MOON BROOK THIRD PARTY ANALYSIS

Prepared for:

City of Rutland Vermont
and
Vermont Agency of Natural Resources

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1.0 INTRODUCTION

The Moon Brook watershed is an 8.8 square mile watershed that drains urbanized areas of Rutland, Vermont before entering Otter Creek. The Vermont Agency of Natural Resources (State) monitored water quality in the Moon Brook watershed, and determined from the data that the stream does not attain its designated aquatic life use as defined in the Vermont Water Quality Standards (WQS) due to stormwater impacts. The City of Rutland (Rutland) has disagreed with the State's assignment of the causes of non-attainment in the Moon Brook watershed.

The State has interpreted the bioassessment data gathered from the Moon Brook watershed to indicate that the impairment is due to urban stormwater discharges. The City and VANR agreed to engage the Kleinschmidt Associates – Midwest Biodiversity Institute (KA-MBI) team as a third party to independently conclude if the impairments were accurately determined through a review and analysis of biological and water quality data collected in the study area and knowledge of water quality and bioassessment techniques. The purpose of this report is to review the available information and provide the conclusions of the third party review.

2.0 DESCRIPTION OF STUDY AREA

The study area includes Moon Brook from mile 3.3 (upstream from Combination Pond to its confluence with Otter Creek (mile 0.0), as well as Mussey Brook, a primary tributary of Moon Brook that joins the lower reach of Moon Brook, and Paint Mine Brook, a secondary tributary that joins the middle reach of Moon Brook (Figure 2-1). The watershed upstream from Combination Pond is surrounded by relatively undeveloped, forested land (Photo 2-1), with the lowest overall levels of impervious surfaces of any part of the watershed. The stream channel features relatively high gradient riffle and run mesohabitats, stable banks, overhead and instream cover, relatively unembedded substrates dominated by cobble, boulder, and gravel.

PHOTO 2-1: MOON BROOK AT RIVER MILE 3.3 ABOVE COMBINATION POND.

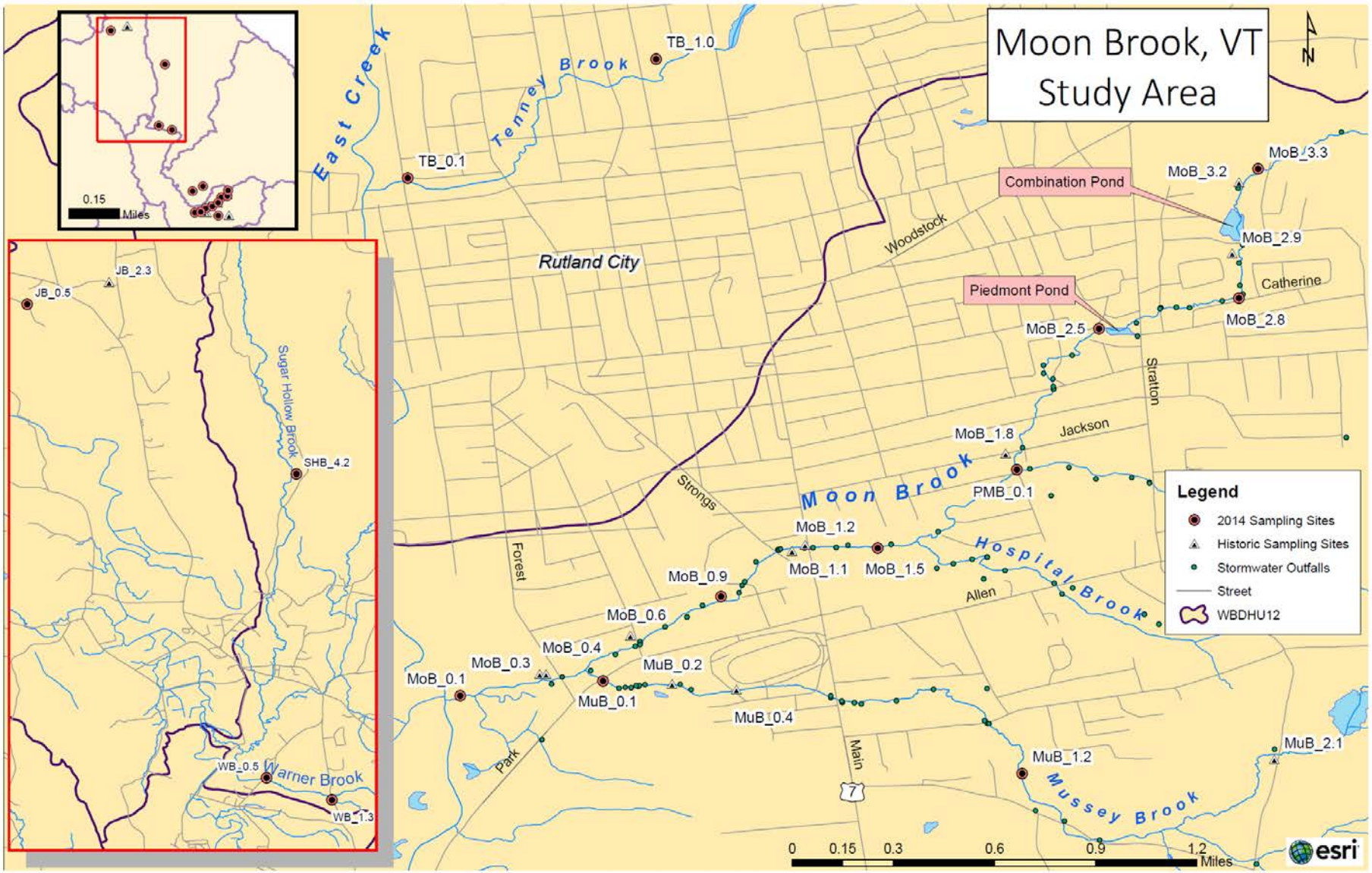

FIGURE 2-1: STUDY AREA

The segment beginning at Combination Pond (just above river mile 2.8) is characterized by limited overhead cover or riparian buffer vegetation, with suburban residential land use including lawns, roads and other impervious surfaces. Combination Pond is a small, shallow reservoir surrounded by homes and lawns (Photo 2-2) that discharges to the downstream reach, through riparian vegetation and past densely settled residential areas, including through a second impoundment (Piedmont Pond) (Photo 2-3 and Photo 2-4). Substrates in this reach are dominated by cobble and gravel and there is limited overhead cover and riparian buffer.

PHOTO 2-2: COMBINATION POND, VIEW LOOKING UPSTREAM FROM NEAR IMPOUNDMENT OUTLET.

PHOTO 2-3: PIEDMONT POND, LOOKING UPSTREAM FROM BELOW THE IMPOUNDMENT OUTLET.

PHOTO 2-4: MOON BROOK DOWNSTREAM FROM PIEDMONT POND IMPOUNDMENT OUTLET.

Moon Brook crosses secondary streets and abuts residences to the confluence with Paint Mine Brook near river mile 1.8 (Photo 2-5). Stream channels have been locally modified by abutting landowners. Several interest points at this location include:

- A geomorphic break exists between the relatively higher gradient upstream reach, and the lower-gradient downstream reach. Below this point Moon Brook broadens and contains a higher percentage of finer substrates as well as evidence of shoreline alterations (rip-rap, etc), channelization, discarded urban debris and increasingly commercial and industrial land uses encroaching on the stream banks.
- Paint Mine Brook has good overhead canopy and undisturbed banks (Photo 2-6) and consistently remains cool (i.e. below 70°F) throughout the summer, although the lowermost reach of Paint Mine Brook immediately at the confluence exhibits stream bank modifications, localized erosion and a lack of vegetative riparian or overhead cover (Photo 2-5)
- Paint Mine Brook contains an abundance of cobble and riffle mesohabitat complexes that are absent in the altered habitat of the contiguous segments of Moon Brook.

PHOTO 2-5: PANORAMA VIEW LOOKING DOWNSTREAM OF MOON BROOK (RIGHT) AND PAINT MINE BROOK (LEFT). NOTE RIPRAP SHORELINE ALTERATIONS.

PHOTO 2-6: PAINT MINE BROOK, VIEW LOOKING UPSTREAM AT TRANSITION FROM UNALTERED TO ALTERED STREAM BANK (LEFT), AND DETAIL OF SUBSTRATES (RIGHT).

The next segment of Moon Brook passes through wetland and low relief terrain with riparian vegetation and overhead cover. The stream channel is wider and the gradient lower than upstream areas. Bank erosion is not as evident as in upstream segments. Substrates are dominated by embedded gravels and fines with some cobbles (Photo 2-7).

PHOTO 2-7: MOON BROOK, IN THE VICINITY OF WHITES PLAYGROUND.

Near Main Street, Moon Brook exhibits signs of stream alteration (channelizing and narrowing), has limited overhead and riparian cover, and is often abutted by commercial land uses such as paved parking lots (Photo 2-8).

PHOTO 2-8: MOON BROOK, IN THE VICINITY OF MAIN STREET.

The lowermost reach of Moon Brook is characterized by bank erosion, extensive channel modifications, and is dominated by sand, silt, and other fine sediments. It is abutted by commercial, agricultural, and residential land uses. Some limited riparian and tree canopy cover exists (Photo 2-9). Mussey Brook confluences with Moon Brook between Main Street and Forest Street, after traversing residential and urban areas including the Vermont State Fairgrounds, which lack riparian vegetation and overhead cover (Photo 2-10).

PHOTO 2-9: MOON BROOK BETWEEN FOREST STREET AND THE CONFLUENCE WITH OTTER CREEK.

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PHOTO 2-10: MUSSEY BROOK AT THE VERMONT STATE FAIRGROUNDS AND NEAR FOREST STREET.

3.0 METHODS

3.1 WATER QUALITY

KA-MBI examined the water column and sediment chemistry collected by VTDEC during 2014 in Moon Brook, several tributaries, and a suite of agreed upon less- developed "similar" sites to compare with the low gradient downstream reaches of Moon Brook[1]. KA-MBI generated measures of impervious land cover (i.e., percent impervious) for each site sampled in 2014 using the 2011 National Land Cover Data (NLCD) impervious surface layer as detailed by Xian et al. (2011). This was then correlated with the water and sediment chemistry results.

KA-MBI assessed concentrations of water column chemistry using the Vermont WQS for Class B waters (VT DEC 2014) and also compared values to benchmarks associated with low (<10% impervious surface) and threshold values of chloride, conductivity, and sodium related to predicted exceedance of total chloride during winter and spring melt and runoff events (Trowbridge et al. 2010). KA-MBI generated "background" value benchmarks for water column parameters separately for base flows and freshets by using data from the 2014 sampling sites with less than 10% impervious land cover[2] (summarized in Table 3-1). Values above these benchmarks are not necessarily associated with aquatic life impairment, but rather are used to determine whether certain parameters have a trend of increasing in magnitude as impervious surface increases.

KA-MBI used a value of 102 mg/L as a threshold for identifying probable exceedances of the 230 mg/L chloride chronic water quality criterion for aquatic life, based on Trowbridge et al. (2010)[3] . We developed relationships between chloride and two other correlated parameters (conductivity and sodium) and derived exceedance benchmarks (60.5 mg/L for sodium, 564.6 µmhos/cm for conductivity) which correspond to the 102 mg/L chloride concentration (Figure 4-1).

[1] Water column chemistry data were collected by VTDEC during both base flow and elevated flow events (storm "freshets") at these sites and these were analyzed separately by these flow categories. VTDEC collected sediment contaminant data in the fall at five Moon Brook sites and one Button Brook site, with a duplicate sample collected at Moon Brook at RM 0.1 (MoB_0.1). Laboratory work was contracted to Test America (2014).
[2] 10% impervious cover is often used as an incipient change point for the influence of urban development on aquatic life (Impervious Cover Model, Center for Watershed Protection 2003).
[3] Trowbridge et al. (2010) predicts that exceedances of the water quality criteria for total chloride increase in frequency as summer average concentrations exceeded 102 mg/L of chloride.

KA-MBI used VTDEC-recommended screening quality guideline values (SQGs) for assessing the potential risk from elevated concentrations of contaminants in the sediments at Moon Brook sites (Table 3-1; VTDEC 2012). These screening values are taken from MacDonald et al. (2000) which are widely used for screening potential adverse effects. Each parameter has an SQG termed a "Threshold Effect Concentration" (TEC) and another termed "Probable Effect Concentration" (PEC). Adverse effects to aquatic invertebrates are considered unlikely to occur at concentrations less than the TEC, but adverse effects are likely above the PEC. KA-MBI calculated total polycyclic aromatic hydrocarbon (PAH) values (simple sum of all PAH parameters) and a total toxic metals index to assess spatial patterns along Moon Brook related to the potential influence of stormwater inputs. Values for metals were standardized to a scale of 0-10 and then summed. We also examined trends in the number of metal or organic parameters detected.

TABLE 3-1: SUMMARY OF VT WATER QUALITY CRITERIA, ASSESSMENT BENCHMARKS, SCREENING SEDIMENT QUALITY GUIDELINES (SQGS) USED IN THIS ASSESSMENT.

	WATER QUALITY CRITERIA CLASS B STREAMS		BENCHMARKS		
PARAMETER	CHRONIC	ACUTE	BASE FLOW BACKGROUND CONCENTRATION[A]	FRESHET FLOW BACKGROUND CONCENTRATION[A]	IMPAIRMENT RISK CONCENTRATION
Dissolved Oxygen	6 mg/L	-	8.01 mg/L	6.80 mg/L	
% DO Saturation	>70%	-	86.9%	75.0%	
Turbidity	10 NTU[b]	-	1.58 NTU	63.6 NTU	
Total Phosphorus					
SHG	12 µg/l	-	17.1 µg/l	272.0 µg/l	
MHG	15 µg/l				
WMG	27 µg/l				
Nitrate	5 mg/L		0.25 mg/L	0.14 mg/L	
Total Nitrogen	-	-	0.37 mg/L	1.30 mg/L	
pH (S.U.)	< 8.5		8.04 S.U.	7.55 S.U.	
Chloride	230 mg/L	860 mg/L	42.9 mg/L	28.0 mg/L	102[d] mg/L
Sodium	-	-			60.5[e] mg/L
Conductivity	-	-	333.3 µmhos	436 µmhos	564.6[e] µmhos
TSS	-	-	4.4 mg/L	109.2 mg/L	
Sulfate	-	-	7.4 mg/L	6.6 mg/L	
Hardness	-	-	159.3 mg/L	141.7 mg/L	

Parameter	Water Quality Criteria Class B Streams		Benchmarks		
	Chronic	Acute	Base Flow Background Concentration[A]	Freshet Flow Background Concentration[A]	Impairment Risk Concentration
Alkalinity	-	-	146.0 mg/L	-	
Calcium	-	-	36.5 mg/L	33.3 mg/L	
Toxic metals – based on hardness and a dissolved to total metals translator (see VT DEC 2014).					
Sediment SQGs					
Sediment Parameter			Category	TEC	PEC
Arsenic			Metals (mg/kg)	9.79	33.0
Cadmium			Metals (mg/kg)	0.99	4.98
Chromium			Metals (mg/kg)	43.4	111
Copper			Metals (mg/kg)	31.6	149
Lead			Metals (mg/kg)	35.8	128
Mercury			Metals (mg/kg)	0.18	1.06
Nickel			Metals (mg/kg)	22.7	48.6
Zinc			Metals (mg/kg)	121	459
Anthracene			PAHs (ug/kg)	57.2	845
Fluorene			PAHs (ug/kg)	77.4	536
Naphthalene			PAHs (ug/kg)	176	561
Phenanthrene			PAHs (ug/kg)	204	1170
Benz(a)anthracene			PAHs (ug/kg)	108	1050
Benzo(a)pyrene			PAHs (ug/kg)	150	1450
Chrysene			PAHs (ug/kg)	166	1290
Dibenz(a,h)anthracene			PAHs (ug/kg)	33	-
Fluoranthene			PAHs (ug/kg)	423	2230
Pyrene			PAHs (ug/kg)	195	1520

a – 75th percentile concentration at sites sampled in 2014 with < 10% impervious surface
b – as an annual base flow average
c - at flows exceeding low median monthly flows, in Class B waters
d - Trowbridge et al. (2010)
e – Derived from correlations with total chloride and Trowbridge chloride indications of impairment.

3.2 Temperature

Water temperature data were collected by Rutland from 2006 through 2014 at monitoring sites within the Moon Brook watershed and nearby tributaries. Some sites corresponded to VTDEC monitoring sites as well as other supplemental sites. Data were gathered using HOBOtemp® sensors anchored at each stream location. Each device continuously recorded water temperature (^{o}F) at 15 minute intervals. Generally the monitors were deployed mid April through October annually although not all sites were monitored every year. At the end of the year, data were downloaded into MS Excel (http://www.rutlandcity.org/index.asp?SEC=68D55380-9FB7-44D1-B8A3-C3384A6B06D7&Type=B_BASIC).

The objective of the analysis was to determine if ambient summer water temperature is a limiting factor for coldwater fish which are part of the aquatic life standard for the study area. June through August were considered to be the period when water temperature is potentially most stressful to coldwater organisms, thus the time period of June 1 through August 31 of each year was selected. Data for each monitoring site were reviewed as follows. The inter-annual temperature range was reviewed to assess the degree of variability among monitoring years. June through August data for all available years of were pooled across years. The frequency of occurrence of temperatures at 5°F intervals from 50°F through 80°F was determined. Each data set was then examined with respect to both avoidance temperature and upper lethal limit range for the coldwater fish (based on brook trout, an intolerant, native coldwater species).

3.3 BIOLOGICAL DATA

3.3.1 MACROINVERTEBRATES

KA-MBI reviewed the **V**ermont water quality standards (VT WQS), to establish the basis for determining whether VTDEC's assessment decisions have been legally consistent and scientifically valid in terms of assessment decisions regarding aquatic life use (ALU) impairment under VT WQS. The team paid particular attention to the ALU and biocriteria applicable to the §303d listing of Moon Brook as ALU-impaired due to stormwater.

KA-MBI reviewed the 2014 benthic macroinvertebrate data as inventoried in Appendix E[4]. KA-MBI also reviewed historical macroinvertebrate data collected by VTDEC. Historical data were reviewed to determine concurrence with VTDEC assessment outcomes, and if macroinvertebrate assemblage characteristics were consistent from year to year within a given sampling site, or unduly influenced by variations in natural factors such as differences in annual climatic or hydrological regimes.

KA-MBI reviewed current VTDEC bioassessment protocols, and considered current program performance and quality assurance practices relative to a comprehensive program review conducted in 2009 (MBI 2011). KA-MBI also evaluated VTDEC's specific performance during 2014 macroinvertebrate data collection and analysis to independently ascertain if standard protocols were properly followed and to determine if sampling or analytical irregularities occurred; MBI (2011) did not directly assess the quality of site-specific monitoring and

[4] This inventory had been reviewed and edited by VTDEC, and also reviewed and agreed to by Rutland.

assessment for Moon Brook. Therefore, to assess specific performance relative to the Moon Brook watershed assessment, KA-MBI examined the agency's bioassessment Quality Assurance Project Plan (QAPP)[5] and data outputs from Moon Brook project sampling, and obtained copies of all historical field data entry sheets, and VTDEC raw biological data files for Moon and Mussey Brooks.

KA-MBI reviewed *small size high gradient (SHG)* and *hard low gradient (HLG)* stream types independently because the Moon Brook watershed and 2014 macroinvertebrate reference datasets contain sites from these two different stream types. Applicable bioassessment protocols differ between high gradient *vs*. low gradient streams, as does the level of completion and vetting of the biocriteria. The 2014 reference sites used to assess low gradient project streams were selected by mutual agreement among all parties (City of Rutland, VTDEC, and KA-MBI).

The Team reviewed the draft low gradient analytical methods document and accompanying Excel spreadsheet provided by VTDEC (VTDEC 2014; 6.2 Unpublished Material VTDEC Document 2) to determine the scientific justification and level of rigor underlying the State's assessment of low gradient streams.

The Team examined taxonomic, computed metric, and habitat data for HLG project streams in relation to the Vermont statewide low gradient database and evaluated statistical approaches against current best practices in bioassessment (US EPA 2013; Birk, et al 2012).

KA-MBI also examined biological response data (macroinvertebrate metrics and taxonomic characteristics) for all project and reference streams in relation to important effects thresholds for chemical and physical stressor data collected at each site to determine stressor-response associations.

3.3.2 FISH ASSEMBLAGE

KA-MBI reviewed fish assemblage data collected during 2014 (Appendix E.), and reviewed historical Moon Brook fish data collected by VT DEC dating to 2008. KA-MBI reviewed the VT WQS to determine whether the VTDEC assessment decisions have been consistent over time and

[5] The federally required QAPP must be prepared prior to field sampling and must be followed precisely to ensure the quality and scientific soundness of data; The VTDEC QAPP (VTDEC 2010) describes all aspects of quality assurance provisions for the biological program: field collections, laboratory; taxonomic precision and accuracy; data quality control and quality assurance.

whether the data supported the §303d listing of Moon Brook as ALU-impaired due to stormwater. Historical data were examined to assess whether assemblage condition was stable or changing in response to particular stressors or natural indicators and whether bioassessment protocols were consistent over time.

Consistent with the macroinvertebrates, Moon Brook fish sites and 2014 reference datasets represent two different stream types, small size high gradient (SHG) and hard low gradient (HLG), the latter which are not yet formalized with specific biocriteria. Consistent with the macroinvertebrates and the methods of VTDEC, when interpreting fish Index of Biotic Integrity (IBI) scores we analyzed the two stream types separately.

However, unlike the macroinvertebrates, there were no comparable analyses about how VTDEC applies the fish biocriteria to low gradient streams. Thus KA-MBI used the results of the macroinvertebrate analyses of low gradient stream types (i.e., the HLG type) when assessing and interpreting fish assemblage patterns in these streams in the lower reaches of Moon Brook. The VT WQS provide for the assessment of HLG stream reach types by using "other appropriate methods of evaluation" as necessary. To determine stressor-response associations, KA-MBI examined fish assemblage response data (fish species and IBI metrics) for all project and reference streams in relation to important effects thresholds for chemical and physical stressor data collected at each site.

3.4 PHYSICAL HABITAT, GEOMORPHOLOGY, SEDIMENT AND FLOW

KA-MBI examined historical stream habitat and geomorphology data collected in the Moon Brook watershed by Bear Creek Environmental (BCE) in 2005 (BCE 2006) as well as supplemental data using the Qualitative Habitat Evaluation Index (QHEI; Ohio EPA 2006) data collected by MBI during a site visit in 2014. VTDEC relies on output from geomorphology and habitat surveys to develop stormwater TMDLs which are based on the link between stormwater and sediment loadings using evidence from biological responses, stream habitat, and geomorphology data linked with altered storm and base flows VTDEC/US EPA (2006). Table 3-2 lists the narrative assessment ranges for the Rapid Habitat Assessment (RHA) and the QHEI.

The identification of stormwater impacts in Vermont relies substantially on biological signatures in fish and macroinvertebrate assemblage data. Patterns in assemblage condition are then

informed by corresponding geomorphic and habitat data and an assessment of changes in habitat and stream channel stability (as influenced by altered stream flows due to increased impervious area with increased urbanization). VTDEC and US EPA (2006) co-authored a technical report (*Expanded Technical Analysis: Utilizing Hydrologic Targets as Surrogates for TMDL Development in Vermont's Stormwater Impaired Streams*) for developing stormwater TMDLs. This document provides the rationale for utilizing flow duration curves for developing stormwater TMDLs. Flow targets for developing TMDLs for Moon Brook were based on duration curves developed with a calibrated rainfall/runoff model (P8 - Urban Catchment Model) based on land use, precipitation, and land cover (TetraTech. 2005).

TABLE 3-2: NARRATIVE RANGES OF HABITAT CONDITION ASSOCIATED WITH VALUES OF THE RHA AND QHEI.

RHA		QHEI	
Score	Range	Score	Range
0.85-1.00	Reference	76-100	Excellent
0.65 – 0.84	Good	55-75	Good
0.25 – 0.64	Fair	45-54	Fair
0.00 – 0.34	Poor	30-44	Poor
		< 30	Very Poor

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 WATER AND SEDIMENT QUALITY

Tables in Appendix E summarize results by station for water chemistry, sediment chemistry, and urban land use parameters. Longitudinal trends were evident in several key parameters in Moon Brook. The degree of impervious surface ranged from 15-41% at the various sampling stations (Appendix E) in Moon Brook, with the lowest percent at the upstream most station (MoB_3.3), 8-21% in Mussey Brook, and approximately 50% in Paint Mine Brook.

Chloride values were lowest at the upstream most site (MoB_3.3), increased at the next four downstream sites, and then declined at the two downstream most sites which are below the confluence with Mussey Brook (Figure 4-1). Mussey Brook appeared to dilute total chloride levels in the lower reach of Moon Brook. Moon Brook sites between river miles 2.8 and 0.9 were above the level (>102 mg/L) associated with chronic criteria exceedance levels likely to occur during midwinter runoff and snow melt events. A similar pattern was observed for conductivity levels and sodium concentrations.

Sediment chemistry results (Appendix E) also showed a positive correlation with decreasing RM (increased % impervious surface) in the Moon Brook watershed (Figure 4-2 although PAHs peaked at RM 2.5 instead of RM 0.9 (Figure 4-2, bottom). A stormwater outfall that collects flow from a developed part of the watershed along Route 7 empties into Moon Brook just downstream of Piedmont Pond upstream from this site.

Both Button Brook and the upstream-most site on Moon Brook (MoB_3.3) were relatively clean compared to those downstream Moon Brook sites with higher %impervious area (Figure 4-2; Appendix E). The site at the mouth of Moon Brook reflect a slight decline in total PAHs (Figure 4-2, bottom) and a bigger decline in total metals (Figure 4-2, top) which may be due to dilution from Mussey Brook which is less impervious than sites immediately upstream in Moon Brook (e.g., MoB_0.9).

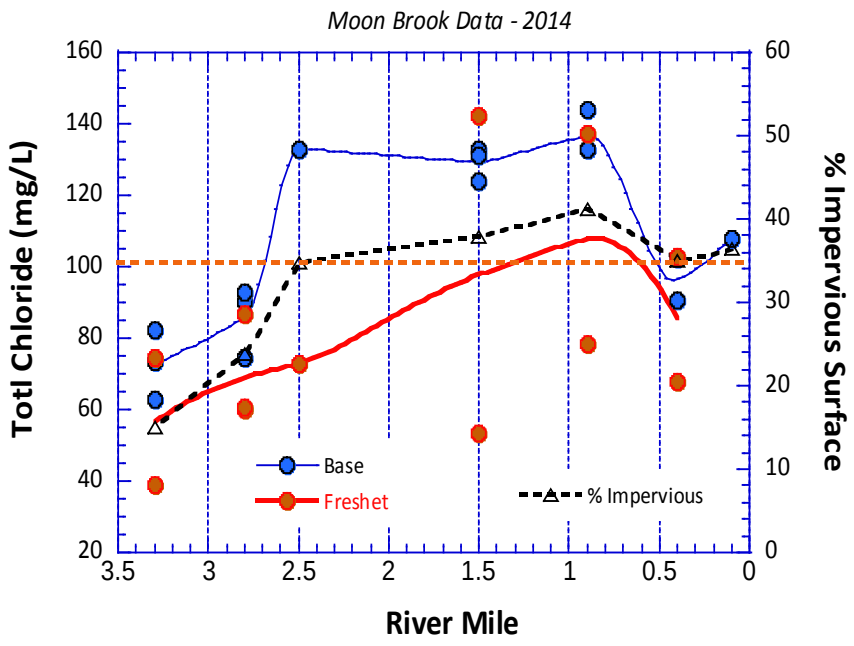

FIGURE 4-1: PLOT OF TOTAL CHLORIDE AND % IMPERVIOUS SURFACE (TRIANGULAR SYMBOLS) BY SAMPLE SITE VS. RIVER MILE IN MOON BROOK FOR ALL SITES SAMPLED IN 2014. BASE FLOW SAMPLES ARE REPRESENTED AS BLUE POINTS AND FRESHET SAMPLES AS ORANGE POINTS. LINES THROUGH THE CHLORIDE DATA ARE INTERPOLATED SMOOTHING CURVES.

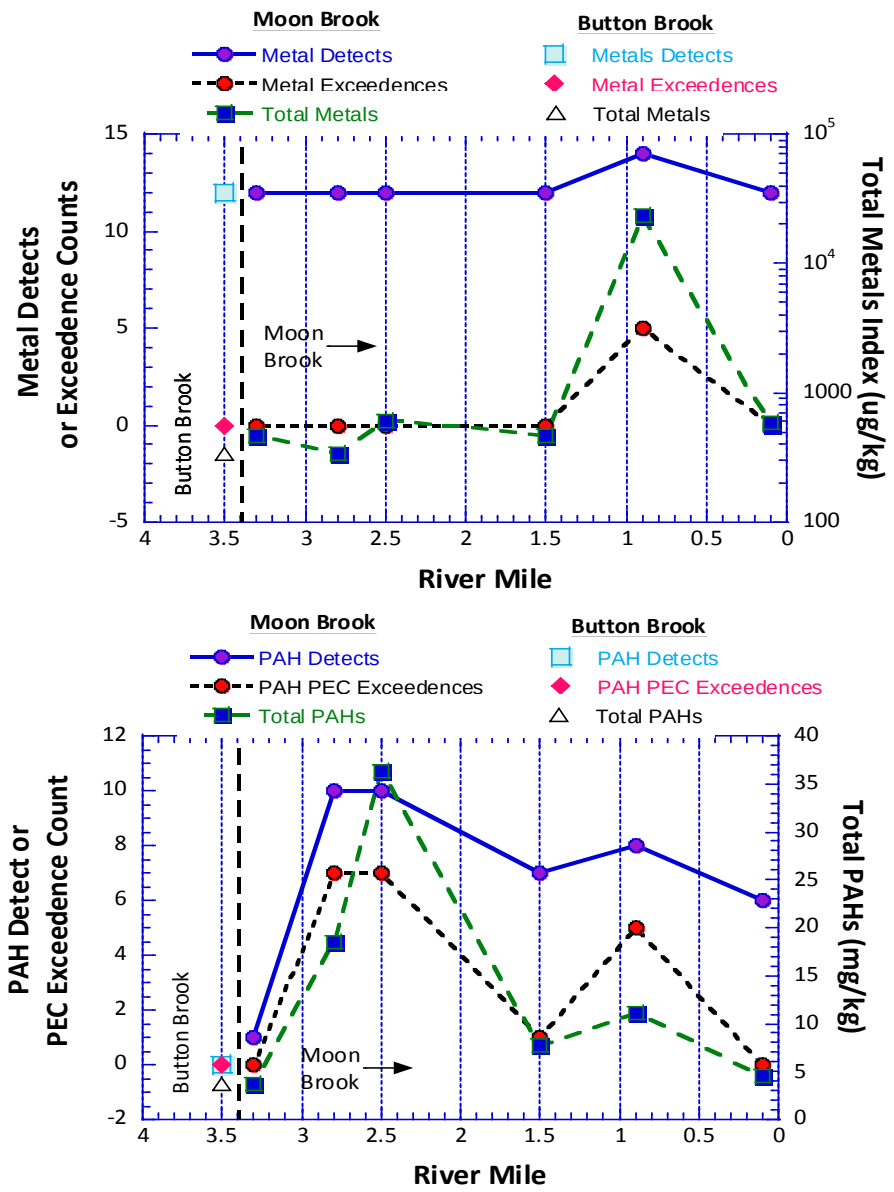

FIGURE 4-2: PLOT OF TOXIC METALS DETECTIONS, PEC EXCEEDANCES, AND A TOTAL TOXIC METALS INDEX (UG/KG; TOP) AND PAH DETECTIONS, PEC EXCEEDANCES, AND TOTAL PAHS (MG/KG; BOTTOM) IN SEDIMENT SAMPLES VS. RIVER MILE IN MOON BROOK DURING 2014.

4.1.2 TEMPERATURE

Nine stations on Moon Brook were monitored from 2006 through 2014. Six of these stations correspond to VTDEC biological and chemical monitoring sites (Table 4-1); two of these sites were monitored for only two years (2006-2007). Tributaries that were monitored include two sites on Mussey Brook (8-9 years of data) and a single site on Paint Mine Brook (7 years of data). Other monitoring sites include Tenney Brook (4-5 years) and East Creek (1 year). All streams are tributaries of Otter Creek which was also monitored for two years. Data from 2006 contained suspect values and thus were omitted from this analysis.

Inter-annual Variability

Overall, the range and frequency of temperatures among years at any given station was relatively consistent. Figure 4-3 provides representative examples[6]. This suggests that it is reasonable to pool data sets among years for any given monitoring location.

Table 4-2 summarizes the frequency (as a percentage of time) that summer water temperatures reach given levels. Two stations (Combination Pond outfall at 20 ft, and Strongs Avenue) only had two years of data and thus were not included in the pooled-year analysis.

[6] Appendix E contains a complete set of figures for all stations.

TABLE 4-1: LOCATIONS AND TIMING OF TEMPERATURE DATA MONITORING ON MOON BROOK, TRIBUTARIES, AND OTHER NEIGHBORING STREAMS CONDUCTED BY RUTLAND, VT , 2006-2014.

MOON BROOK	CORRESPONDING VTDEC STATION	2006	2007	2008	2009	2010	2011	2012	2013	2014
above Combination Pond	MoB 3.3	X	X	X	X	X	X	X	X	X
Combination Pond outfall 3 ft	MoB 2.9	X	X	X	X	X		X	X	X
Combination Pond outfall 20 ft	MoB 2.9	X	X							
above Piedmont Pond	No station	X	X	X	X	X	X	X	X	X
Piedmont Pond outfall	No station	X	X	X	X	X	X	X	X	X
Perry Street	(MoB 1.8)					X	X	X	X	X
Whites Playground	MoB 1.5	X	X	X						
Strong Avenue	MoB 1.1	X	X							
Forest Street	MoB 0.9	X	X	X	X	X	X	X	X	X
Tributaries										
Mussey Brook at Main St	No station	X	X	X	X	X	X	X		X
Mussey Brook at Park St	MuB 0.1	X	X	X	X	X	X	X	X	X
Paint Mine Brook	PmB 0.1	X	X	X	X	X	X			X
Tenney Brook at Lincoln St	TB 1.0			X	X	X	X			X
Tenney Brook at Seward St	unknown				X	X	X			X
East Creek	unknown					X				
Otter Creek	unknown				X	X				

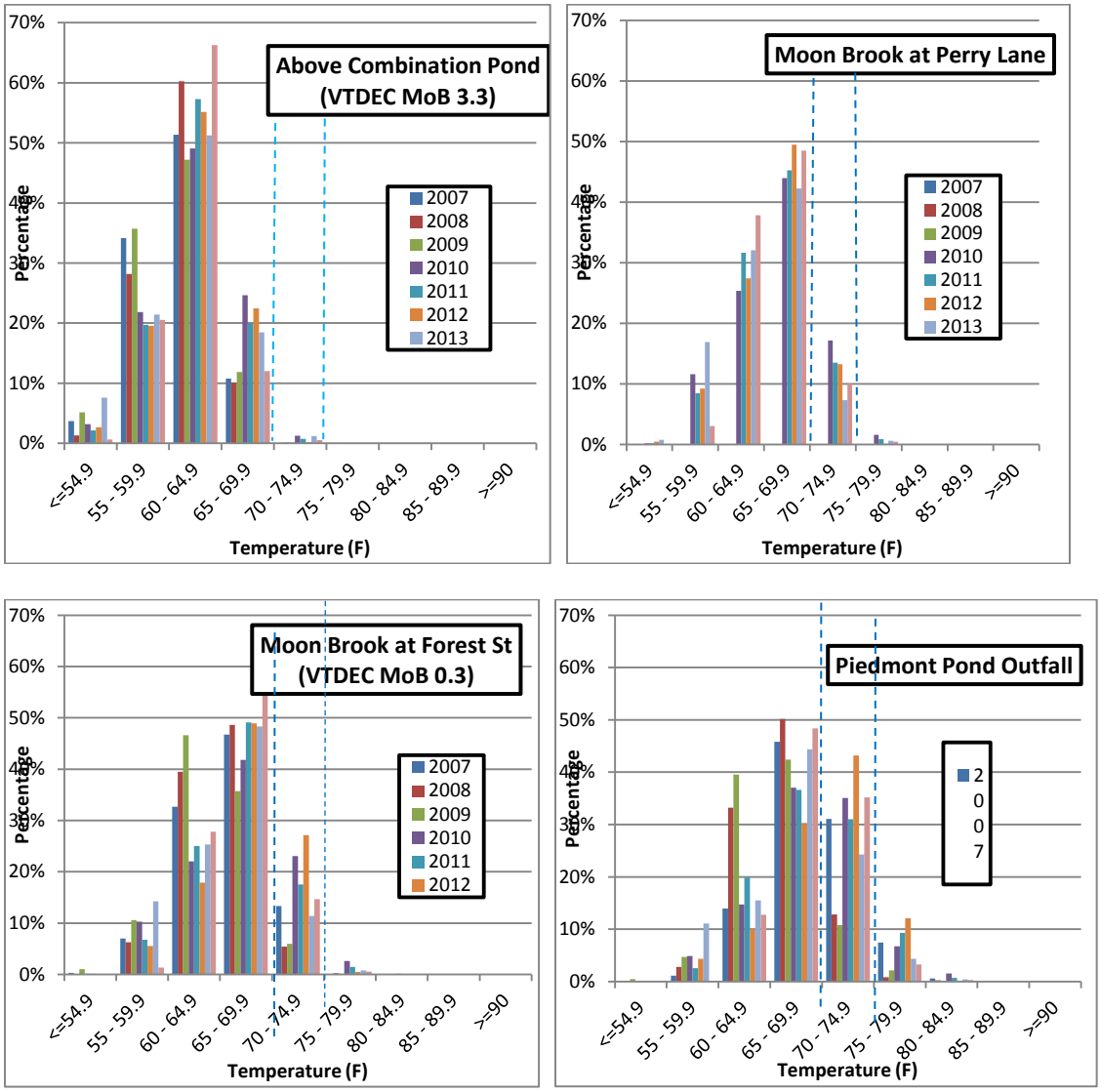

FIGURE 4-3: FREQUENCY OF OCCURRENCE OF STREAM TEMPERATURES AT FOUR MONITORING SITES ON MOON BROOK, RUTLAND VT, JUNE THROUGH AUGUST, 2007-2014. BLUE- DASHED LINES INDICATE AVOIDANCE (70°F) AND UPPER LETHAL LIMIT (75°F) THERMAL THRESHOLDS FOR BROOK TROUT.

TABLE 4-2: PERCENTAGE OF TIME OF OCCURRENCE OF JUNE THROUGH AUGUST STREAM TEMPERATURES (AT FIVE DEGREE (^{O}F) INCREMENTS) ON MOON, MUSSEY, TENNY, AND PAINT MINE BROOKS, OTTER AND EAST CREEKS BASED ON 2007-2014 DATA.

	PERCENTAGE OF TIME AT TEMPERATURE (^{O}F) INCREMENTS							
Moon Brook	**< 54.9**	**55-55.9**	**60-64.9**	**65-69.9**	**70-74.9**	**75-79.9**	**80 >**	**Temperature meets or exceeds 70° F**
above Combination Pond	5	25	55	15	2	0	0	**2 %**
Combination Pond outfall	5	19	32	30	12	1	1	**14 %**
above Piedmont Pond	1	5	23	45	24	2	0	**26 %**
Piedmont Pond outfall	1	4	20	42	27	5	1	**33 %**
Perry Street	1	10	30	44	13	2	0	**15 %**
Whites Playground	0	8	39	43	9	1	0	**10 %**
Forest Street	0	8	29	46	15	2	0	**17 %**
Tributaries								
Mussey Brook at Main St	0	8	38	46	8	0	0	**8 %**
Mussey Brook at Park St	1	7	40	32	16	3	1	**20 %**
Paint Mine Brook	2	24	53	20	1	0	0	**1 %**
Tenney Br. at Lincoln St	1	5	28	41	20	4	1	**25 %**
Tenney Br. at Seward St	1	9	28	42	16	3	1	**20 %**
East Creek	0	14	47	25	14	0	0	**14 %**
Otter Creek	1	9	22	38	24	5	1	**30 %**

The data time series collected throughout the Moon Brook watershed spans eight consecutive years and shows that locations experience a similar thermal regime from year to year and that temperatures downstream from Combination Pond are thermally elevated.

Moon Brook immediately upstream from Combination Pond rarely exceeded the 65-69.9^{o}F range. By contrast, summer temperatures reach or exceed 70°F for 10-33% of the time during the summer season downstream from Combination Pond. The abrupt increase in summer thermal loadings observed at the discharge of Combination Pond likely reflects solar warming of Combination Pond which explains much of the increase in the downstream reaches. A similar but lesser effect is seen downstream from Piedmont Pond with a trend of fewer exceedances of 70°F further downstream. Paint Mine Brook, a small, un-impounded tributary positioned in the middle reaches of the Moon Brook watershed, exhibits thermal characteristics similar to Moon Brook above Combination Pond. Other tributaries and small streams experience greater summer thermal loadings. Mussey Brook experiences temperatures of 70°F or greater 8-20% of the time, Tenney Brook 20-25% of the time, and East Creek 14% of the time. Otter Creek exhibits a thermal regime very similar to that of Moon Brook immediately below Piedmont Pond.

4.1.3 BIOLOGICAL DATA

4.1.3.1 MACROINVERTEBRATES

The 2014 Macroinvertebrate Dataset and Stream Typing

The 2014 macroinvertebrate dataset contains sampling results from eighteen (18) project-related sites. Nine of these sampling sites fall within VTDEC provisions for analysis using *small-size high gradient methods* (SHG) (Table 4-3, and Appendix E). The State further determined that six (6) sites are low gradient sites and do not fit the standard *small high gradient* sampling and analytical methods (Table 4-4). These 2014 low gradient sites are termed *hard low gradient* (HLG) and required application of alternative assessment methods.

TABLE 4-3: 2014 SMALL-SIZE HIGH GRADIENT (SHG) STREAM SITE RESULTS

VT DEC SITEID	LOCATION	STATION RIVER MILE	SITE PURPOSE	PRE-2014 ASSESSMENTS	VT-DEC 2014 ASSESSMENT	AQLU STATUS	INVERTEBRATES MODEL-TYPE	EXPOSURE							
								%TIA	OTHER STRESSOR (PAH) EXCEEDANCES	METAL EXCEEDANCES - SEDIMENTS	URBAN SW EXCEEDANCES	NUTRIENT EXCEEDANCES	SEDIMENT EXCEEDANCES	% TEMPERATURE EXCEEDANCES	HABITAT QUALITY 1
553900000033	Moon Brook	3.3	upstrm control-project site	Pre-2005: VG/G '05-'06: VG/G '12-'13: G	Ex-Very Good	Full Support	SHG	15.02	n			Tot. N; Nitrate N; TP; Tot. Hrdness	none	0%	Fair
553900000025	Moon Brook	2.5	project site	no data	Fair-Poor	Impaired	SHG	34.79	**Y**		Sp.C; Cl;	Tot. alk; Tot N; TP; Tot. Hrdness	Anthracene (0.490); Benzo[a]anthracene (3.500); Benzo[a]pyrene (4.100); Chrysene (4.900); Dibenz(a,h)anthracene (1.100); Fluoranthene (8.700); Fluorene (0.220); Phenanthrene (4.100); Pyrene (8.200)		Good
553900000015	Moon Brook	1.5	project site	Pre-2005: F '10: G '12-'13: F/P	Good	Full Support	SHG	37.76	**Y**		Sp. C; Cl;	Tot. N; Nitrate N; Tot. Hrdness	Anthracene (0.077); Benzo[a]anthracene (0.650); Benzo[a]pyrene (0.880); Chrysene (0.930); Fluoranthene (1.500); Phenanthrene (0.620); Pyrene (1.600)		Good
553900000009	Moon Brook	0.9	project site	Pre-'05: P '08: F/P '12-'13: F/P	Fair-Poor	Impaired	SHG	41.27	**Y**	**Y**	Sp. C; Cl; Na	Tot.alk; Tot. N; Nitrate N; Tot. Hrdness	Anthracene (0.190); Benzo[a]anthracene (0.900); Benzo[a]pyrene (1.000); Chrysene (1.400); Dibenz(a,h)anthracene (0.260); Fluoranthene (2.400); Phenanthrene (1.200); Pyrene (2.500); **METALS:** Copper (2110); Lead (134); Nickel (18.7); Zinc (453);		Poor
553903000001	Paint Mine Brook	0.1	project site		Good	Full Support	SHG	49.73				Tot. N; Nitrate N			Good
553901000012	Mussey Brook	1.2	project site		Very Good	Full Support	SHG	8.39				-			Fair
553901000001	Mussey Brook	0.1	project site		Fair	Impaired	SHG	21.44				Tot. alk; Tot. N; Tot. Hrdness			Fair
554400000003	Airport Brook	0.3	project site		Good	Full Support	SHG	8.74				-			na
553801000010	Tenney Brook	1	project watershed site		Fair	Impaired	SHG	29.14				Tot. N; TP; Tot. Hrdness			na
553801000001	Tenney Brook	0.1	project watershed site		Fair	Impaired	SHG	33.53				Tot. N; TP; Tot. Hrdness			na

VT DEC SiteID	Location	Station river mile	Site Purpose	Pre-2014 Assessments	VT-DEC 2014 Assessment	AQLU Status	Invertebrates Model-type	EXPOSURE							
								%TIA	Other Stressor (PAH) Exceedances	Metal Exceedances - sediments	Urban SW Exceedances	Nutrient Exceedances	Sediment Exceedances	% Temperature Exceedances	Habitat Quality 1
553101000013	Warner Brook	1.3	CITY suggested ref (SHG model applied)		Excellent	Full Support	SHG					-			na
554800000006	Button Brook	0.6	project site		Excellent	Full Support	SHG	1.76				-			na

TABLE 4-4: 2014 HLG LOW GRADIENT STREAM SITE RESULTS

VT DEC SITEID	LOCATION	STATION RIVER MILE	SITE PURPOSE	VT-DEC 2014 PROVISIONAL ASSESSMENT	INVERTEBRATES MODEL-TYPE	PROBABILITY OF MEMBERSHIP IN HLG TYPE	EXPOSURE							
							%TIA	OTHER URBAN	METAL EXCEEDANCES - SEDIMENT	URBAN SW EXCEEDANCES	NUTRIENT EXCEEDANCES	SEDIMENT EXCEEDANCES	TEMPERATURE EXCEEDANCES	HABITAT QUALITY 1
553900000001	Moon Brook	0.1	project site-low grad	Fair/Impaired	SW/HLG	87%	36.37		n	Sp. C; Cl; Na	Tot. alk; Tot. N; Tot. Hrdness;	n		Good
554400000002	Airport Brook	0.2	project watershed site-low grad	na [1]	SW/HLG	100%	8.75				Tot. Hrdness			
552500000005	Jones Brook	0.5	CITY-low gradient **reference**	na	SW/HLG	90%	5.82				Tot. Hrdness			
553101000005	Warner Brook	0.5	CITY-low gradient **reference**	na	SW/HLG	100%					-			
554800000001	Button Brook	0.1	DEC-low gradient **reference**	na	SW/HLG	68%	3.26		Y (Pb)	y (Pb)	Tot. P	n		
553102000042	Sugar Hollow Brook	4.2	DEC-low gradient **reference**	na	SW/HLG	97%	0.8				-			

SMALL-SIZE HIGH GRADIENT (SHG) MACROINVERTEBRATE ASSESSMENTS

VTDEC has promulgated biological criteria for high/moderate gradient streams that yield assessment results that determine attainment of VT's water quality standards VT-WQS. These biocriteria have been increasingly used for regulatory assessments since the major revision of VT-WQS that occurred in 2000.

SHG assessment outcomes for the 2014 field season, as well as available sampling events from previous years, are shown in Table 4-4 andTable 4-5. Of the six 2014 SHG Moon and Mussey Brook sites, three were assessed as impaired in 2014 (*Fair* or *Poor* ratings) and four had received at least one *Fair* or *Poor* rating in previous sampling years. Twenty out of twenty-one SHG Moon Brook sampling events from throughout Moon Brook (i.e., RM 2.9 through RM 0.4) were assessed as Fair or Poor as summarized in VTDEC Document 1 (the 2010 Moon Brook Bioassessment Report).

TABLE 4-5: STANDARD SHG METRIC VALUES FOR MOON BROOK AND 2014 REFERENCE STREAMS, AS REPORTED BY VTDEC. RED HIGHLIGHTED SITES INDICATE DEPARTURE FROM EXPECTED VALUES FOR REFERENCE.

DATE	LOCATION	RIVER MILE	VVTDEC ASSESSMENT	MEANDENSITY	MEANRICHNESS	MEANEPTRICHNESS	PMA-O1	MEANNEW_BI	MEANOLIGOCHAETA%	MEANEPT/EPT+CHIRO	PPCS-1
9/24/2014	Warner Brook	1.3	Exc	2296.0	54.0	26.0	77.6	2.60	2.3	0.90	0.70
9/24/2014	Warner Brook	1.3	Exc	2288.0	56.0	29.0	81.0	2.07	2.3	0.88	0.72
9/26/2014	Tenney Brook	0.1	Fair	7772.0	57.0	23.0	58.9	**4.89**	0.1	0.94	**0.29**
9/26/2014	Tenney Brook	1	Fair	3460.0	46.0	20.0	64.9	**5.32**	0.0	0.68	**0.31**
9/25/2014	Moon Brook	0.9	F-poor	3524.0	40.0	**11.0**	58.1	4.30	0.2	0.87	0.44
9/25/2014	Moon Brook	1.5	Good	6188.0	55.0	**18.5**	65.2	**4.42**	0.1	0.83	**0.42**
9/25/2014	Moon Brook	2.5	F-poor	3808.0	36.0	**10.0**	55.9	5.98	0.0	0.89	**0.33**
9/26/2014	Moon Brook	3.3	Ex-Very good	2564.0	49.5	24.5	58.4	3.10	3.9	0.89	0.52
9/26/2014	Mussey Brook	0.1	Fair	2754.0	45.5	18.0	77.2	**4.69**	0.0	0.89	**0.29**
9/26/2014	Mussey Brook	1.2	very Good	3638.0	58.5	22.0	73.2	**3.26**	0.0	0.90	**0.43**
9/25/2014	Paint Mine Brook	0.1	Good	5232.0	54.0	**17.0**	75.9	**4.19**	0.0	0.88	0.55
9/23/2014	Airport Brook	0.3	Good	6116.0	48.0	21.0	73.7	**4.38**	0.5	0.87	**0.40**
9/24/2014	Button Brook	0.6	Exc	3628.0	55.0	33.0	84.0	2.32	0.3	0.86	0.66

TABLE 4-6: METRIC VALUES FOR MOON BROOK AND 2014 REFERENCE STREAMS, AS REPORTED BY VT-DEC USING "BEST-PERFORMING" HLG LOW GRADIENT STREAM CANDIDATE METRIC. RED HIGHLIGHTED SITES INDICATE DEPARTURE FROM EXPECTED VALUES FOR REFERENCE.

LOCATION	STATION RIVER MILE	SITE PURPOSE	EOT RICHNESS	EOT PERCENT (MODIFIED)	BIOTIC INDEX	BCG (INDEX)	BCG RICHNESS (1-3)	PMAO (HLG)	OTHER INSECTA &NON-INSECT %	AMPH+ISOPOD(-HYALELLA)%	SHREDDERS/COLL-FILT	*VT-DEC BPJ PROVISIONAL ASSESSMENT*	*AQLU STATUS*
Moon Brook	0.1	project site-low grad	11.50	11.80	6.35	4.21	9.00	57.20	22.10	2.93	16.84	*2008: F* *2014: F*	*Impaired*
Airport Brook	0.2	project watershed site-low grad	17.00	21.40	4.91	4.07	10.00	70.10	11.70	1.63	0.31	na	
Jones Brook	0.5	CITY-low gradient **reference**	20.00	24.90	4.31	3.76	16.00	71.00	4.10	0.61	0.12	*na*	
Warner Brook	0.5	CITY-low gradient **reference**	34.00	49.40	3.71	3.35	33.00	77.50	1.20	0.00	0.49	*na*	
Button Brook	0.1	DEC-low gradient **reference**	18.00	40.70	4.03	3.77	14.00	84.70	12.10	0.00	0.89	*na*	
Sugar Hollow Brook	4.2	DEC-low gradient **reference**	27	13.4	3.974	3.54	27	67.5	5.8	0	0.4	*na*	
		Mean of Rutland Reference Streams:	**23.20**	**29.96**	**4.19**	**3.70**	**20.00**	**74.16**	**6.98**	**0.45**	**0.44**		
		Mean of Statewide HLG Reference Streams:	**17.30**	**38.90**	**4.36**	**3.65**	**16.00**	**74.20**	**13.30**	**0.00**	**3.64**		
		Median of Statewide HLG Reference Streams:	**14.50**	**38.60**	**4.08**	**3.69**	**14.50**	**74.90**	**7.70**	**0.00**	**0.93**		
		Higher Value = more disturbed:			**Y**	**Y**			**Y**	**Y**	**Y?**		

Hard Low Gradient Stream (HLG) Macroinvertebrate assessments

Consideration of the six low gradient sites sampled in 2014 (Table 4-4 and Table 4-6) required a different approach. Because VTDEC has not completed technical development of biocriteria for low gradient streams KA-MBI recommended a reference site approach to compare the biological status of low gradient reaches of the project streams against low gradient streams not affected by stormwater. By mutual agreement among the 3 parties (City, State and KA-MBI) the State sampled a set of 4 low gradient reference sites (Button RM 0.1; Jones RM 0.5; Sugar Hollow RM 4.2 and Warner (aka Pine Hill) RM 0.5) using the VTDEC standardized sweep-net methods that VTDEC established as appropriate for low gradient stream habitats. Additionally Moon Brook RM 0.1 and Airport Brook RM 0.2 were sampled and analyzed using low gradient methods.

The State's low gradient statistical analysis methods are described in VTDEC Document 2 (LGcriteria_Summary092014_Rutland), the unpublished draft VTDEC low gradient methods document and accompanying Excel data file. HLG is one of two low gradient types identified in the State. The other type is termed "*Soft Low Gradient*" (SLG). VTDEC first examined the taxonomic composition of a statewide dataset of reference-quality low gradient streams. Two-Way Indicator Species Analysis (TWINSPAN) identified two distinct natural taxonomic groups among these low gradient reference sites. Next, using canonical correlation analysis (CCA), VTDEC identified characteristic differences in physical and geographic factors for the sites making up each of these taxonomic composition groups. CCA demonstrated that these two low gradient stream types are distinguished by statistically significant differences in such proximal and distal natural factors as substrate composition, percentage of wetland land cover in the upstream watershed, and upstream slope at 2500 feet and 1 mile.

VTDEC uses Discriminant Function Analysis (DFA) to determine the group membership of new sites. DFA determined that all six of the 2014 low gradient sites (including both reference and project streams) belonged to the low gradient stream-type "*Hard Low Gradient*" (HLG) at very high probabilities (Table 4-4). Because the low gradient sites discussed in this report are all of the HLG type the SLG type will not be discussed further.

Provisional assessment of Low Gradient sites

VTDEC has analyzed the status of Moon Brook RM 0.1 via their current *draft* low gradient biocriteria. For purposes of the Moon Brook evaluation staff evaluated the discriminatory performance of candidate metrics computed for Moon Brook RM 0.1, in the context of a statewide database of 44 reference and disturbed low gradient sites from the HLG stream type. They also analyzed Moon Brook RM 0.1 against the four low gradient reference sites agreed upon by the parties. Low gradient reference sites were distinguished in the statewide dataset by selecting the upper 25th percentile of sites in terms of land use and chemical water quality variables (e.g., in part, % development, % agriculture, conductivity, nutrient concentrations, etc)

Based on their on-going low gradient biocriteria development efforts, VTDEC used nine of what they deemed to be the best-performing candidate low gradient metrics (retaining only those metrics that were not significantly correlated with each other), to characterize differences in the biological condition of Moon Brook RM 0.1 versus the 2014 suite of HLG reference sites. Their work is reproduced here in Table 4-6. VTDEC assigned a Best Professional Judgment attainment status of *Fair* to Moon Brook RM 0.1 with the proviso that final metric selection and WQS attainment thresholds have not yet been established for HLG low gradient streams.

Evaluation of appropriateness of VT-DEC analytical protocols and models for assessment of SHG and HLG sites

VT-DEC's standard high gradient (SHG) sampling and analytical methods are well-designed, well-vetted and fully appropriate for application to most sites in the Moon Brook watershed. However, Moon Brook RM 0.1 presented challenges because application of VT-DEC standard small-size high gradient methods could not be justified due to differences in stream gradient and substrate composition. The City was concerned that the fine-grained substrates and slower water velocities in lower Moon Brook created naturally different biological expectations, and thus, Moon Brook RM 0.1 could never be expected to attain SHG biocriteria due to largely natural causes.

KA-MBI agreed that it was inappropriate to apply SHG methods to the lowest reach of Moon Brook. By mutual agreement all parties decided to use a site-specific reference stream approach. The objective was to locate 'as similar as possible' streams, preferably in the Otter Creek watershed, having substrate, gradient, and landscape position (i.e., site location within a watershed relative to stream origin and mouth of the stream) characteristics comparable to Moon Brook RM 0.1, but

having a mostly forested or non-urbanized watershed. All parties agreed to four low gradient reference streams. Two were advocated by the City (Jones Brook RM 0.5 and Warner Brook RM 0.5, *aka Pine Hill*,), and two were advocated by VT-DEC (Button Brook RM 0.1 and Sugar Hollow Brook RM 4.2). The Moon Brook RM 0.1 site had a TIA of 36% while the average for the reference streams was 4.65%. Table 4-7 presents physical habitat similarities and difference between Moon Brook and the other low gradient streams sampled in 2014.

TABLE 4-7: SIZE AND SUBSTRATE COMPOSITION SIMILARITIES AND DIFFERENCE BETWEEN LOW GRADIENT HLG MOON BROOK AT RM 0.1 AND OTHER LOW GRADIENT REFERENCE STREAMS SAMPLED IN 2014.

Location	Station	SubBoulder%	Sub Cobble%	Sub Coarse Gravel%	Sub Gravel%	Sub Sand%	Sub Silt%	Sub Clay%	Large Woody Debris	BankFull Width	Wetted Width	Canopy%
Moon Brook	0.1	0	0	1	10	64	20	5	10	11	7	70
Button Brook	0.1	0	0	2	8	30	40	20	4	2.5	1.5	60
Sugar Hollow Brook	4.2	0	2	8	20	40	30	0	30	4.5	3.5	70
Warner Brook	0.5	0	0	0	20	70	10	0	10	4.5	2	70
Jones Brook	0.5	0	0	5	5	80	10	0	20	4.5	3.5	40
Airport Brook	0.2	0	5	15	25	45	10	0	3	3	2	20

While Moon Brook at RM 0.1 is somewhat larger than the other streams, it does not exhibit biologically important differences in substrate composition thus we find the biological comparison with local reference streams to be valid.

KA-MBI also reviewed the VT-DEC statewide low gradient dataset and the uni- and multivariate statistical analysis (Appendix B) that concluded that Moon Brook Rm 0.1 is appropriately categorized in low gradient stream type HLG, with 87% probability (Table 4-4). The discriminant function model that assigns low gradient stream type considers variables at both the local, site-scale (e.g., including pH, % canopy, alkalinity) as well as larger scale, landscape position characteristics Slope at 1000', 2500' and 1 mile upstream; % wetland in the watershed).

KA-MBI found the statistical objectivity and rigor of this analysis to be very convincing that Moon Brook RM 0.1 was appropriately classified as HLG, and that Moon Brook RM 0.1 exhibited markedly poorer biological condition than that expected from both the statewide, and the local HLG reference stream datasets used for comparison.

Macroinvertebrate assessment outcomes and exposure to chemical and physical stressors

Macroinvertebrate results for both SHG and HLG stream sites reflect the influence of physical and chemical stressors on the biological condition of Moon Brook. Temperature influences on

presence, absence and numbers of individuals of cold-water dependent taxa (Plecoptera and Ephemeroptera) show absence of stoneflies when comparing Moon Brook RM 3.3 (above Combination Pond) to Moon Brook RM 2.5 below Combination Pond (Table 4-8). However stoneflies are present in good numbers at Moon Brook 1.5 and present but in low numbers at Moon Brook 0.9. Plecoptera as an order have relatively low tolerance to elevated temperature. Nebeker and Lemke (1968) reported that LC 50 temperatures (the temperature at which 50% died after 96 hours) ranged from 21°C(69.8 F) , for *Taeniopteryx maura* (Plecoptera, winter stonefly) to 33°C (91.4 F) for *Ophiogomphus rifpinsulensis* (Odonata, dragonfly).

TABLE 4-8: TEMPERATURE INFLUENCES FROM INSTREAM PONDS

ABOVE OR NOT INFLUENCED BY INSTREAM POND				
	PLECOPTERA DENSITY	PLECOPTERA RICHNESS	EPHEMEROPTERA DENSITY	EPHEMEROPTERA RICHNESS
Moon Brook RM 3.3 (SHG)	84	10	6.7	7
Warner Brook RM 1.3 (SHG)	92	4	18.1	9
Paint Mine Brook RM 0.1 (SHG)	36	4	12.6	4
BELOW COMBINATION POND				
Moon Brook RM 2.5	0	0	20	3
Moon Brook RM 1.5	42	4	9.2	6
Moon Brook RM 0.9	4	1	80	4
Moon Brook RM 0.1	0	0	78	7

The most heat sensitive stonefly mentioned by Nebeker and Lemke (1968), *Taeniopteryx*, was found in Jones and Warner Brooks, Sugar Hollow, Moon Brook RM 3.3 and Moon Brook RM 1.5. This study also reported *Ephemerella subvaria* to be very temperature sensitive having an LC 50 of 21.5°C (70.7 F). The genus Ephemerella was present at Moon Brook RM 2.5 (density of 4 individuals), Moon Brook RM 1.5 (density of 108 individuals), and at Moon Brook RM 0.9 (density of 12 individuals).

These findings suggest that elevated summer water temperature downstream of Combination Pond is likely to be contributing to some depressions in numbers and types of cold-loving macroinvertebrates, but it does not explain the full suite of observed changes in taxonomic composition and performance of metrics describing macroinvertebrate community structure in lower Moon Brook (Table 4-5 and Table 4-8). The finding that some populations of coldwater

dependent taxa are being sustained at sites in the lower reaches of Moon Brook indicates their capacity to survive the temperature regimes below Combination Pond.

Moon Brook sites RM 2.5, 1.5, 0.9 and 0.1 all had conductivity and chloride values above VT WQ criteria impairment risk concentrations. All except RM 1.5 were assessed as impaired for the 2014 macroinvertebrate data. Moon Brook RM 1.5 was assessed as *Good* in 2014, but *Fair* prior to 2005 and *Fair* to *Poor* in 2012. Although subjected to high levels of urban chemical stressors the occasional higher assessment outcomes for Moon Brook RM 1.5 may be attributable to the finding that the site scored relatively high for habitat quality (Figure 4-6). It is also located a short distance downstream of the confluence of Hospital Brook (not sampled) which may offer some unknown ameliorating effects. Historical data for the next nearest downstream site, Moon Brook RM 1.1 (sampled in 2006, 2010 and 2012) all were assessed as *Fair* to *Poor*. Paint Mine Brook, with conductivity and chloride concentrations higher than non-urban reference streams, but lower than impairment risk concentrations was assessed as *Good* in 2014. As noted conductivity is a surrogate for a number of urban-induced disturbances to stream chemistry and increased chloride concentrations are associated with winter snow and ice treatment on roads.

4.1.3.2 FISH ASSEMBLAGE

Fish IBI data and brook trout abundance are summarized in Appendix E and species by site are available in spreadsheets from VTDEC. VTDEC has established reference conditions for two wadeable stream classifications, small coldwater streams, medium-sized coldwater streams, and warmwater streams. The Cold Water Index of Biological Integrity (CWIBI) is applied in small coldwater streams and the Mixed Water Index of Biological Integrity (MWIBI) is applied in medium-sized coldwater and warmwater streams.

The Moon Brook sites upstream from Mussey Brook were assessed by VTDEC using either the MWIBI (MoB_0.9 to MoB_2.5) or the CWIBI (MoB_3.3). Figure 4-4 illustrates the longitudinal pattern of the IBIs by river mile in Moon and Mussey Brooks in 2014. The MWIBI as calculated was not applied to MoB_0.1 because it represents a low gradient soft bottom stream type that does not as yet have an IBI. VT DEC applied the MWIBI with best professional judgment, as is permitted by their protocols, to arrive at a narrative rating of fair (impaired) for MoB_0.1. They concluded that the fish assemblage at MoB_0.1 was unbalanced due to the “irruptive influence” of tessellated darters *(Etheostoma olmstedi)* which disproportionately influenced three of the

proportional metrics of the MWIBI. To illustrate how the MWIBI might better perform if adjusted to reflect the abnormal irruption of highly abundant species or in other situations with very low numbers of fish (i.e., using the "low end" scoring method of Rankin and Yoder 1999) we adjusted the affected MWIBI metric scores to better reflect the actual condition of the assemblage at this site. We adjusted three proportional metrics by scoring them as a '1' instead of '5' to account for the irruptive influence of tessellated darter. This adjustment resulted in the adjusted MWIBI scoring in the fair range which agrees with the narrative assessment produced by VTDEC using best professional judgment.

Other than the site at RM 3.3 on Moon Brook above Combination Pond, the next two sites had marginal fish assemblages. The site at RM 2.5 (Combination Pond outfall) was considered fair and at RM 1.5 was considered good. These results are consistent with past years of data. The two sites in the lower one mile of Moon Brook were considered fair or poor (impaired) and also consistent with previous years of sampling.

Using the applicable MWIBI model for the sites at RM 2.5 and 0.9, the IBI scores were considered to be fair, which does not attain the Class B goal for Moon Brook. The site at river mile 2.5 had a high species richness, but was dominated by tolerant individuals and a number of the species were either invasive or macrohabitat generalists (likely escapees from Combination Pond). The site at RM 0.9 had fewer species, but no intolerants and was dominated by generalist species (e.g., Creek Chub). The fish assemblage at the site at RM 0.1 was highly skewed by a single species with other species represented by only a few individuals. A cluster analyses of the 2014 data demonstrates that the Moon Brook site at RM 0.9 was substantially different in composition from the upstream Moon Brook sites, and also from the other nearby low gradient reference streams that were sampled in 2014 (Figure 4-6). It is likely that the finer substrates are the result of materials exported from upstream bank and bed erosion and this inhibits fish species that are dependent on larger and less embedded substrates.

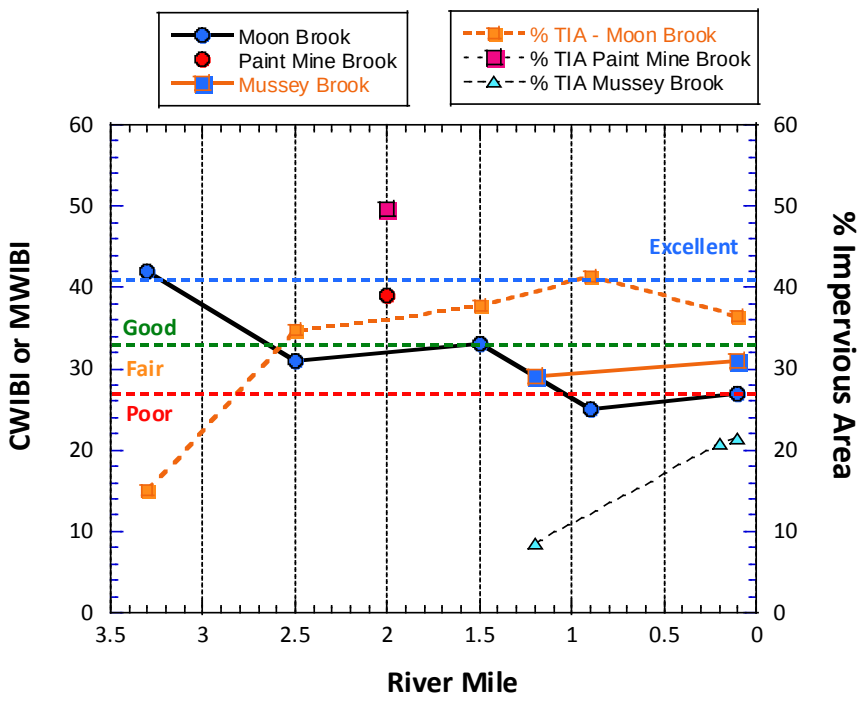

FIGURE 4-4: PLOT OF THE CWIBI OR MWIBI AND %TIA VS. RIVER MILE FOR MOON BROOK, MUSSEY BROOK, AND PAINT MINE BROOK FOR 2014. DASHED LINES ILLUSTRATE INDEX BOUNDARIES FOR THE RESPECTIVE NARRATIVE RANGES OF THE IBI.

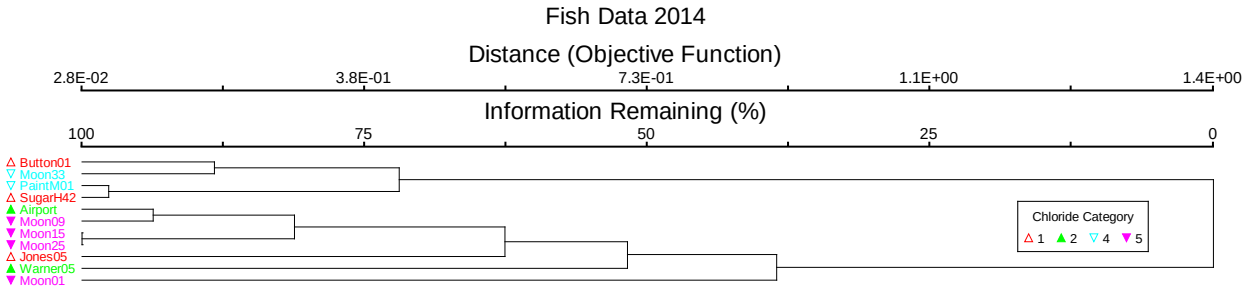

FIGURE 4-5: CLUSTER ANALYSIS DENDOGRAM OF FISH SITES SAMPLED IN MOON BROOK AND IN LOW GRADIENT REFERENCE SITES SAMPLED IN 2014. SITE NAMES ARE COLOR CODED BY THE RANGES OF MEAN CHLORIDE (1 - < 20 MG/L; 2 – 20 TO < 50 MG/L; 4 – 50 - <100 MG/L AND 5 - > 100 MG/L).

4.1.4 PHYSICAL HABITAT, GEOMORPHOLOGY, AND FLOW

Habitat and geomorphology data from the Bear Creek Environmental studies along with QHEI data collected by KA-MBI in 2014 are summarized in Appendix E. We were interested in whether geomorphology and habitat conditions are influenced by impervious land cover and stormwater and whether values were in ranges that could explain some of the variation in fish and macroinvertebrate assemblages and attainment of biocriteria benchmarks that are appropriate to reaches of Moon Brook.

Longitudinal plots illustrate a general decline in habitat quality with downstream distance as measured by both the RHA and QHEI (Figure 4-6, upper) and individual QHEI metrics (Figure 4-6, lower). The RHA index is calibrated to Vermont stream types and conditions (VTANR 2008) and is the primary habitat assessment tool for Vermont. The QHEI (Rankin 1995, Ohio EPA 2006) provides some additional insights about habitat conditions and it has been used to derive habitat TMDLs (Ohio EPA 2010) and to design and establish benchmarks for stream restoration (Phillips 2012) in the Midwest. Potential impacts to aquatic life are particularly evident in the lower 1.3 miles of Moon Brook based on QHEI channel and substrate metrics (Figure 4-6, lower). These reaches are also associated with the greatest degree of direct physical alterations to the Moon Brook channel (BCE 2006, 2008).

While the RHA and QHEI each measure habitat features that are important to aquatic life, the geomorphic assessments conducted in Vermont (VTANR 2005a,b) assess the stability and function of stream channels with the goal of understanding factors which could form the basis for channel restoration (e.g., BCE 2008). As used by VTANR (2005a,b) this data can also be used to determine the relative influence of stormwater on direct habitat alterations that may be limiting to aquatic life.

BCE (2006) conducted a Phase II RGA in 2005 and rated the geomorphic condition of Moon Brook (Appendix E). BCE (2006) estimated that five reaches were in good geomorphic condition, four in fair, and one in poor condition which is within the Route 7 corridor of Rutland. BCE also identified hydrologic watershed input stressors and reach modification stressors as part of the Phase II assessment (summarized in Appendix E). BCE (2008) concluded that percent of urban development and road density were most often the extreme input stressors followed by stormwater inputs. BCE also concluded that high urban land use and high road density is linked

to higher peak flows and less water retained (via infiltration) in the watershed. These phenomena consequently alter geomorphic conditions and aquatic habitats. The hydrologic factors are thought to be directly linked to the habitat alterations documented by BCE that include channelization/straightening, encroachment on the riparian zone, bank erosion, and bank armoring/revetments.

BCE (2008) concluded that the site at RM 0.1 in Moon Brook has almost certainly been relocated and channelized as is illustrated on aerial photo (Figure 4-7). The proximity of nearby, upstream higher slope segments is a predictor variable of the HLG stream category (VTDEC Document 2) that predicts the occurrence of coarser substrates in this reach. It is likely that this site, prior to channelization, had substrates more closely associated with the HLG stream category even though they are finer at present. BCE (2006,2008) identified that aggradation of fine sediments was characteristic of many of the reaches in the Moon Brook watershed that have been altered through straightening and influenced by the hydrologic alterations resulting from stormwater (e.g., bank erosion). The low gradient lower reach of Moon Brook is now a depositional area where the energy needed to move sediments further downstream is compromised by the lessened stream power complicated by the apparent channelization.

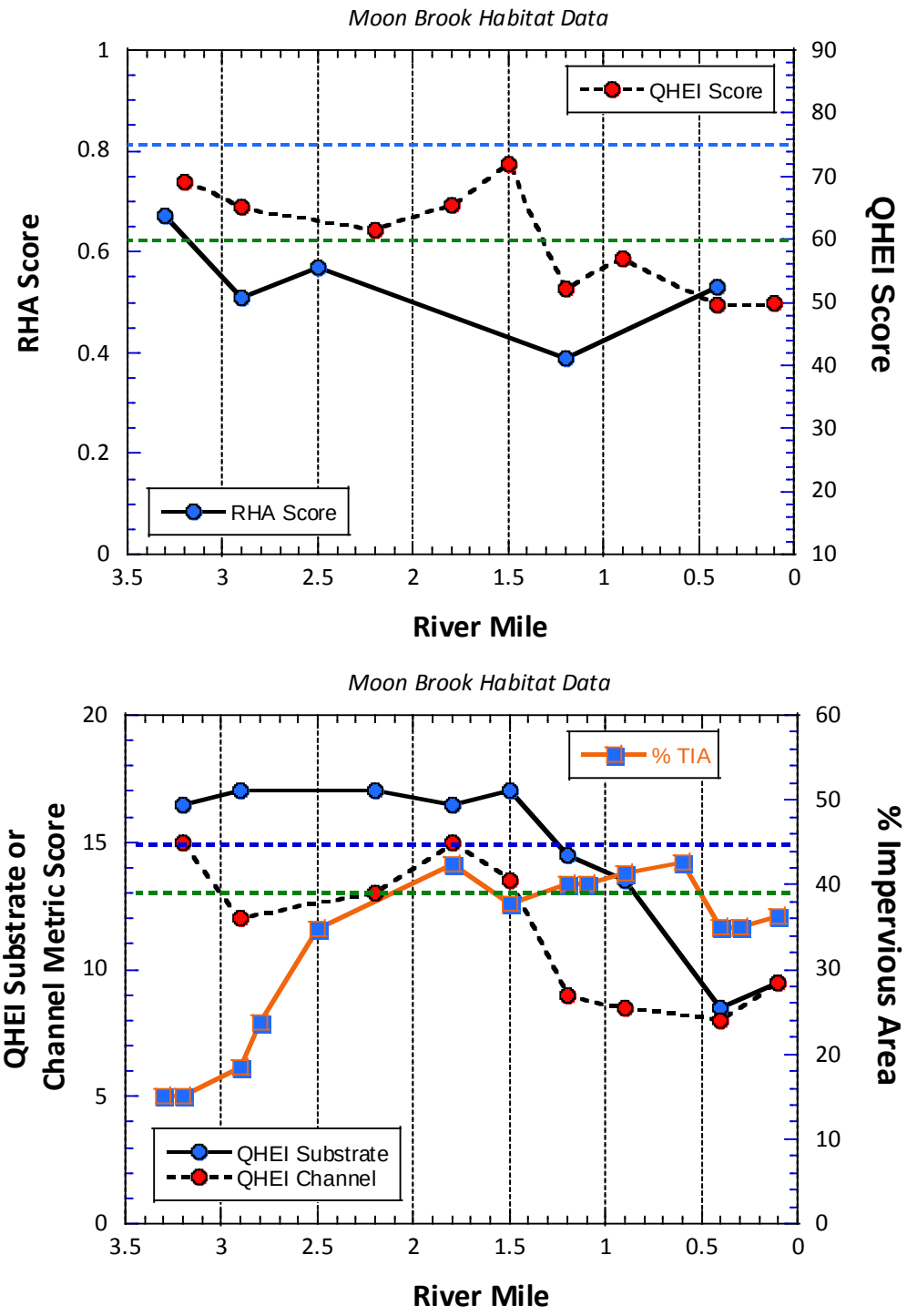

FIGURE 4-6: PLOTS OF THE RHA AND THE QHEI VS. RIVER MILE (UPPER) AND QHEI CHANNEL AND SUBSTRATE METRICS AND PERCENT IMPERVIOUS AREA (LOWER) IN MOON BROOK. HORIZONTAL DASHED LINES REPRESENT TYPICAL HABITAT TMDL TARGETS EXCEPTIONAL (BLUE) AND "GENERAL" WARMWATER (GREEN) IN OHIO.

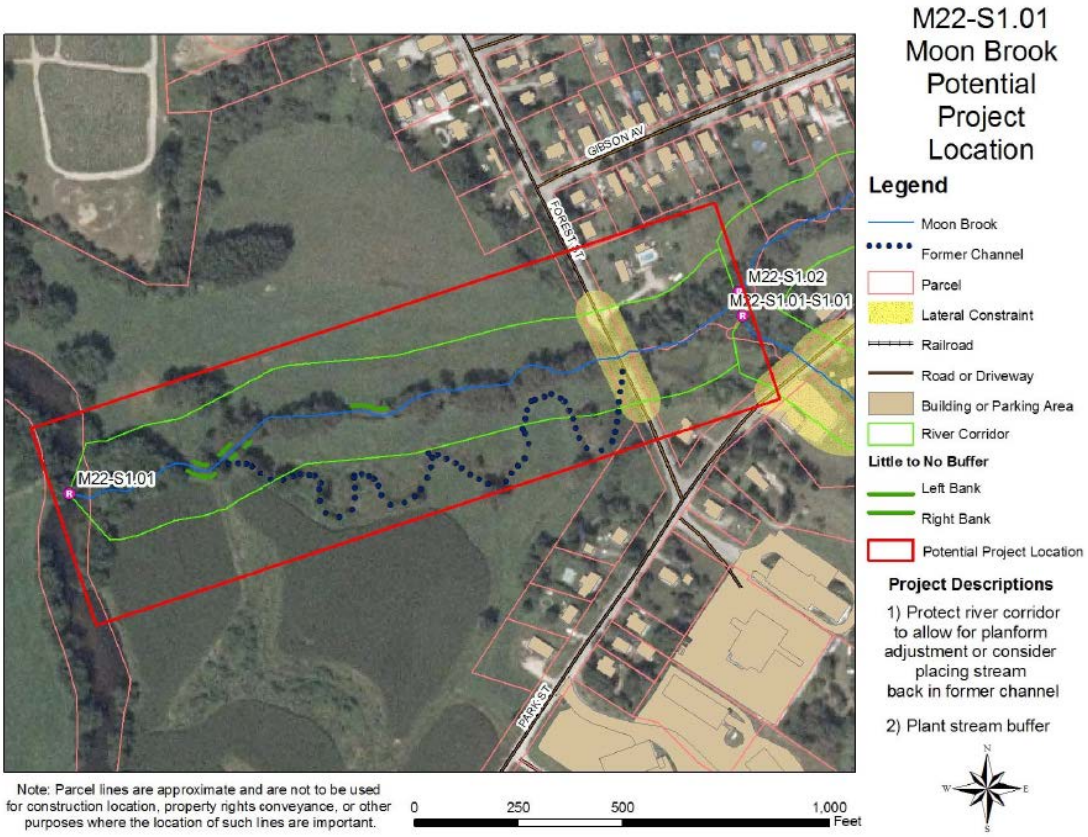

FIGURE 4-7: MAP OF THE LOWER REACH OF MOON BROOK TAKEN FROM BCE (2008) ILLUSTRATING THE FORMER LOCATION OF THE NATURAL CHANNEL AND THE CURRENT RELOCATED AND STRAIGHTENED CHANNEL.

4.2 DISCUSSION

The KA-MBI independent assessment of the causes of aquatic life impairment in reaches of the Moon Brook watershed used existing biological, habitat, geomorphology, water temperature and sediment data collected by the VTDEC and City of Rutland that was used in the prior assessment and biological, physical and water chemistry data (water column and sediment) collected in 2014 (Section 4.1). We also reviewed literature regarding urbanization and stormwater with a particular focus on New England to inform this effort, particularly where monitoring data were more detailed.

4.2.1 WATER QUALITY AND SEDIMENT CHEMISTRY

Impervious surface vs. total chloride for all sites sampling in 2014 showed a strong correlation, particularly at base flows (Figure 4-6). The pattern of generally higher concentrations during

base flow than freshets was similar to Trowbridge et al (2010) in New Hampshire and Bartlett and Bowden (2014) in Vermont. Bartlett and Bowden (2014) data are from the Champlain watershed (like Moon Brook) and they also document a decline in macroinvertebrate assemblages associated with increased impervious cover. Paint Mine Brook, a small tributary of Moon Brook is an outlier (Figure 4-6) in that is has the highest percent impervious in the study (nearly 50%), but relatively lower total chloride. Paint Mine Brook has a very small drainage area (0.3 sq. mi.), but the elevated ground water flow in this stream, which contains brook trout, clearly originates from a larger groundwater watershed that likely contains input from wooded hills east of the stream.

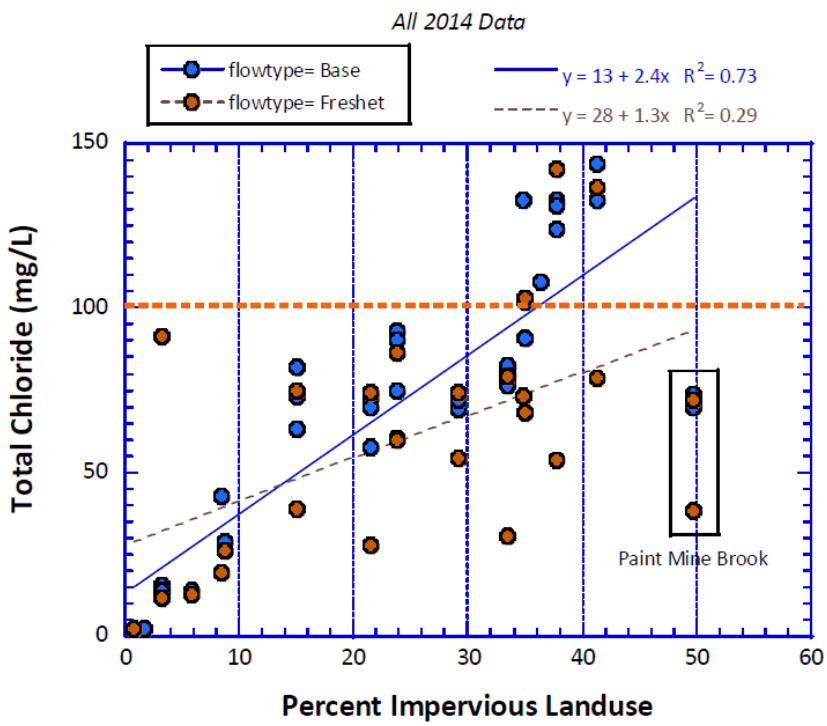

FIGURE 4.6: PLOT OF % IMPERVIOUS SURFACE VS. TOTAL CHLORIDE FOR ALL SITES SAMPLED IN 2014. BASE FLOW SAMPLES ARE REPRESENTED AS BLUE POINTS AND FRESHET SAMPLES AS ORANGE POINTS. LINES THROUGH THE CHLORIDE DATA ARE LINEAR REGRESSION CURVES.

Although the 102 mg/L threshold effect was used to predict values that exceed water quality standards, more recent studies have found that other organism groups may respond to increased chloride levels at lower concentrations. In an Ontario study (Porter-Goff et al. 2013) identified changes in diatom communities in streams at concentrations as low as 37 mg/L. The effects of

chloride concentrations may also have been underestimated in the initial assessment of causes of impairment in Moon Brook. The 230 mg/L chronic aquatic life water quality criteria threshold is rarely exceeded during most summer and fall sampling events and often discounted as a cause of impairment. Year-round chloride data from neighboring New Hampshire has identified that annual average chloride values above 102 mg/L are associated with increasing frequency of exceedances of the 230 mg/L chronic criteria during winter snowmelt events (Trowbridge et al. 2010). The identification of multiple sites in Moon Brook with summer-fall values > 102 mg/.L suggests the influence of chloride may be underestimated. Even more problematic is the finding that in New England streams are increasingly becoming more saline over time (Kaushal et al. 2005) as chloride and sodium build up in soils and groundwater. This suggests that unless abated the influence of chloride may intensify (more exceedances at higher magnitudes) even at the current flow regime.

The previous work on the effects of toxicants on Moon Brook relied heavily on water column chemistry results. For many toxicants, elevated concentrations of these parameters can be episodic and difficult or impossible to detect with grab samples. For example substantial concentrations of metals and other parameters may be delivered in a “first flush” (Bertrand-Krajewski et al. 1998) in stormwater from a rainstorm after an extended dry period, but subsequent samples may show low concentrations. Surficial sediments, however, tend to concentrate contaminants, especially hydrophobic compounds such as PAHs, and are a better measure of toxicant exposure. Sediment sampling data from 2014 identifies results of PAHs throughout the urban reach that was above the “probable effect concentration” (PEC) threshold of Vermont (VTDEC 2012). This suggests that PAHs are likely contributing to impairment of the benthic assemblages in particular. The fact that both metals and PAHs had compounds greater than the PEC benchmarks at some sites indicate that these contaminants may contribute to biological impairment in Moon Brook, particularly between RM 2.5 and 0.9. This level of contamination is not unique to Moon Brook. In a study of sediment contamination in New England, Chalmers et al. (2007) found that PEC levels were exceeded in one quarter to one half of sites sampled and that commercial, industrial, and transportation (CIT) land use totals above 10 percent were associated with these levels of contamination. PEC benchmarks are typically derived from toxicity testing studies using mortality as an endpoint. Recent work on the effects of metals on salmonids in the Pacific Northwest (Sandahl et al. 2007) has demonstrated that: “short-term exposures to dissolved copper diminish the olfactory sensitivity of juvenile Coho

salmon and that this loss of sensory function leads, in turn, to a failure to initiate predator avoidance behaviors." They suggest that even low levels of development may be a factor influencing the loss of salmonids and that metals can affect the olfactory systems of other species as well (Sandahl et al. 2007).

4.2.2 TEMPERATURE DISCUSSION

Temperature is a critical influence in determining the presence or absence of coldwater fauna in streams (Hokanson 1977) and likely influenced IBI metrics of samples collected in Moon Brook. Brook trout (*Salvelinus fontinalis*), the keystone native coldwater fish species of northern New England stream ecosystems, are sensitive to land use changes, and also intolerant of elevated water temperature, and thus a good indicator of elevated thermal conditions (Hudy et al. 2005). Optimal temperatures for brook trout are in the 64-68°F (18-20°C) range; stress thresholds are above 68°F; avoidance is exhibited at approximately 70°F (21.1^{o}C) and 75 (24°C) is an upper lethal limit threshold (Cherry et al. 1977).

Hokanson (1977) described a temperature based classification scheme that categorizes fish species as temperate stenotherms, mesotherms, and eurytherms (Table 4-9). In common terms these are referred to as cold, cool and warm water species groupings.

Based on IBI sampling data collected by VTDEC (*R. Langdon, VTDEC, personal communication, November 24, 2014*), the distribution of brook trout in Moon Brook is negatively correlated with summer ambient temperatures that exceed 70°F (Table 4-10). Brook trout abundance in Moon Brook was high at stations where 70°F was not, or only rarely, exceeded; conversely no brook trout occurred where temperature exceeded 70°F for more than 10 percent of the time. Despite the fact that Paint Mine Brook exhibits an area of approximately 50% impervious surface subject to run off, it remains suitably cold for book trout; brook trout comprised a significant amount of the surveyed fish assemblage in 2014. This strongly indicates that sources of thermal loading such as Combination Pond and Piedmont Pond may lower coldwater fish metrics independently of stormwater effects associated with impervious surfaces. Combination Pond and Piedmont Ponds are both shallow, surrounded by residential homes, and generally lack overhead cover and thus are prone to both solar warming and receiving run-off from adjacent lands.

TABLE 4-9: DENSITY AND ABUNDANCE OF BROOK TROUT IN VTDEC SAMPLES COLLECTED AT MOON BROOK WATERSHED TEMPERATURE MONITORING LOCATIONS DURING 2014. YELLOW-HIGHLIGHTED STATIONS ARE THOSE WHERE BROOK TROUT WERE FOUND.

MOON BROOK	PERCENTAGE OF TIME EXCEEDING 70°F.[7]	DENSITY AND % OF BROOK TROUT[8]
above Combination Pond	***0***	*15.8 / 96.3*
Combination Pond outfall	**14**	0 / 0
Whites Playground	**10**	0.8 / 0.7
Forest Street	**17**	0 / 0
Tributaries		
Mussey Brook at Main St	***8***	*0.9 / 1.7*
Mussey Brook at Park St	**20**	0 / 0
Paint Mine Brook	***1***	*14/19.5*

TABLE 4-10: TEMPERATURE CLASSIFICATION OF TEMPERATE CLIMATE FISH SPECIES WITH SPECIFIC REFERENCE TO SELECTED NEW ENGLAND FISH SPECIES (AFTER HOKANSON 1977). INTRODUCED SPECIES ARE DENOTED WITH AN ASTERISK (*). THERMAL RANGE DATA OBTAINED FROM YODER (2012).

CLASSIFICATION	CRITERIA/THRESHOLDS	NEW ENGLAND SPECIES
Temperate stenotherm	Gonadal growth (summer) <20°C Spawning (fall to spring) <15°C Physiological optimum <20°C UUILT[9] <26°C	Brook trout, Round whitefish, Rainbow* & Brown trout*, Atlantic salmon, Pearl dace, Longnose sucker, Slimy sculpin
Temperate mesotherm	Gonadal growth (Fa&Wi) <12°C Spawning (Sp) 3-23°C Physiological optimum 20-28°C UUILT[1] 28-34°C	White sucker, Yellow perch Northern pike*, Muskellunge, Northern redbelly dace, Fallfish, E. Blacknose dace
Temperate eurytherm	Gonadal growth (long days) >12°C Spawning (spring to fall) 15-32°C Physiological optimum >28°C UUILT[1] >34°C	Redbreast sunfish, Pumpkinseed sunfish, Smallmouth bass*, Largemouth bass*, Black & White crappie, Common carp*, Creek chub, Golden shiner

[7] From Table 4.1.6.2.2
[8] From R. Langdon, VTDEC, personal communication Nov. 24, 2014.
[9] Ultimate Upper Incipient Lethal Temperature (UUILT) after Fry (1947).

Other factors may work directly or indirectly to induce unsuitably warm water temperatures. For example, brook trout are less likely to occur in stream reaches surrounded by agricultural or developed land cover, suggesting that agricultural land cover also results in an increased sensitivity to water temperature (DeWeber and Wagner, 2014).

The reach downstream from both Combination and Piedmont ponds has limited riparian cover and also passes through residentially developed districts with little to no vegetation canopy. From this point downstream the stream traverses relatively densely developed residential, commercial and agricultural land uses to the confluence with Otter Creek. In most locations there is limited overhead vegetative cover and evidence of extensive channel modifications. Riffles, riparian cover, or other stream channel mechanisms that could provide natural cooling due to surrounding land uses are generally absent, altered or limited. Impervious surfaces adjacent to the stream likely periodically concentrate and funnel thermally enriched stormwater to the stream during summer rains. By contrast, Moon Brook above Combination Pond is characterized by tree canopy and generally well developed riparian zones, and riffles, which provide shelter from solar warming, buffer nonpoint-source runoff, and promote cooling.

The absence of brook trout from a coldwater stream acts to lower coldwater and mixed water IBI metrics, and as an intolerant species, serves as a potential signature of environmental stress. In addition to temperature, Moon Brook watershed land use, geomorphology and riparian zone alterations are consistent with those that are negatively correlated with brook trout occurrence (Hudy, et al, 2005) and likely contribute to lower the IBI scores documented in lower reaches of Moon Brook.

4.2.3 BIOLOGICAL DATA

4.2.3.1 MACROINVERTEBRATES

Cuffney et al 2010 provide context for the Moon Brook macroinvertebrate results based on national research on Effects of Urbanization on Stream Ecosystems (USGS-EUSE) that included a northeastern focal study area. This U.S Geological Survey study found that the number of EPT taxa (EPT Richness), and the mean pollution-tolerance value of organisms at a site (Biotic Index) were the best indicators of urbanization effects. Richness metrics were better indicators of urban effects than were abundance metrics. Diversity indices, functional groups, behavior, and dominance metrics were not good indicators of urbanization.

The VTDEC draft protocols for HLG assessment relied upon nine metrics of community structure, some of which the USGS found to be not particularly good indicators of urbanization effects (eg, *Shredders/Collector-Filterers*: functional groups; *% Other insecta &Non-Insect:* dominance metrics). Table 4-8 presents values of USGS highlighted metrics for Moon Brook RM 0.1 versus average values obtained from the VT HLG reference site dataset illustrating differences in performance of Richness and Biotic Index metrics for Moon Brook HLG sites relative to VT HLG reference streams.

TABLE 4-8. VALUES FOR USGS METRICS FOR LOW GRADIENT MOON BROOK RM 0.1 VERSUS AVERAGE VALUES OBTAINED FROM THE VT LOW GRADIENT HLG REFERENCE SITE DATASET.

PARAMETER	MEAN FOR ALL VT HLG REFERENCE STREAMS	2014 / 2008 MOON BROOK RM 0.1 (HLG)
Physical Chemical Parameters		
Combined %silt+%clay	29%	25% / 35%
Wetted width	6.24	7 / 5.5
Conductivity	148 umhos	625 / 600 umhos
Chloride	7 mg/l	108 /96 mg/l
Biological Metrics		
Biotic Index (0 *best* - 10 *worst*)	**4.36**	**6.35 / 5.2**
EPT Richness (intolerant groups)	**16.8**	**8.5/3**
Richness	50.5	57.5 / 33
Intolerant EPT Richness	8.8	na / 2.5
Mean Ephemeroptera Richness (intolerant)	6.5	5 / 3
Mean Plecoptera Richness (intolerant)	3	0 / 0
Mean Trichoptera Richness (intermediate tolerance)	7.3	4 / 3
Mean Chironomidae Richness (tolerant group)	16.2	24 / 12.5

The Biological Condition Gradient (BCG; Davies and Jackson 2006) is another way to describe and communicate observed biological responses to human disturbance. The 2009 VTDEC Bioassessment Program Review (MBI 2011) determined that VT ALU General Class B is approximately equivalent to BCG tiers 2-4. Tier 2 represents minimal changes in structure and

function and BCG Tier 4 representing moderate changes in structure, with minimal changes in function.

A companion publication in the USGS-EUSE series presents a Bayesian Network (Bayesnet) approach to predicting biological responses to percent development in a watershed in terms of expected attainment of tiers of the Biological Condition Gradient (Kashuba et al 2012). Kashuba et al 2012 present a conceptual diagram that summarizes the mechanisms of urban impacts on biota as primarily caused by alteration of hydrology, alteration of habitat and alteration of stream chemistry. This model predicts only a 24% probability of attaining a BCG Tier 3 or better (i.e., Tier 1, 2 or 3) when development in the upstream watershed is > 31%. (Figure 4-6 and Appendix E) presents Moon Brook RM 0.1 as having 36% Total Impervious Area (TIA), *High* % Road Density and *Extreme* Urban disturbances in the watershed. The association of poor biological outcomes with high percent TIA, road density and generalized urban disturbance provides evidence linking the cause of biological impairment in Moon Brook RM 0.1 to the effects of urban development.

We conclude that aquatic macroinvertebrate data indicate that biota and habitat uses are impaired as defined by Vermont water quality standards. Vermont Water Quality Standards grant VANR the authority to set numeric biological criteria. *Ch 3 §3-01(D)(1)* specifies that standard sampling and analytical procedures should be established and that biocriteria should consider biological integrity of a test site relative to pre-established reference conditions derived from biological characterization of non-impacted streams of the same type. Procedures concerning numeric biocriteria for *Small Size High Gradient Streams* (SHG) are thoroughly developed, well documented (VT DEC 2004) and extensively used. In our judgment the Vermont SHG numeric biocriteria, and the findings of ALU impairment in Moon Brook are scientifically sound and fully comply with the legislative intent and specific provisions for biocriteria in Vermont Water Quality Standards.

All parties agreed that the Moon Brook RM 0.1 site could not appropriately be assessed with SHG methods. With reference to the less formally developed methods for bioassessment of low gradient sites, in our professional opinion VTDEC has made a credible case for impairment at the uncontested non-SHG site, Moon Brook RM 0.1. For its assessment the State relied on an extensive, statewide database for low gradient sites, amassed over the last ten years, to establish

reference conditions for the low gradient reach of Moon Brook. As directed in VT WQS, VTDEC computed numerous (over 100) "characteristic measures of biological integrity" for each low gradient site, thus providing a robust depiction of reference conditions to which Moon Brook could be compared.

In terms of legal authority, VT WQS, in *Ch 3 §3-01(D)(2)* provides for application of "*other appropriate methods of evaluation*" in cases such as this where, for example, reference conditions have not yet been established, or assessment methods are not yet finalized. This is the case for all Vermont *Hard, Low Gradient Streams* (HLG), the stream type to which Moon Brook RM 0.1 has been assigned via univariate and multivariate statistical analysis (CCA).

While metric thresholds have not been formally established or vetted, VTDEC's analysis is thorough and technically rigorous in its characterization of type-specific low gradient reference conditions. The analysis supports the finding of impaired biological condition in lower Moon Brook as compared to conditions found in statewide and locally established fully attaining, low gradient HLG reference sites in the Vermont statewide database.

4.2.3.2 FISH ASSEMBLAGE

Based on our interpretation of the VT WQS (2014), the methods described in the Vermont Biocriteria document (VTDEC 2007), and the 303(d) listing methodology (VT DEC 2011) VTDEC properly analyzed fish data and correctly applied the methods for assessment attainment and not-attainment of aquatic life use. The site near the mouth which was low gradient and soft bottom was a site where no reference condition existed and VANR properly used a weight-of-evidence approach and best professional judgment to list this site as impaired.

We conclude that biological data were correctly transformed and analyzed in a manner consistent with Vermont DEC methods. Current fish biocriteria are applicable to most of Moon Brook. Alternate fish criteria for the lower 0.5 miles have not yet been derived and the existing weight-of-evidence/BPJ approach is acceptable as performed.

4.2.4 HABITAT, GEOMORPHOLOGY, AND FLOW

The Rapid Geomorphic Assessment (RGA) assessments provide an evaluation of reach condition (departure from reference condition) and reach sensitivity. Deviation from expected reach condition can be a result of direct modifications to channels or the product of altered stream

flows related to impervious surface which causes “hydromodification” of channels and bed features. Reach sensitivity describes how sensitive a stream reach is to further change which can be accelerated by increasing stormwater flows or perhaps moderated by restoration of habitats and floodplain/riparian features and control of stormwater flows (i.e., goal of flow-based TMDL approach).

The BCE reports (2006, 2008) form the foundation of identifying stormwater as a cause and threat of aquatic life impairment in the Moon Brook watershed. The pervasiveness of channels considered to have “high” to “extreme” sensitivity to further change and the identification of stormwater, road density and percent urban land uses are used by Vermont as the key evidence identifying stormwater as an important contributor to the impaired condition of Moon Brook.

The literature on urban impacts to aquatic life recognizes the contribution of stormwater flows on the delivery of pollutants and changes to the physical template (geomorphology and habitat) of streams (Roy et al. 2008). Many of these studies identify hydromodification from stormwater to be a major influence on the physical ecosystem which in turn contribute to declines in aquatic life in urban areas. Roy et al. (2008) concluded that:

> “because hydrology is a ‘‘master’’ variable, with direct and indirect impacts on most components of stream ecosystems (Konrad and Booth 2005), protection and restoration of natural hydrologic regimes is a necessary and critical component of sustainable management in urban landscapes. We do not presume that hydrologic restoration will necessarily restore urban streams; rather, we suggest that ecosystem sustainability cannot occur without hydrologic restoration.”

Konrad and Booth (2005) identified four characteristics of flow that influence the ecology of streams from urban stormwater which include: “increased frequency of high flows, redistribution of water from base flow to storm flow, increased daily variation in streamflow, and reduction in low flow.” The data provided by the geomorphology and habitat studies, particularly as a result of increased peak flows from impervious areas are evidence of stormwater contributions to aquatic life impairment are consistent with strong identified links between habitat, geomorphology and aquatic assemblages in Vermont (Sullivan et al. 2006). Actual data on ecological flow regimes, typically derived from daily or hourly flow data, in Moon Brook is

lacking; however the link between impervious area and increased stormwater flows is well documented (Center for Watershed Protection 2003; Shuster et al. 2005; Walter and Vogel 2010).

In summary, habitat, sediment, and geomorphic conditions show signs of alterations in Moon Brook which are a result of direct alterations to channel and riparian features and to hydromodification from increase peak flows (BCE 2006, 2008). Habitat, sediment, and geomorphic deviations from natural channel characteristics have been associated with impaired biological assemblages in Vermont streams (Sullivan et al. 2006, Ziegler, Richard C. et al 2007).

Vermont has a well-developed habitat and geomorphology assessment program and protocol and the results of their assessment of habitat conditions were consistent with conclusions we arrived at using QHEI scores during a site visit in 2014. Both VT and QHEI scoring identified areas with degraded habitat conditions and aggrading sediments that were particularly limiting in the lower mile of Moon Brook. BCE (2008) concluded that sediment aggradation and habitat degradation were a result of direct manipulation of habitat (*e.g.*, channel straightening,), but also the result of hydromodification of habitat from higher and more frequent peak flows from stormwater run-off from impervious surfaces. The link between impervious surfaces and changes in peak flows has been well documented (Center for Watershed Protection 2003; Shuster et al. 2005; Walter and Vogel 2010; Walsh et al. 2012).

The conclusion about the source of the sediment at the mouth of Moon Brook was more complex. The recent analyses of VTDEC on low gradient stream types classified lower Moon Brook as most likely a “Hard-Bottom Low Gradient” (HLG) stream type, because of its proximity of upstream higher gradient reaches. The KA-MBI team agrees that the statistical evidence presented by VT DEC supports the lower reach as HLG type stream. This conclusion, along with evidence that the lower reach was very likely straightened in the past (BCE 2008) led us to conclude the predominance of fine sediments in the lower reach of Moon Brook is at least partly related to bank erosion from upstream reaches of Moon and Mussey Brooks.

4.2.2.1 VT DEC Flow Model Outputs

In developing their TMDLs for stormwater impaired watersheds VT DEC used flow measures rather than a pollutant approach (e.g., sediment or chemical loads) as the best surrogate approach

for stormwater TMDLs. The assumption is that reductions in storm flow pulses (and supplementation of base flows) will reduce multiple stressors (VT DEC 2004, VT DEC and USEPA 2006). Although there is uncertainty in selecting flow targets for TMDLs (VT DEC 2004, 2010, VT DEC and USEPA 2006) the Vermont Water Resources Board report noted that there is significantly less uncertainty about stream hydrology than there is about stream sediment dynamics.

The KA-MBI team concurs with the VT DEC contention that stormwater contributes to habitat geomorphology impacts in Moon Brook, particularly in the lower reaches. The now large literature on urban stormwater impacts supports strong and widespread associations between urbanization and flow (e.g.,Shuster et al. 2005). These factors in turn are strongly associated with aquatic life impairment and with chemistry, sediment and habitat impacts. In an extensive review on urban stormwater management in the United States the National Academy of Science (NRC 2009) recommended that recommended that: the full distribution and sequence of ***flows*** (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams. The KA-MBI team agree that flows are an important component of stormwater impacts and are significant in Moon Brook, but also agree with the National Academy of Science (NRC 2009) recommendation that streams requires an approach that incorporates all stressors, i.e., the temperature, sediment, chemical, and the habitat stressors also identified here.

4.2.5 ASSIGNMENT OF ASSOCIATED CAUSES (AGENTS) AND SOURCES (ACTIVITIES) TO THE IMPAIRMENT OF AQUATIC LIFE USES BY VTDEC

Because we conclude that certain reaches of Moon Brook have impaired aquatic life, our next step was to review causes and sources of this impairment. The process VTDEC uses to assign causes and sources to impaired uses is summarized in their 303(d) listing methodology (VT DEC 2011). It is strongly informed by a weight of evidence approach centered on biological assessment data, including biological monitoring data, stream geomorphic and physical habitat assessments, conventional pollutants, toxicants and invasive aquatic species.

When identifying the causal agent of impairment, VTDEC will use violation of any numeric criteria as an evident cause of impairment. When identifying a cause where there is a biological impairment, VTDEC: and US EPA. 2006 “

. . . subscribes to EPA's Stressor Identification Methodology (USEPA 2000) or similar process. These assess site specific stressors and indictors such as biological and habitat indicators, land use information, proximity of known pollutant sources or other relevant information to identify by inference the most probable causal pollutants or stressors. This process can provide a defensible list of pollutant stressors or suite of stressors of common origin as in the case of runoff from impervious surfaces (i.e., stormwater)."

VTDEC evolved a more detailed rationale for their approach to stormwater TMDL development over time (VT DEC 2004 and VT DEC and USEPA 2006). These cited documents detail the decision to use a weight of evidence and approach and rely on the biological assemblages and Vermont's habitat and geomorphology capabilities to link aquatic life impairment to sections of Vermont's WQS (VT DEC 2014) related to protecting habitat and natural flow regimes required to protect aquatic life including water level fluctuations and high flow regimes.

VTDEC used a detailed example of Potash Brook in an expanded technical analysis using hydraulic targets as TMDL surrogates for stormwater impaired streams (VT DEC and USEPA 2006). In this example, VTDEC concluded that habitat loss and sedimentation concerns were the most likely major *causes* of impairment with nutrients and toxicants of medium importance. Vermont DEC inferred that altered hydrology (stormwater) led to increased erosion and habitat degradation, although channelization was a possible source of some of the habitat degradation. They concluded that flow management held the best possibility to address the suite of stormwater related causes to aquatic life impairment. The concluded that:

> *"Hydrology is a major driver for both upland and stream channel erosion. Consequently, control of high water flows will also achieve reductions in delivery and transport of sediment in Potash Brook. Best professional judgment suggests that a storm water management plan targeted toward restoring an appropriate balance of water flow and sediment loading has the greatest potential for success."*

Our review of the biological, habitat and geomorphology data, temperature data, and water chemistry data used in the initial listing of the stream as impaired by stormwater and temperature to be consistent with agency protocols and criteria; however as discussed in Section 4.2.1, other causes of impairment, including chlorides and contaminated sediments may also contribute to some of the observed impairment.

5.0 DISCUSSION AND SUMMARY

Providing answers to the five "Questions at Issue" that are part of the settlement agreement between the City of Rutland and the VANR is a key objective of the KA-MBI third party review. These questions are directed at evaluating how the VANR approach to assessing aquatic life impairments and assigning associated causes and sources was applied to Moon Brook. The KA-MBI team provides answers and discussion based on the preceding data analyses. The following discussion is organized by each of the five questions as they appeared in the original request for proposals.

Specific parameters that the Team evaluated included:

1. The Vermont Water Quality Standards (WQS), specifically the content and detail of the aquatic life designated-use narratives and the biological criteria;
2. The transformation of biological data collected in the field to an assessment of aquatic life status consistent with the specification in #1 based on the Vermont DEC methods;
3. The assignment of associated causes (agents) and sources (activities) to the impairments of aquatic life uses as provided by #2 and consistent with the criteria in #1;
4. The design and execution of the stream bioassessments by VANR, both generally as a standard practice and specifically as it was applied in the Moon Brook study area; and,
5. The overall rigor and completeness of the VANR biological assessment program against nationally accepted standards and our extensive knowledge of best practices among state programs.

The KA-MBI team analysis and conclusions follow.

5.1 ARE THE AQUATIC BIOTA AND AQUATIC HABITAT USES OF THE SPECIFIED REACHES OF MOON BROOK AND MUSSEY BROOK IMPAIRED PURSUANT TO VERMONT WATER QUALITY STANDARDS?

YES.

To answer this question the KA-MBI team determined if the delineation of aquatic life use impairments was performed in conformance with the Vermont WQS that are applicable to the Moon Brook watershed study area based on the written regulations and our understanding of the watershed characteristics. The team also determined if the correct aquatic life standards and assessment criteria were applied and whether the data collection and analysis conducted by VTDEC was consistent with their biocriteria assessment protocols. The Team also determined the extent and severity of the impairments in the study area. The Team concluded that the

VTDEC analyses were complete and were consistent with their bioassessment and biocriteria protocols.

As explained in detail below, the VT WQS grant VANR the authority to set numeric biological criteria. *Ch 3 §3-01(D)(1)* specifies that standard sampling and analytical procedures should be established and that biocriteria should consider the biological integrity of a test site relative to pre-established reference conditions derived from biological characterization of non-impacted streams of the same type. Procedures concerning numeric biocriteria for *small size high gradient streams* (SHG) are thoroughly developed, well documented (VT DEC 2004), and extensively used. In our judgment the VT SHG numeric biocriteria, and the findings of aquatic life use (ALU) impairment in Moon Brook are scientifically sound and fully compliant with the legislative intent and specific provisions for biocriteria in the VT WQS.

All parties agreed that the Moon Brook RM 0.1 site (MoB_0.1) could not be assessed with SHG methods. With reference to the less formally developed methods for bioassessment of low gradient sites, in our professional opinion VTDEC has made a credible case for impairment at the uncontested non-SHG site, Moon Brook RM 0.1. For its assessment the State relied on an extensive, statewide database of low gradient sites, amassed over the last ten years, to establish reference conditions for the low gradient reaches of Moon Brook. As directed in the VT WQS, VTDEC computed numerous (more than 100) "characteristic measures of biological integrity" for each low gradient site, thus providing a robust depiction of reference conditions to which Moon Brook RM 0.1 could be compared.

In terms of legal authority, VT WQS, in *Ch 3 §3-01(D)(2)* provides for the application of "*other appropriate methods of evaluation*" in cases such as this where, for example, reference conditions have not yet been formally established, or assessment methods are not yet finalized. This is the case for all VT *hard, low gradient streams* (HLG), the stream type to which Moon Brook RM 0.1 has been assigned via univariate and multivariate statistical analysis (e.g., Two-Way Indicator Species Analysis, Canonical Correspondence Analysis and Discriminant Function Analysis).

While this was admittedly a more *ad hoc* effort because metric thresholds have not been formally established or vetted, the VTDEC analysis was both thorough and technically rigorous in its characterization of the type-specific low gradient reference conditions. The analysis supports the

finding of impaired biological condition in lower Moon Brook as compared to conditions found in statewide and locally established, fully attaining, low gradient HLG reference sites in the database.

5.1.1 VERMONT WATER QUALITY STANDARDS

Along with ambient chemical water quality criteria, VTDEC utilizes environmental response indicators of both physical and biological condition in their ALU assessment process. Consideration of the status of chemical, physical, and biological ALU criteria for streams and rivers to a large extent informs and directs the subsequent water quality management strategies that the State applies in order to maintain WQS, or to bring a waterbody into compliance with applicable WQS. The Vermont WQS, Environmental Protection Rule Chapter 29(a) give broad discretion to the Secretary of the VT Agency of Natural Resources (VANR), or to authorized representatives of the Secretary, to establish numeric biocriteria to determine attainment of VT ALUs. Authority over technical details pertaining to the design and implementation of biocriteria resides within the Agency, under the authority of the Secretary (VT WQS Ch. 3 §3-01(D), pg 25):

> *Ch 3 §3-01(D)(2). In addition, the Secretary may determine whether there is full support of aquatic biota and aquatic habitat uses through other appropriate methods of evaluation, including habitat assessments.*

Although Vermont has formally recognized as many as twelve sub-classes that categorize streams *by* aquatic life use (ALU) class *by* Water Management Types (WMT) and *by* Stream-type, 96% of all streams in VT are designated as "General Class B", with biocriteria thresholds set at Water Management Type B- 2/3. As stated in the 2008 Moon Brook Total Maximum Daily Load Report, section on Designated Uses (p. 10), Moon Brook is designated Class B[10].

All streams discussed in this report are designated as General Class B/WMT B-2/3 or Water Supply Class A2, having identical ALU standards and numeric biocriteria (Appendix E). All waters in VT not otherwise designated (e.g., as warmwater fish habitat) are designated in VT WQS as cold water fish habitat. The Moon Brook watershed, including all tributaries, is

[10] §3-04(A) of the VTWQS states: Class B waters shall be managed to achieve and maintain a high level of quality that is compatible with the following beneficial values and uses: §3-04(A)(1): aquatic biota and wildlife sustained by a high quality aquatic habitat with additional protection in those waters where these uses are sustainable at a higher level based on Water Management Type designation.

designated in the VT WQS as cold water fish habitat. General Class B/WMT B-2/3 and Class A2 represent the lowest numeric biocriteria thresholds and lowest expectations for biological condition set by the VT WQS (Appendix E). To report stream ALU attainment status (e.g., for Clean Water Act Section 305[b] reporting and Section 303[d] listings) VTDEC places surface waters into one of four categories;*"Full Support, "Stressed", "Altered", and "Impaired"*. Assignment of these status categories is determined by assessing whether or not the waters meet the applicable biocriteria set by the Secretary pursuant to the VT WQS.

Stream gradient is an additional category that can be used to determine the applicable numeric biocriteria in Vermont. Within a given water quality classification, attainment thresholds of biological metrics for *Full Support, Stressed, Altered, or Impaired* are set at different levels based on "Stream-types" that represent natural differences in biotic expectations among each stream type (Appendix E). The streams in this report fall into either the SHG type or the yet to be formalized category HLG.

The VTDEC bioassessment program has concentrated over the past 20 years on characterizing small to medium-sized, mid to high gradient streams, and warm water, medium gradient streams and rivers. Biocriteria applicable to these stream types are well vetted, have a long history of regulatory use, and are regarded as technically sound (MBI 2011). Most of the Moon Brook project streams are thus appropriate for assessment using the Vermont high gradient methodologies (VT DEC 2004). However, at least part of the lowest reaches of Moon Brook (e.g., downstream of RM 0.9) is in a different stream-type than the standard high gradient types, as determined by statistical analysis (TWINSPAN and CCA). Biocriteria applicable to the low gradient reaches are in development, thus formal assessment by VTDEC for regulatory purposes may not appear as straight-forward. As noted above, the VTWQS Ch 3 §3-01(D) (pp. 25-26), allow the Secretary to make use support determinations in the absence of formally adopted numeric biocriteria. The low gradient stream reaches in the Moon Brook watershed and in the project reference streams (Table 4-4) fall into this assessment category whereby "*other appropriate methods of evaluation*" are necessary.

5.1.2 TRANSFORMATION OF BIOLOGICAL DATA

We conclude that the biological data were correctly transformed and analyzed in a manner consistent with the VT WQS and VTDEC methods. Our review of the Moon Brook watershed

bioassessment found no evidence of quality control gaps in VTDEC's rendering of standard SHG sampling data into ALU status assessments. Further, field methods for macroinvertebrate data collections at low gradient HLG sites complied with recommendations for low gradient sites as documented in the VT Consolidated Assessment and Listing Methodology (VTDEC 2011) and the VT Bioassessment QAPP (VTDEC 2010). Analytical methods for low gradient sites are under development, but VTDEC provided sufficient evidence in the 7 page summary of low gradient biocriteria development methods[11] that the provisional low gradient protocols concerning criteria for reference sites, statistical data analysis, and setting of biocriteria thresholds for macroinvertebrate metrics are consistent with, and closely parallel, the approved methods used to develop the high gradient biocriteria.

VTDEC also properly assessed the fish data and correctly applied the methods to assess attainment and non-attainment of aquatic life use in all reaches of Moon Brook. Best professional judgment was used to assess the low gradient and soft bottom Moon Brook RM 0.1 site where no reference condition exists. The KA-MBI team adjustments made to selected MWIBI metrics resulted in the IBI score yielding the same narrative assessment as the BPJ approach used by VTDEC.

5.1.3 ASSIGNMENT OF ASSOCIATED CAUSES (AGENTS) AND SOURCES (ACTIVITIES)

VTDEC did in fact follow their own protocols for assigning causes and sources of aquatic life impairment, specifically when addressing stormwater as a source. Vermont identifies the rationale for identifying stormwater as a source of impairment and using flow as a surrogate measure in several technical documents (Vermont Water Resources Board 2004; VTDEC/US EPA 2006). Some of this rationale was developed based on experiences in deriving the Potash Brook TMDL (VTDEC 2006). For stormwater TMDLs, Vermont relies on identifying impairments based on biocriteria and biological responses and assumes that biological improvements will occur if stormwater is controlled. Hydrology and sediment based targets were derived from a set of "attainment streams" in the VTDEC statewide database. Given the strong geomorphology program at VTDEC a major focus is on reducing channel instability via the restoration of a more balanced flow hydrograph. Flow as a surrogate for TMDL development has been used more widely over the past few years (Saravanapavan et al. 2014). The National

[11] VT-DEC September 18, 2014. "A summary of preliminary analyses for the establishment of biocriteria for low gradient Vermont streams".

Academy of Sciences report on urban stormwater management in the U.S. (NRC 2009) recommended that the full distribution and sequence of flows (i.e., the flow regime) should be taken into consideration when assessing the impacts of stormwater on streams and that the protection of aquatic life in urban streams requires an approach that incorporates all stressors. The 2014 sampling provided additional chemical data that was not previously available in Moon Brook and it proved to be useful in verifying the role of stormwater as a source of chemical contaminants in addition to its effects on the flow regime and stream habitat.

5.1.4 DESIGN AND EXECUTION OF THE STREAM BIOASSESSMENTS

The VTDEC general bioassessment methods as well as Moon Brook-specific protocols are described in several documents reviewed by KA-MBI. These include *Review Documents 19, 22, 23, 29, 31, 39, 41, 46, 47, 49c*, and *Additional Documents A, B, and D*. Furthermore, on September 18, 2014 VTDEC submitted a working document[12] describing methods used to develop the low gradient biocriteria used to assess lower Moon Brook.

We found the VTDEC design and execution of both the 2014 field data collections, as well as previous Moon Brook bioassessments, to be scientifically sound and compliant with their own quality assurance protocols. This conclusion is based on our in-depth understanding of the VTDEC then-current bioassessment methods, gleaned from the bioassessment program review (MBI 2011) and the KA-MBI current examination of 2014 and historical Moon Brook watershed and reference site field data sheets, raw taxonomic names, organism count data, review of algorithms for computed metric data, and the review of statistical analysis procedures and data results summaries produced during VT-DEC's analytical exercises. Furthermore, direct communications with VTDEC in the course of this investigation, including staff responsiveness to requested information, and their detailed and scientifically sound responses to technical questions, affirmed the impression of an experienced and technically proficient bioassessment program.

[12] VT-DEC September 18, 2014. "A summary of preliminary analyses for the establishment of biocriteria for low gradient Vermont streams". In two files received from S. Fiske 1/27/2015, filename: "LGcriteria_Summary092014_Rutland.doc, and Excel spreadsheet of the same name

5.1.5 OVERALL RIGOR AND COMPLETENESS OF THE VANR BIOLOGICAL ASSESSMENT PROGRAM

U.S. EPA has been working with state programs to systematically evaluate their biological assessment and water quality monitoring programs in support of Tiered Aquatic Life Uses (TALU) and biological criteria since 2002. A primary objective is to determine at what level of rigor, as defined by U.S. EPA (2013), these programs operate and to determine how each supports water quality management decision-making. The goal is to improve the level of rigor such that each state provides for water body assessments, 303[d] listing, 305[b] reporting, refined aquatic life uses, developing biological criteria, and determining levels of impairment and associated causes with a TALU-based program[13]. The critical elements (CE) process scores 13 elements about the technical aspects of a bioassessment program, awarding scores from 1 to 4 (in 0.5 increments), with a 4 being the maximum score possible for each element. The element scores are summed to obtain the CE raw score which is normalized to a percentage score. A critical technical element is a specific component that pertains to how biological data are collected, interpreted, and used to support water quality assessment and management. A critical elements (CE) matrix is completed and recommendations are made for making further improvements including what is needed in the way of technical changes to elevate the score of each critical element that was below the maximum. Four levels of rigor are recognized with Level 4 being the most robust. The data collected via 23 state program reviews since 2002 clearly indicates that a Level 4 program is practical necessity to support tiered aquatic life uses (TALU) and biocriteria in the state WQS (U.S. EPA 2013). Attaining a Level 4 program status and having full TALU program support and implementation are therefore *mutually inclusive.*

The VTDEC bioassessment program was evaluated in 2009 (MBI 2011) and was determined to be a Level 3+ program. The in-depth program review was conducted to determine what improvements were needed to attain Level 4 program status. The VTDEC program scored 93.3% which is just shy of Level 4 and is considered to be a Level 3+ program. Evidence presented in the 2014 VTDEC Moon Brook assessment indicates it is extremely likely since the 2009 review that some of the recommendations have been addressed which would elevate the CE score to Level 4, (e.g., improvements in element 4- more objective methods for identifying reference

[13] The "TALU-based approach" includes tiered aquatic life uses (TALU) based on numeric biological criteria and implementation via an adequate monitoring and assessment program that includes biological, chemical, and physical measures, parameters, indicators and a process for stressor identification.

sites; element 9- improvements in data management; and Element 10- ecological attributes - greater adherence to BCG-based metrics). Regardless, VTDEC has demonstrated the technical capacity to fulfill all of the outputs and outcomes of a TALU based program. That capacity was evident in the conduct of the 2014 and prior Moon Brook bioassessments particularly in the adjustments and supporting work that were done to address the technical challenges presented by the low gradient reaches of Moon Brook and elsewhere in Vermont.

5.2 WHAT IS THE PRINCIPAL CAUSE OF THE IMPAIRED BIOLOGICAL CONDITION WITHIN THE STREAM REACHES AT ISSUE, IF ANY?

The VTDEC bioassessments of Moon Brook concluded that the biological impairments are due to the impacts from stormwater, thermal alteration, and habitat degradation. It is important to note that while the emphasis of the VTDEC assignment of causes and sources appear to emphasize stormwater, the other causes related to thermal modification and habitat alterations are also acknowledged.

The KA-MBI team assessment agrees with the assignment of these categories to the impairments observed in Moon Brook. However, the additional detail provided by the analysis of temperature monitoring, the 2014 chemical assessment (water column and sediment chemistry), and analyses of the RHA and QHEI results helped to refine our understanding of reach-specific causes of impairment Moon Brook.

The upstream reaches are also impacted by the thermal alterations resulting from the effluents of Combination Pond and Piedmont Pond. The severity of the impacts to the thermal regime of Moon Brook decline in a downstream direction, but are nonetheless evident in the lower reaches.

Chemical impacts are evident in the exceedances of aquatic life thresholds for chlorides and dissolved constituents related to the use of road salt during the winter months, but leave a residual signature that is measurable during summer low flow months. There was additional evidence that runoff events during the summer actually dilute these effects. Organic chemicals associated with urban runoff were evident in the number and concentration of PAH compounds in the middle reaches of Moon Brook.

Habitat impacts were in the form of the indirect effects from stormwater runoff (eroding banks, channel instability, increased fines in substrates) and direct effects due to riparian encroachment,

bank armoring, and outright stream relocation, the latter being most evident in the lower reach of Moon Brook. These were indicated by both the RHA and QHEI assessments. Thus the independent review and assessment of the KA-MBI team essentially verified the findings of VTDEC by relying on more detailed and different information than had been previously available.

5.3 HAVE THE STREAM REACHES AT ISSUE BEEN PROPERLY BIOLOGICALLY ASSESSED USING APPROPRIATE MACROINVERTEBRATE AND FISH COMMUNITY CRITERIA?

YES.

The detailed review of the application of the macroinvertebrate and fish methods and assessment protocols by KA-MBI have determined that all of the reaches of Moon Brook were properly assessed with the appropriate biological criteria and/or alternate methods and procedures permitted by the VT WQS. The use of the alternate methods to evaluate the low gradient reaches of Moon Brook were valid and well supported by underlying analyses with the statewide database and are an example of the technical flexibility of the VTDEC program.

5.4 IF NOT, WHAT ALTERNATIVE MACROINVERTEBRATE OR FISH COMMUNITY BIOCRITERIA SHOULD BE EMPLOYED FOR THOSE HABITAT REACHES TO PROPERLY ASSESS THE BIOLOGICAL CONDITION OF THESE REACHES?

Because we concluded in 5.3 that VTDEC used appropriate methods and biocriteria to ascertain the ALU status of all reaches of Moon Brook there is no need to use “alternative macroinvertebrate or fish community biocriteria”. In many ways the analyses that VTDEC performed in support of the HLG stream type represents an alternate set of methods and biocriteria. The application of the low end IBI scoring approach for fish of Rankin and Yoder (1999) is also an alternate approach, the results of which agreed with the VTDEC BPJ approach for Moon Brook RM 0.1.

5.5 AND IF AN ALTERNATIVE BIOLOGICAL EXPECTATION IS RECOMMENDED AND CRITERIA EMPLOYED, DO THESE REACHES COMPLY WITH VERMONT WATER QUALITY STANDARDS (CLASS B ALS – NO GREATER THEN A MODERATE LEVEL OF DEPARTURE FROM "NATURAL EXPECTATION"), AND IF NOT, WHAT IS THE PRINCIPAL CAUSE OF THAT IMPAIRMENT?

Because we concluded in 5.4 that alternate biological criteria are not needed there is no recommendation to be made here. The VTDEC bioassessments including the alternate approaches used for the low gradient reaches of Moon Brook resulted in the causes of impairment being correctly identified.

6.0 LITERATURE CITED

Bartlett, J. and W. B. Bowden. 2014. Impacts of Transportation Infrastructure on Stormwater and Surfaces Waters in Chittenden County, Vermont, USA. Report by Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT.

Bear Creek Environmental (BCE). 2008. "River Corridor Plan, Moon Brook Watershed, Rutland City, Rutland Town, and Mendon, Vermont." Prepared for Rutland Natural Resource Conservation District, 170 South Main Street, Suite 4, Rutland, VT.

Bear Creek Environmental (BCE). 2006. "Phase 1 and Phase 2 Stream Geomorphic Assessments, Moon Brook Watershed, Rutland City, Rutland Town and Mendon, Vermont." Prepared for the VTDEC Water Quality Division.

Bertrand-Krajewski, J.L.,G. Chebbo, and A. Saget. 1998. Distribution of pollutant mass vs. volume in stormwater discharges and the first flush phenomenon. Water Research, Volume 32(8): 2341-2356.

Brown, L.R., T. F. Cuffney, J. F. Coles, F. Fitzpatrick, G. McMahon, J. Steuer, A. H. Bell, and J.T. May. 2009. Urban streams across the USA: lessons learned from studies in 9 metropolitan areas. Journal of the North American Benthological Society 28(4): 1051–1069.

Birk, S., Bonne, W., Borja, A., Brucet, S., Courrat, A., Poikane, S., Solimini, A.G., van de Bund,W., Zampoukas, N., Hering, D., 2012. Three hundred ways to assess Europe's surface waters: an almost complete overview of biological methods to implement the Water Framework Directive. Ecological Indicators 18, 31–41.

Center for Watershed Protection. 2003. Impacts of Impervious Cover on Aquatic Systems. March 2003, Prepared by: Center for Watershed Protection, 8391 Main Street, Ellicott City, MD 21043. Watershed Protection Research Monograph No. 1.

Chalmers, A.T., P.C. Van Metre, and E. Callender. 2007. The chemical response of particle-associated contaminants in aquatic sediments to urbanization in New England, U.S.A. Journal of Contaminant Hydrology 91(1-2): 4-25.

Cherry, D. S. K. L. Dickson and J. Cairns Jr. 1977. Preferred, avoided, and lethal temperatures of fish during rising temperature conditions. J. Fish. Res. Bd. Can. 34: 239-46.

Cuffney, T.F., Brightbill, R.A., May, J.T., and Waite, IR., 2010, Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan area, Ecological Applications, 20(5): 1384–1401.

Davies, S.P., and Jackson, S.K., 2006, The biological condition gradient—A descriptive model for interpreting change in aquatic ecosystems: Ecological Applications, v. 16, no. 4, p. 1251–1266.

DeWeber, J.T. and T. Wagner, 2015. Predicting brook trout occurrence in stream reaches throughout their native range in the eastern United States, Transactions of the American Fisheries Society, 144:1, 11-24.

Hokanson, K.E.F. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. J. Fish. Res. Bd. Can. 34: 1524-1550.

Hudy, M., T. M. Thieling, N. Gillespie, E. P.Smith., 2005. Distribution, status and perturbations to brook trout within the eastern United States. Final Report: Eastern Brook Trout Joint Venture (EBTJV). October 28, 2005. Trout Unlimited, Arlington, VA. 35 pp. plus appendices.

Kaushal, S.S., P.M. Groffman, G.E. Likens, K.T. Belt, W.P. Stack, V.R. Kelly, L.E. Band, G.T. Fisher. 2005. Increased salinization of fresh water on the northeastern United States. Proc. National Academy of Science. 102:13517-13520.

Kashuba, R.O., McMahon, Gerard, Cuffney, T.F., Qian, S., Reckhow, K., Gerritsen, J., and Davies, S., 2012, Linking urbanization to the Biological Condition Gradient (BCG) for stream ecosystems in the Northeastern United States using a Bayesian network approach: U.S. Geological Survey Scientific Investigations Report 2012-5030, 48 p.

Konrad C.P. and Booth, D.B. 2005. Hydrologic changes in urban streams and their ecological significance. In: Brown LR, Gray RH, Hughes RM, Meador MR (eds) Effects of urbanization on stream ecosystems: American Fisheries Society Symposium (47). American Fisheries Society, Bethesda, MD, pp 157–177.

MBI. 2011. Region I State Biological Assessment Programs Review: Critical Technical Elements Evaluation (2006-2010). Submitted to: Jennie Bridge, Project Officer U.S. Environmental Protection Agency, Region 1, Boston, MA. U.S. EPA Grant X7-97166801-4. 41 pgs. Nebeker, A.V. and A.E. Lemke. 1968. Preliminary studies on the tolerance of aquatic insects to heated waters. Journal of Kansas Entomological Society 41:413-418.

National Research Council (NRC). 2008. Urban Stormwater Management in the United States. National Research Council, Committee on Reducing Stormwater. Contributions to Water Pollution. National Academy Press, Washington, DC.

Nebeker, A.V., and A.E. Lemke. 1968. Preliminary studies on the tolerance of aquatic insects to heated waters. J. Kansas Ent. Soc. 41: 413-418.

Ohio EPA. 2010. Total Maximum Daily Loads for the Twin Creek Watershed. State of Ohio. Environmental Protection Agency, Division of Surface Water, Columbus, Ohio.

Ohio EPA. 2014. Delisting Guidance and Restoration Targets for Ohio Areas of Concern. http://www.epa.state.oh.us/portals/35/lakeerie/Ohio_AOC_Delisting_Guidance.pdf

Ohio EPA. 2006. Methods for assessing habitat in flowing waters: using the qualitative habitat evaluation index (QHEI). Division of Surface Water, Ecological Assessment Section, Columbus, OH. 23 pp.

Phillips, S. 2012. How long is long enough to make a Water Quality improvement? Steve Phillips, CPESC, Oxbow River & Stream Restoration, Inc. file:///C:/Users/erankin/ACTIVE%20PROJECTS/Moon%20Brook/References/Steve%20Philips%20How%20long%20is%20long%20enough%20to%20make%20a%20Water%20Quality%20improvement.pdf.

Porter-Goff, E.R., P. C. Frost, and M.A. Xenopoulos. 2013. Changes in riverine benthic diatom community structure along a chloride gradient. Ecological Indicators 32 (2013): 97– 106.

Rankin, E.T. and C.O. Yoder. 1999. Adjustments to the Index of Biotic Integrity: A summary of Ohio experiences and some suggested modifications, pp. 625-638. in T. Simon (ed.). Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press, Boca Raton, FL.

Rankin, E.T. 1995. Habitat indices in water resource quality assessments, pp. 181- 208 in Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Davis, W.S. and Simon, T.P. (eds.), Lewis Publishers, Boca Raton, FL.

Roy, A.H., S. J. Wenger, D. Fletcher, C. J. Walsh, A. R. Ladson, W. D. Shuster, H. W. Thurston and R. R. Brown. 2008. Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States. Environmental Management 42:344–359.

Sandahl, J.F., D.H. Baldwin, J.J. Jenkins, and N.L. Scholz. 2007. A sensory system at the interface between urban stormwater runoff and salmon survival. Environmental Science and Technology. 2007(41): 2998-3004.

Saravanapavan, T, E. Yamaji, M. Voorhees, and G. Zhang. 2014. Using Hydrology as a Surrogate in TMDL Development for Impairments Caused by Multiple Stressors. Advances in Water Resource and Protection (AWRP) Volume 2: 1-10. http://www.seipub.org/awrp/paperInfo.aspx?ID=11290.

Shields Jr., F.J., R. E. Lizotte Jr., S. S. Knight, C. M. Cooper, and D. Wilcox. 2010. The stream channel incision syndrome and water quality. Ecological Engineering 36: 78–90.

Shuster, W. D., J. Bonta, H. Thurston, E. Warnemuende and D. R. Smith. 2005. Impacts of impervious surface on watershed hydrology: A review. Urban Water Journal. 2(4): 263–275.

Sullivan, S.M.P., M.C. Watzin and W.C. Hession. 2006. Influence of stream geomorphic condition on fish communities in Vermont, U.S.A. Freshwater Biology (2006) 51, 1811–1826.

Sullivan, S.M.P., M.C. Watzin and W.C. Hession. 2006. Influence of stream geomorphic condition on fish communities in Vermont, U.S.A. Freshwater Biology (2006) 51, 1811–1826.

Tetra Tech, Inc. 2005. Stormwater modeling for flow duration curve development in Vermont: Final Report. Page 1-73. Fairfax.

Trowbridge, P., J.S. Kahl, D. Sassan, D. Heath, and E. Walsh, 2010. Relating road salt TMDLs to exceedances of the water quality standard for Cl in NH streams. Environ. Sci. Technol., 44: 4903-4909.

U.S. EPA. 2007. Causal Analysis of Biological Impairment in Long Creek, a Sandy-Bottomed Stream in Coastal Southern Maine (External Review Draft). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-06/065A.

USEPA (Environmental Protection Agency). 2011. A primer on using biological assessments to support water quality management. Office of Science and Technology, Office of Water, Washington, DC. Document No. EPA 810-R-11-01 Available online at: http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/upload/primer_update.pdf.

USEPA 2013. The bioassessment program review: Assessing level of technical rigor to support water quality management. Office of Water, Washington, DC EPA/ 820-R-13-001. 158 pp.

Vermont Agency of Natural Resources. 2008. The Vermont Agency of Natural Resources Reach Habitat Assessment (RHA), June 2008, Prepared for: Vermont Agency of Natural Resources, Departments of Environmental Conservation and Fish and Wildlife, Waterbury, VT. Prepared by: Milone & MacBroom, Inc. South Burlington, VT.

Vermont Agency of Natural Resources. 2005a. Vermont Stream Geomorphic Assessment Phase 1 Handbook: Watershed Assessment Using Maps, Existing Data, and Windshield Surveys. Waterbury, VT.

Vermont Agency of Natural Resources. 2005b. Vermont Stream Geomorphic Assessment Phase 2 Handbook: Rapid Stream Assessment, Field Protocols. Waterbury, VT.

Vermont Agency of Natural Resources. 2007. Vermont Agency of Natural Resources Phase 2Handbook, Rapid Stream Assessment Field Protocols (May 2007). Vermont Agency of Natural Resources, Department of Environmental Conservation, River Management Program, Waterbury, VT.

Vermont Agency of Natural Resources. 2008. The Vermont Agency of Natural Resources Reach Habitat Assessment (RHA), June 2008, Prepared for: Vermont Agency of Natural Resources, Departments of Environmental Conservation and Fish and Wildlife, Waterbury, VT. Prepared by: Milone & MacBroom, Inc. South Burlington, VT.

Vermont Agency of Natural Resources. 2005a. Vermont Stream Geomorphic Assessment Phase 1 Handbook: Watershed Assessment Using Maps, Existing Data, and Windshield Surveys. Waterbury, VT.

Vermont Agency of Natural Resources. 2005b. Vermont Stream Geomorphic Assessment Phase 2 Handbook: Rapid Stream Assessment, Field Protocols. Waterbury, VT.

Vermont Agency of Natural Resources. 2007. Vermont Agency of Natural Resources Phase 2Handbook, Rapid Stream Assessment Field Protocols (May 2007). Vermont Agency of

Natural Resources, Department of Environmental Conservation, River Management Program, Waterbury, VT.

Vermont Dept. of Environ. Cons. (VTDEC) 2004. Wadeable Stream Biocriteria Development and Implementation Methods for Fish, Macroinvertebrate Assemblages in VT Wadeable Streams and Rivers, 158 pp.

VT DEC. 2006. Total Maximum Daily Load to Address Biological Impairment in Potash Brook (VT05-11), Chittenden County, Vermont, October 2006. Prepared By: Vermont Department of Environmental Conservation, Water Quality Division, Waterbury, VT.

VT DEC. 2009. Total maximum daily load to address biological impairment in Moon Brook (VT03-06) Rutland County, Vermont, October 2008, Approved by EPA Region 1: February 19, 2009. Prepared By: Vermont Department of Environmental Conservation, Water Quality Division, Waterbury, VT 05671-0408.

VT DEC 2010. Biological Assessments of Running Waters in Vermont: Quality Assurance Project Plan Vermont DEC and the US EPA. 2006. Expanded Technical Analysis: Utilizing Hydrologic Targets as Surrogates for TMDL Development in Vermont's Stormwater Impaired Streams. Prepared by the U.S. Environmental Protection Agency and the Vermont Department of Environmental Conservation, September, 2006.

VT DEC. 2010. A framework for remediation of Vermont's stormwater-impaired waters. Vermont Department of Environmental Conservation, Water Quality Division, Montpelier, VT.

VT DEC. 2011. Vermont Surface Water Assessment and Listing Methodology (in accordance with US EPA 2006 guidance, Vermont Department of Environmental Conservation, Water Quality Division, Montpelier, VT.

VT DEC. 2012. Investigation and remediation of contaminated properties procedure. Effective: April 2012. Waste Management and Prevention Division, Waterbury, VT 05671-0404.

VT DEC and US EPA. 2006. Expanded Technical Analysis: Utilizing Hydrologic Targets as Surrogates for TMDL Development in Vermont's Stormwater Impaired Streams. Prepared by the U.S. Environmental Protection Agency and the Vermont Department of Environmental Conservation, September, 2006.

Vermont Water Resources Board. 2004. Final Report. Investigation into Developing Cleanup Plans for Stormwater-impaired Waters. Docket No. INV-03-01.

Walsh, C.J., Fletcher T.D., and Burns, M.J. 2012. Urban Stormwater Runoff: A New Class of Environmental Flow Problem. PLoS ONE 7(9): e45814. doi:10.1371/journal.pone.0045814.

Walter, M. and R.M. Vogel. 2010. Increasing trends in peak flows in the Northeastern United States and their impacts on design. Proceedings 2nd Joint Federal Interagency Conference, Las Vegas, NV, June 27 - July 1, 2010.

Xian, G., Homer, C., Dewitz, J., Fry, J., Hossain, N., and Wickham, J., 2011. The change of impervious surface area between 2001 and 2006 in the conterminous United States. Photogrammetric Engineering and Remote Sensing, Vol. 77(8): 758-762.

Yoder, C.O. 2012. Development of a Database for Upper Thermal Tolerances for New England Freshwater Fish Species. MBI Technical Report MBI/2012-4-6. Submitted to Environmental & Natural Resources Law Clinic, Vermont Law School, Burlington, VT. 69 pp.

Ziegler, Richard C. et al 2007. "Causal analysis of biological impairment in Long Creek: A sandy-bottomed stream in coastal southern Maine" National Center for Environmental Assessment Office of Research and Development U.S. Environmental Protection Agency, Washington, DC, 225 pp.

UNPUBLISHED MATERIAL

VTDEC Document 1. Biological and Aquatic Life Use Attainment Assessment of Moon Brook – 2010. prepared by Vermont Department of Environmental Conservation, Water Quality Division Biomonitoring and Aquatic Studies Section, RA La Rosa Environmental Laboratory103 South Main Street Waterbury, VT

VTDEC Document 2. September 18, 2014. "A summary of preliminary analyses for the establishment of biocriteria for low gradient Vermont streams". In two files received from S. Fiske 1/27/2015, filename: "LGcriteria_Summary092014_Rutland.doc, and Excel spreadsheet of the same name)

Vermont Water Resources Board, 2004. Final Report. Investigation into Developing Cleanup Plans for Stormwater-impaired Waters. Docket No. INV-03-01.

APPENDIX A

MEETING SUMMARIES

APPENDIX B

INVENTORY OF DATA CONSULTED
(ORIGINAL VTDEC DATA ASSUMED TO BE PLACED ON THE RUTLAND WEBSITE)

APPENDIX C

COPIES OF ANY ADDITIONAL LITERATURE

APPENDIX D

SITE PHOTOS AND/OR MAPS RELIED ON BY THE TEAM
NO ADDITIONAL PHOTOS

APPENDIX E

SUPPLEMENTAL DATA