeast from Gilboa Pond)	10-JUL-2008
Middle River[1]	B0097	42.241737 -71.803135	~500 meters downstream/east from McKeon Road, Worcester, MA (downstream/south of Riley Research)	9-JUL-2008
Blackstone River	B0661	42.192425 -71.767152	~170 meters downstream of Water Street, Millbury	8-JUL-2008
Blackstone River[1]	B0093	42.154986 -71.653909	~150 meters upstream/northwest from Sutton Street, Northbridge, MA	8-JUL-2008
Blackstone River[1 2]	B0090	42.026244 -71.581848	~30 meters upstream/northwest from Central Street, Millville, MA (in southern most channel)	7-JUL-2008
Blackstone River	B0660	42.013379 -71.552837	~245 meters downstream/south of the Stone Diversion Dam (west of Country Street, Blackstone), sampled in Rhode Island.	7-JUL-2008

Notes:
R = 2008 Reference Site
1 = 1998 Benthic Station
2 = 2003 Benthic Station

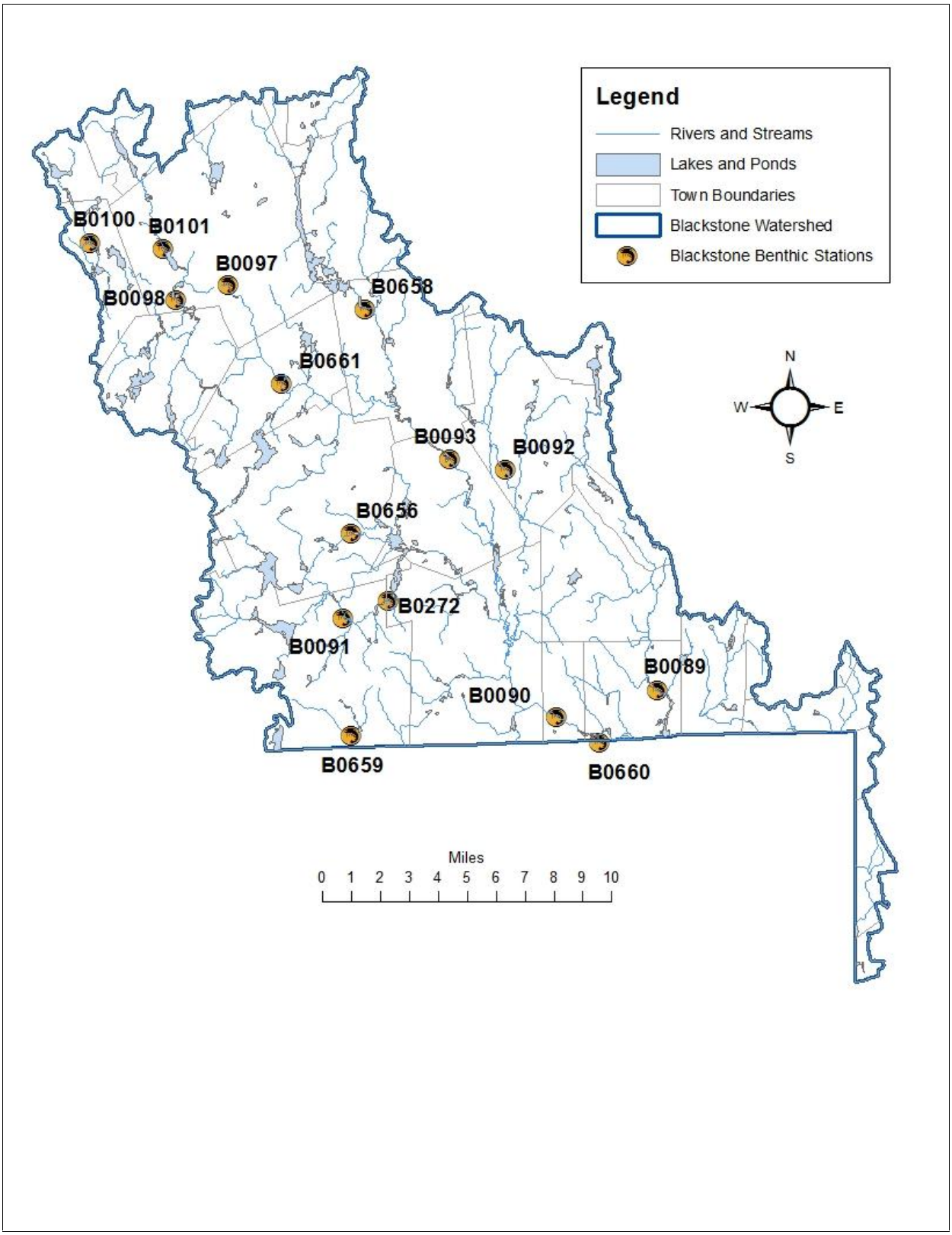

Figure 1. Geographic locations of benthic macroinvertebrate sampling locations during the 2008 Blackstone River Watershed surveys.

Table 2. Habitat Measures for the 2008 Blackstone River Watershed Benthic Macroinvertebrate Sites; USGS StreamStats, MassDEP Human Disturbance Index (HDI), MassDEP Benthic Habitat Assessment Scores.

Site Name	Cook Allen Brook	Kettle Brook	Tinkerville Brook	UNT to Middle River	West River	Mumford River	Quinsigamond River	Mill River	UNT to Middle River	Mumford River	Middle River	Blackstone River	Blackstone River	Blackstone River	Blackstone River
Site Number	B0656	B0100	B0659	B0101	B0092	B0091	B0658	B0089	B0098	B0272	B0097	B0661	B0093	B0090	B0660
Watershed Area (mi^2)	1.1	3.9	4.1	10.2	14.9	24.1	25.6	28.9	31.4	31.5	62.3	70.5	140	261	264
% Slope	4.7	3.7	3.4	6.9	4.6	3.8	3.8	3.6	3.7	3.7	4.4	4.4	4.2	4.0	4.0
# NPDES Discharges	0	0	0	1	1	0	10	1	2	4	12	12	27	33	33
% Impervious Cover	4.4	4.6	3.0	26.5	9.9	6.6	17.6	7.3	31.7	11.4	38.6	21.5	11.1	10.6	10.6
% Urban	1.8	12.1	3.7	27.1	10.2	6.8	56.7	18.9	27.9	8.4	45.7	46.7	43.3	29.1	29.1
HDI Score	4	4	2.5	3	4.5	3	5	3	4.5	3.5	5	5	4.5	4.5	4.5
Habitat Score	186	184	152	125	177	162	177	164	145	165	137	148	130	170	187

approximately 100 organisms (±10%) were extracted. Specimens were identified to genus or species as allowed by available keys, specimen condition, and specimen maturity.

Based on the taxonomy, various community, population, and functional parameters, or "metrics", were calculated, allowing measurement of important aspects of the biological integrity of the macroinvertebrate community. This integrated approach provides more assurance of a valid assessment because a variety of biological parameters are evaluated, and the deficiency of any one metric should not invalidate the entire approach (Plafkin et al. 1989). Taxonomic data were analyzed using a modification of Rapid Bioassessment Protocol III (RBP III) metrics and scores (Plafkin et al. 1989). The modifications were: substitution of "reference site affinity" (RSA) for the Community Loss Index and elimination of the shredder/total ratio (no separate leaf-pack material was collected). The reference site affinity metric is a modification of Percent Model Affinity (Novak and Bode 1992). Instead of using the model's percentages for Oligochaeta, Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Chironomidae, and "other," these percentages were taken from the reference site data. The RSA score is then calculated as:

$$100 - \Sigma (\delta \times 0.5)$$

where δ is the difference between the reference percentage and the sample percentage for each taxonomic grouping. RSA percentages convert to RBP III scores as follows: 0 points for <35%; 2 points in the range from 35 to 49%; 4 points for 50 to 64%; and 6 points if ≥65%. The entire suite of metrics used for the analysis was:

- Richness—the total number of different species present in the subsample plus those detected from a "large/rare" search of the whole sample (those taxa missed in subsampling);

- HBI—Hilsenhoff Biotic Index (Hilsenhoff 1982, 1987), as modified in Nuzzo (2003); the HBI is the sum of the products of each taxon's abundance and its corresponding pollution tolerance value, divided by the total count in the subsample;

- EPT—sum of richness among the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) as determined from the specimens in the subsample plus those detected in a "large/rare" search of the whole sample; these orders tend to be dominated by species generally considered to be pollution sensitive;

- EPT/Chiro—ratio of total abundance among EPT taxa to total abundance among Chironomidae taxa;

- SC/FC—ratio of the proportion of sample that is represented by individuals that predominantly feed by scraping to those that are primarily filter-feeders;

- % Dominant—most abundant taxon as a percent of the assemblage; >20% is generally considered hyperdominant and indicative of a stressor impact;

- RSA—reference site affinity (described above).

Metric values for each station were scored based on comparability to the reference station, and scores were totaled. The percent comparability of total metric scores for each study site to those for the selected "least-impacted" reference station yielded an impairment score for each site. RBP III analysis separates sites into four categories: "non-impaired", "slightly impaired", "moderately impaired", and "severely impaired". Each impairment category corresponds to a specific *Aquatic Life* use-support determination used in the CWA Section 305(b) water quality reporting process—non-impaired and slightly impaired benthic invertebrate communities are generally indicative of conditions supporting the *Aquatic Life* use, whereas water bodies exhibiting moderately or severely impaired communities are generally assessed as "non-support."

Habitat Assessment

Habitat qualities were scored for each sampling reach using the assessment procedure in Plafkin et al. (1989), as modified in Barbour et al. (1999). An evaluation of physical and biological habitat quality is critical to any assessment of ecological integrity (Karr et al. 1986; Plafkin et al. 1989). Habitat assessment supports understanding of the relationship between physical habitat quality and biological conditions, identifies obvious constraints on the attainable potential of a site, assists in the selection of appropriate sampling stations, and provides basic information for interpreting biosurvey results (US EPA 1995). The matrix used to assess habitat quality is based on key physical characteristics of the water body and the immediate riverfront area. Most parameters evaluated are instream physical attributes that are potential sources of limitation to the aquatic biota (Plafkin et al. 1989). The ten habitat parameters are as follows: instream cover, epifaunal substrate, embeddedness, sediment deposition, channel alteration, velocity/depth combinations, channel flow status, right and left bank vegetative protection, right and left bank stability, right and left bank riparian vegetative zone width. Habitat parameters are scored, totaled, and compared to the reference station to infer the extent to which the condition of the habitat, rather than water quality effects, may account for differences in macroinvertebrate community structure at the study sites.

RESULTS AND DISCUSSION

Mumford River (B0091) was used as the reference condition for the 2008 Blackstone River Watershed benthic monitoring survey. The list of habitat measures noted in Table 2 indicates the appropriateness of this station to serve as the reference condition. Also, B0091 was used as the reference station in the two previous benthic surveys of the Blackstone River (1998 and 2003).

Habitat measures, in the sub-watershed scale, were also examined in assessing the geomorphic and land-use characteristics of the 2008 macroinvertebrate sites. StreamStats (USGS, 2012) data depict the contributing watershed to the benthic sampling location (Table 2). Perhaps the most interesting of the measures available from StreamStats are the “Percent Impervious Cover” and the “Percent Urban Land Use”. Both are measures of direct human perturbations within the subwatershed.

A Human Disturbance Index (HDI) (Meek, 2013) was also examined. This index is calculated from such measures as urban land use, agricultural land use, NPDES discharges, dam density, and impervious surface density, and yields a score for each HUC 12 (12-digit Hydrologic Unit Code) watershed. The lower the resultant score, the less measureable is human disturbance (Table 2). The Mumford River (B0091) obtained an HDI score of 3.0 (Table 2). Although Tinkerville Brook (B0659) scored better (2.5), its watershed was too diminutive to serve as a representative reference station.

A taxonomic list of the macroinvertebrate organisms collected at each sampling station during the 2008 biomonitoring survey is provided in Appendix 2. Included in the list are total organism counts, the functional feeding group designation (FFG) for each macroinvertebrate taxon, and the tolerance value (TV) of each taxon. Tables 3A and 3B present summaries of the habitat and RBP III macroinvertebrate data analyses for all 2008 Blackstone River Watershed Benthic sites. Included for each sampling site are the habitat comparability to the reference condition, biological metric calculations, metric scores, and impairment designations.

Nine of the 14 test stations (64%) in this study were found to be either non-impaired or only slightly impaired when compared to the reference station (B0091). As such, these stations support their *Aquatic Life* use designation. Five of the test stations (36%) were found to be either moderately impaired or severely impaired, and do not support their *Aquatic Life* use designations. The Blackstone River station B0661 was found to be severely impaired. At this station, there were no Ephemeroptera, Plecoptera, or Trichoptera (EPT) present. The absence of all three of these insect orders indicates impairment. Station B0661 was also highly dominated by worms (35%). High percent domination by a single taxon (especially pollution tolerant taxa) indicates a stressed and impaired condition.

Nine of the stations investigated in 2008 were the subjects of previous bioassessments performed by the MassDEP/DWM (Table 4). Four indicative community metrics from the RBP III analyses and the overall

impairment status assessments resulting from those analyses were compared from year to year to determine whether the biological condition had changed at those sites (Table 4). While a determination of true statistical trends is not possible using screening level techniques such as the RBP, the overall assessment of most sites remained consistent over the time represented by these surveys.

Table 3A. Summary of habitat analysis (i.e. comparability to the reference habitat condition) and RBP III analysis of macroinvertebrate communities sampled in the Blackstone River Watershed on 7, 8, 9 and 10 July 2008. Shown are the calculated metric values, metric scores (in italics) based on comparability to the reference station (Mumford River – B0091), and the corresponding assessment designation for each biomonitoring station. Complete habitat evaluations are presented in Appendix 1. Refer to Table 1 for a listing and description of sampling stations. (NOTE: Table 3 has been split into Table 3A and Table 3B in order to fit this document)

SAMPLING STATION	B0091		B0100		B0659		B0101		B0092		B0656		B0658		B0089		B0098		B0272	
STREAM	Mumford River		Kettle Brook		Tinkerville Brook		UNT to Middle River		West River		Cook Allen Brook		Quinsigamond River		Mill River		UNT to Middle River		Mumford River	
HABITAT SCORE	162		184		152		125		177		186		177		164		145		165	
HABITAT % REFERENCE	--		114%		94%		77%		109%		115%		109%		101%		90%		102%	
HABITAT COMPARABILITY	--		Comparable		Comparable		Support		Comparable		Comparable		Comparable		Comparable		Comparable		Comparable	
TAXA RICHNESS	25	*6*	24	*6*	23	*6*	23	*6*	25	*6*	26	*6*	10	*2*	26	*6*	12	*2*	14	*2*
BIOTIC INDEX	3.95	*6*	4.38	*6*	3.98	*6*	5.15	*4*	4.07	*6*	3.01	*6*	5.48	*4*	3.77	*6*	5.22	*4*	4.45	*6*
EPT INDEX	15	*6*	13	*4*	9	*0*	6	*0*	13	*4*	7	*0*	3	*0*	14	*6*	3	*0*	9	*0*
EPT/CHIRONOMIDAE	8.88	*6*	1.63	*0*	1.02	*0*	4.00	*2*	6.00	*4*	1.41	*0*	7	*6*	5.18	*4*	14.7	*6*	25.3	*6*
SCRAPER/FILTERER	0.51	*6*	0.07	*0*	0.41	*6*	0.41	*6*	0.64	*6*	0.38	*6*	--	*0*	1.23	*6*	0.60	*6*	0.22	*4*
REFERENCE AFFINITY	100%	*6*	58%	*4*	47%	*2*	84%	*6*	82%	*6*	33%	*0*	63%	*4*	81%	*6*	70%	*6*	63%	*6*
% DOMINANT TAXON	17%	*6*	16%	*6*	27%	*4*	21%	*4*	20%	*6*	27%	*4*	31%	*2*	16%	*6*	23%	*4*	27%	*4*
TOTAL METRIC SCORE	*42*		*26*		*24*		*28*		*38*		*22*		*18*		*40*		*28*		*28*	
% COMPARABILITY TO REFERENCE	--		62%		57%		67%		90%		52%		43%		95%		67%		67%	
BIOLOGICAL CONDITION -DEGREE IMPACTED	**REFERENCE**		**SLIGHTLY IMPAIRED**		**SLIGHTLY IMPAIRED**		**SLIGHTLY IMPAIRED**		**NON-IMPAIRED**		**SLIGHTLY/ MODERATELY IMPAIRED**		**MODERATELY IMPAIRED**		**NON-IMPAIRED**		**SLIGHTLY IMPAIRED**		**SLIGHTLY IMPAIRED**	

Table 3B. Summary of habitat analysis (i.e. comparability to the reference habitat condition) and RBP III analysis of macroinvertebrate communities sampled in the Blackstone River Watershed on 7, 8, 9 and 10 July 2008. Shown are the calculated metric values, metric scores (in italics) based on comparability to the reference station (Mumford River – B0091), and the corresponding assessment designation for each biomonitoring station. Complete habitat evaluations are presented in Appendix 1. Refer to Table 1 for a listing and description of sampling stations. (NOTE: Table 3 has been split into Table 3A and Table 3B in order to fit this document)

SAMPLING STATION	B0091		B0097		B0661		B0093		B0090		B0660	
STREAM	Mumford River		Middle River		Blackstone River		Blackstone River		Blackstone River		Blackstone River	
HABITAT SCORE	162		137		148		130		170		187	
HABITAT % REFERENCE	--		85%		91%		80%		105%		115%	
HABITAT COMPARABILITY	--		Support		Comparable		Support		Comparable		Comparable	
TAXA RICHNESS	25	*6*	21	*6*	10	*2*	20	*4*	18	*4*	21	*6*
BIOTIC INDEX	3.95	*6*	5.66	*4*	8.24	*0*	6.44	*2*	5.14	*4*	5.23	*4*
EPT INDEX	15	*6*	2	*0*	--	*0*	4	*0*	9	*0*	9	*0*
EPT/CHIRONOMIDAE	8.88	*6*	0.92	*0*	--	*0*	1.00	*0*	5.36	*4*	31.5	*6*
SCRAPER/FILTERER	0.51	*6*	0.11	*2*	--	*0*	0.17	*2*	0.04	*0*	0.22	*4*
REFERENCE AFFINITY	100%	*6*	49%	*2*	11%	*0*	34%	*0*	67%	*6*	59%	*4*
% DOMINANT TAXON	17%	*6*	15%	*6*	35%	*2*	21%	*4*	35%	*2*	15%	*6*
TOTAL METRIC SCORE	*42*		*20*		*4*		*12*		*20*		*30*	
% COMPARABILITY TO REFERENCE	--		48%		10%		29%		48%		71%	
BIOLOGICAL CONDITION -DEGREE IMPACTED	**REFERENCE**		**MODERATELY IMPAIRED**		**SEVERLY IMPAIRED**		**MODERATELY IMPAIRED**		**MODERATELY IMPAIRED**		**SLIGHTLY IMPAIRED**	

Table 4. Selected macroinvertebrate RBPIII community metrics and impairment status for nine sampling stations in the Blackstone River Watershed sampled by MassDEP/DWM in 2008 and on at least one previous occasion. See text for a description of the metrics.

Water Body	Year	Community Metrics				Impairment Status
		Total Richness	EPT Richness	Biotic Index	% Dominant Taxon	
Mumford River, Uxbridge (B0091)	1998	28	8	4.04	17	Reference
	2003	19	8	4.45	19	Reference
	2008	25	15	3.95	17	Reference
Unnamed tributary to Middle River, Worcester[1] (B0098)	1998	18	7	3.88	23	Slightly-Impaired
	2008	12	3	5.22	23	Slightly-Impaired
Kettle Brook, Leicester (B0100)	1998	27	10	4.72	16	Reference
	2008	24	13	4.38	16	Slightly-Impaired
Unnamed tributary to Middle River, Worcester[2] (B0101)	1998	18	6	5.08	23	Slightly-Impaired
	2008	23	6	5.15	21	Slightly-Impaired
West River, Upton (B0092)	1998	28	10	5.34	21	Non-Impaired
	2008	25	13	4.07	20	Non-Impaired
Mill River, Blackstone (B0089)	1998	26	11	4.31	27	Non-Impaired
	2008	26	14	3.77	16	Non-Impaired
Middle River, Worcester (B0097)	1998	16	1	6.86	30	Mod-Impaired
	2008	21	2	5.66	15	Mod-Impaired
Blackstone River, Northbridge (B0093)	1998	23	2	7.63	22	Mod-Impaired
	2008	20	4	6.44	21	Mod-Impaired
Blackstone River, Millville (B0090)	1998	15	5	6.41	41	Mod-Impaired
	2003	12	6	5.47	56	Mod-Impaired
	2008	18	9	5.14	35	Mod-Impaired

Notes: [1] This site designated as Kettle Brook (KB02) in 1998
[2] This site designated as Tatnuck Brook (TB02) in 1998

SUMMARY

Sampling of the benthic macroinvertebrate community was carried out in July 2008 at fifteen sites in the Blackstone River Watershed to evaluate the biological health of selected streams and to determine their status with respect to the support of the *Aquatic Life* use, as designated in Massachusetts' Surface Water Quality Standards. Station B0091, on the Mumford River, served as the reference site for all sites.

While two-thirds of the sites examined supported their *Aquatic* Life use designation, a third of the stations examined were found to not support their *Aquatic Life* use designation. A reduction in the EPT taxa at affected sites was the most common symptom of stressors degrading aquatic community health.

Although all the proximal ("within reach") habitat measures were deemed to be either "supporting" or "comparable" when compared to the reference station, the landscape measures (Table 2) point towards potential human impacts. Individual potential human impacts to the landscape are compiled in the Human Disturbance Index score. These perceived impacts describe potential contributing impairments that can cause the test stations to fail in their support of their *Aquatic Life* use designations (such as, Percent

Impervious Cover, and number of contributing NPDES discharges). All of the five stations failing to support their *Aquatic Life* use designations have some notable similarities in contributing watershed land use: All have at least 10 NPDES discharges, at least 10% Impervious Cover, and at least 25% Urban Land use (Table 2). All of these human impacts point toward potential degradation of water quality and habitat.

The mainstem Blackstone River receives the outfall from the Upper Blackstone Wastewater Treatment Plant (WWTP). This discharge represents a substantial load to (at the point of discharge) a small river. However, the Blackstone River station B0660 (the furthest downstream, mainstem station), which has similar land use characteristics as the five stations mentioned above, obtained a slightly impaired rating, and supports its *Aquatic Life* use. There is no single reason for the improvement in the biota encountered at B0660. Just as there is no single reason for the impairments encountered at other stations. It is quite possible that the impoundment just upstream of B0660 is settling out organic sediments, and that the coarse substrates at this station are re-aerating the water. Both of these conditions (and others) can increase the assimilative capacity at B0660. However, water chemistry examinations performed at, or near, these benthic stations may shed further light as to the causes of impairment. It is quite likely that the impacts to the Blackstone River are a combination of both habitat and water chemistry perturbations.

Station B0661 (Blackstone River) remains of great concern as it is severely impaired. This station is downstream of several historic and existing NPDES discharges (including the Upper Blackstone WWTP) as well as extensive, and proximal, urban and industrial land use. However, it is impossible to determine with assurance what impact(s) are responsible for this poor condition from benthic data alone. Water chemistry data should be examined in concert with biological data to reach sound conclusions.

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Appendix 1. Habitat assessment summary for biomonitoring stations sampled during the 2008 Blackstone River Watershed survey. For within-reach parameters, scores ranging from 16-20 = optimal; 11-15 = suboptimal; 6-10 = marginal; 0-5 = poor. For riparian parameters, scores ranging from 9-10 = optimal; 6-8 = suboptimal; 3-5 = marginal; 0-2 = poor. Maximum habitat score for any site = 200. Refer to Table 1 for a listing and description of sampling stations.

STATION	Cook Allen Brook	Kettle Brook	Tinkerville Brook	Unnamed Tributary to Middle River	West River	Mumford River	Quinsigamond River	Mill River	Unnamed Tributary to Middle River	Mumford River	Middle River	Blackstone River	Blackstone River	Blackstone River	Blackstone River
Station Code	**B0656**	**B0100**	**B0659**	**B0101**	**B0092**	**B0091**	**B0658**	**B0089**	**B0098**	**B0272**	**B0097**	**B0661**	**B0093**	**B0090**	**B0660**
INSTREAM PARAMETERS (range is 0-20)	SCORES														
INSTREAM COVER	17	19	13	13	18	18	19	12	18	17	11	16	17	16	16
EPIFAUNAL SUBSTRATE	18	20	17	16	19	18	18	16	19	18	11	15	13	18	18
EMBEDDEDNESS	18	19	19	19	19	16	19	18	18	15	10	10	4	18	19
CHANNEL ALTERATION	20	20	19	14	18	18	15	20	18	19	18	18	11	14	19
SEDIMENT DEPOSITION	18	19	19	19	18	17	18	16	17	14	13	6	8	17	20
VELOCITY-DEPTH COMBINATIONS	15	10	10	10	15	10	17	10	10	13	16	18	18	16	18
CHANNEL FLOW STATUS	20	19	9	9	18	19	19	14	17	17	15	19	19	19	19
RIPARIAN ZONE PARAMETERS (range is 0-10 for each bank)	SCORES														
BANK VEGETATIVE PROTECTION left	10	10	10	7	10	10	10	10	2	10	10	10	9	10	9
BANK VEGETATIVE PROTECTION right	10	10	10	3	10	10	10	10	10	10	10	10	9	10	10
BANK STABILITY left	10	10	10	5	6	10	7	9	4	8	7	7	10	9	10
BANK STABILITY right	10	10	10	3	9	5	10	9	7	9	9	8	9	9	10
RIPARIAN VEGATIVE ZONE WIDTH left	10	9	3	5	7	9	5	10	1	5	2	1	1	9	9
RIPARIAN VEGATIVE ZONE WIDTH right	10	9	3	2	10	2	10	10	4	10	5	10	2	5	10
TOTAL SCORE	**186**	**184**	**152**	**125**	**177**	**162**	**177**	**164**	**145**	**165**	**137**	**148**	**130**	**170**	**187**

Appendix 2. Taxa list and counts, functional feeding groups (FFG), and tolerance values (TV) for macroinvertebrates collected from stream sites during the 2008 Blackstone River Watershed survey from 7 to 10 July 2008. Refer to Table 1 for a listing and description of sampling stations.

TAXON		FFG[1]	TV[2]	B0091 Mumford River[3]	B0656 Cook Allen Brook	B0100 Kettle Brook	B0659 Tinkerville Brook	B0101 UNT to Middle River	B0092 West River	B0658 Quinsigamond River	B0089 Mill River	B0098 UNT to Middle River	B0272 Mumford River	B0097 Middle River	B0661 Blackstone River	B0093 Blackstone River	B0090 Blackstone River	B0660 Blackstone River
Family	**Genus/Species**																	
Ancylidae	*Ferrissia fragilis*	SC	6															2
Pisidiidae	--	FC	6			1		7		1						1		
Pisidiidae	*Musculium* sp.	FC	6															
Pisidiidae	*Pisidium* sp.	FC	6									1		3				
Pisidiidae	*Sphaerium* sp.	FC	6							1								6
Enchytraeidae	--	GC	10											1		3		
Naididae	--	GC	9														1	
Naididae	*Nais bretscheri*	GC	6													20		
Naididae	*Nais communis/variabilis*	GC	8					1								2		
Naididae	*Nais elinguis*	GC	10												17			
Naididae	*Ophidonais serpentina*	GC	6												3			
Naididae	*Pristina aequiseta*	GC	8													1		
Tubificidae	*Limnodrilus hoffmeisteri*	GC	10													1		1
Tubificidae IWB	--	GC	10											1	32	13		
Lumbriculidae	--	GC	7									1						
Erpobdellidae	--	PR	8															2
Asellidae	*Caecidotea* sp.	GC	8															2
Asellidae	*Caecidotea racovitzai racovitzai*	GC	8							6								
Crangonyctidae	*Crangonyx* sp.	GC	6					3		2					1			7
Gammaridae	*Gammarus* sp.	GC	6									24		14			18	2

Hydrachnidia	*Hydrachnidia*	PR	6															
Hygrobatidae	*Hygrobates* sp.	PR	6					1		1								
Lebertiidae	*Lebertia* sp.	PR	6		1									3				
Baetidae	--	GC	4	1		2												
Baetidae	*Acentrella turbida*	GC	4			2												
Baetidae	*Acerpenna pygmaea*	GC	4	1														
Baetidae	*Baetis* sp.	GC	6		1	1												2
Baetidae	*Baetis flavistriga*	GC	4					1	1		6		6			1	2	14
Baetidae	*Baetis intercalaris*	GC	6															2
Baetidae	*Iswaeon anoka*	SC	2						1							4	2	
Baetidae	*Plauditus* sp.	GC	4	4		1												
Heptageniidae	--	SC	4	2														6
Heptageniidae	*Epeorus vitreus*	SC	0	1		1												
Heptageniidae	*Maccaffertium* sp.	SC	3				2	3	3		2		13					
Heptageniidae	*Maccaffertium modestum*	SC	1					1					2					
Heptageniidae	*Stenacron interpunctatum*	SC	7														1	
Isonychiidae	*Isonychia* sp.	FC	2	5					12		2		4					
Gomphidae	--	PR	5								1							
Chloroperlidae	*Sweltsa* sp.	PR	0		2													
Leuctridae	*Leuctra* sp.	SH	0	3	29		9		1		1		3					
Peltoperlidae	*Tallaperla maria*	SH	0				7											
Perlidae	Perlidae	PR	1		2		2											
Perlidae	*Acroneuria abnormis*	PR	0			10			1		9							
Perlidae	*Eccoptura xanthenes*	PR	3		2													
Perlidae	*Paragnetina media*	PR	5			1			9									
Corydalidae	*Corydalus cornutus*	PR	4	2														
Corydalidae	*Nigronia serricornis*	PR	0		1		5		1		2							
Apataniidae	*Apatania* sp.	SC	3								4							
Brachycentridae	*Brachycentrus numerosus*	FC	1						2								2	
Brachycentridae	*Micrasema* sp.	SH	2	2			9											
Glossosomatidae	*Glossosoma* sp.	SC	0								4							
Hydropsychidae	--	FC	4				2							8				
Hydropsychidae	*Cheumatopsyche* sp.	FC	5	2		4	2	23	5	20	9	10	29	12		9	38	15
Hydropsychidae	*Diplectrona modesta*	FC	0				4											
Hydropsychidae	*Hydropsyche* sp.	FC	4	2													9	2

Hydropsychidae	*Hydropsyche betteni*	FC	7	3		10	5	12	1	24	1	13	17	15		8	3	3
Hydropsychidae	*Hydropsyche bronta*	FC	6								9							
Hydropsychidae	*Hydropsyche morosa*	FC	6				4										5	9
Hydropsychidae	*Hydropsyche sparna*	FC	6	14		5		1	8		5		1				4	1
Hydropsychidae	*Macrostemum* sp.	FC	3	7														
Hydroptilidae	*Leucotrichia* sp.	SC	6															2
Hydroptilidae	*Mayatrichia* sp.	SC	6	3														
Lepidostomatidae	*Lepidostoma* sp.	SH	1		1													
Leptoceridae	*Oecetis* sp.	PR	5	1														
Odontoceridae	*Psilotreta labida*	SC	0								3							
Philopotamidae	*Chimarra aterrima*	FC	4	18		9		15	1		1		9					
Philopotamidae	*Chimarra obscura*	FC	4	1		3			21	33		21	17				9	7
Philopotamidae	*Dolophilodes* sp.	FC	0		3													
Philopotamidae	*Dolophilodes distinctus*	FC	0			1												
Polycentropodidae	*Neureclipsis* sp.	FC	7	1														
Polycentropodidae	*Polycentropus* sp.	PR	6		1													
Rhyacophilidae	*Rhyacophila fuscula*	PR	0			2					1							
Elmidae	*Microcylloepus pusillus*	GC	3					2										
Elmidae	*Optioservus ovalis*	SC	4						8		4							
Elmidae	*Oulimnius latiusculus*	SC	4	4	2		2		8		16	11	1					
Elmidae	*Promoresia tardella*	SC	2	15	7	3	5		1									
Elmidae	*Stenelmis* sp.	SC	5						6		10			6				2
Elmidae	*Stenelmis crenata*	SC	5	3				19				17	1					
Psephenidae	*Psephenus herricki*	SC	4					2	5			1						
Ptilodactylidae	*Anchytarsus bicolor*	SH	4		5													
Ceratopogonidae	*Probezzia* sp.	PR	6			1												
Chironomidae	*Chironomini*	GC	6				1											
Chironomidae	*Chironomus* sp.	GC	10												2			
Chironomidae	*Microtendipes pedellus* gr.	FC	6								3							
Chironomidae	*Phaenopsectra* sp.	SC	7													1		
Chironomidae	*Polypedilum* sp.	SH	6				1											
Chironomidae	*Polypedilum aviceps*	SH	4	2		6												
Chironomidae	*Polypedilum flavum*	SH	6			3		3	3	11		1		1	13	3	1	
Chironomidae	*Polypedilum halterale* gr.	SH	6													2		
Chironomidae	*Polypedilum illinoense* gr.	SH	6		1		1							1				

Chironomidae	*Polypedilum scalaenum* gr.	SH	6											1				
Chironomidae	*Xenochironomus* sp.	PR	0								1							
Chironomidae	*Micropsectra* sp.	GC	7				29				1			1		1		
Chironomidae	*Rheotanytarsus exiguus* gr.	FC	6				4				2	2		3			1	
Chironomidae	*Rheotanytarsus pellucidus*	FC	5			16	1				3		2					
Chironomidae	*Stempellinella* sp.	GC	2		2													
Chironomidae	*Tanytarsus* sp.	FC	6		5									6				
Chironomidae	*Diamesa* sp.	GC	5										1					
Chironomidae	*Potthastia longimana* gr.	GC	2											2				
Chironomidae	*Brillia* sp.	SH	5					1										
Chironomidae	*Brillia flavifrons*	SH	5	1														
Chironomidae	*Cardiocladius obscurus*	PR	5												2	5	4	2
Chironomidae	*Chaetocladius* sp.	GC	6					2										
Chironomidae	*Corynoneura* sp.	GC	4				2	1										
Chironomidae	*Cricotopus* sp.	SH	7												3	2	1	
Chironomidae	*Cricotopus bicinctus*	GC	7			3	1								1			
Chironomidae	*Cricotopus tremulus*	SH	7														3	
Chironomidae	*Cricotopus/Orthocladius* sp.	GC	7		1			1						4	7	3	1	
Chironomidae	*Eukiefferiella claripennis* gr.	GC	8											1				
Chironomidae	*Heterotrissocladius marcidus*	GC	4		1													
Chironomidae	*Parachaetocladius* sp.	GC	2		1													
Chironomidae	*Parametriocnemus* sp.	GC	5	1	6			2	5				1					
Chironomidae	*Rheocricotopus* sp.	GC	6			2	1		1									
Chironomidae	*Synorthocladius* sp.	GC	6											1		1		
Chironomidae	*Thienemanniella* sp.	GC	6		2													
Chironomidae	*Tvetenia paucunca*	GC	5	2	6	2	2		1									
Chironomidae	*Tvetenia vitracies*	GC	5											16		4	3	
Chironomidae	*Guttipelopia* sp.	PR	5					2										
Chironomidae	*Larsia* sp.	PR	6				1											
Chironomidae	*Paramerina* sp.	PR	6				1											
Chironomidae	*Thienemannimyia* gr.	PR	6	2	4			2	1		1			1	1			

Empididae	--	PR	6					1										
Empididae	*Hemerodromia* sp.	PR	6			1				1								
Empididae	*Neoplasta* sp.	PR	6		2													
Empididae	*Roederiodes* sp.	PR	6		1													
Simuliidae	*Simulium* sp.	FC	5	2	16	8		3		5		1		9	9	11	1	11
Simuliidae	*Simulium verecundum* cplx.	FC	5			2												
Tipulidae	*Antocha* sp.	GC	3														1	2
Tipulidae	*Dicranota* sp.	PR	3		3		4											
Tipulidae	*Limonia* sp.	SH	6															1
Tipulidae	*Tipula* sp.	SH	6						1		1							
TOTAL				**105**	**108**	**100**	**107**	**109**	**107**	**105**	**102**	**103**	**107**	**110**	**91**	**96**	**110**	**103**

[1]Functional Feeding Group (FFG) lists the primary feeding habit of each species and follows the abbreviations: SH-Shredder; GC-Gathering Collector; FC-Filtering Collector; SC-Scraper; PR-Predator.

[2]Tolerance Value (TV) is an assigned value used in the calculation of the Biotic Index. Tolerance values range from 0 for organisms very intolerant of organic wastes to 10 for very tolerant organisms.

[3] Reference station