EIGHTEENMILE CREEK AREA OF CONCERN

Degradation of Benthos
Beneficial Use Impairment Removal Report

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Prepared by:

New York State Department of Environmental Conservation

and

Niagara County Soil and Water Conservation District

This Beneficial Use Impairment (BUI) Removal Report was prepared by the New York State Department of Environmental Conservation (NYSDEC) and Niagara County Soil and Water Conservation District (NCSWCD) with substantial funding provided by the United States Environmental Protection Agency (USEPA) through the Great Lakes Restoration Initiative (GLRI). The NYSDEC and NCSWCD acknowledge the significant efforts of the Remedial Advisory Committee (RAC) in engaging stakeholders and the public throughout the BUI removal process. Additionally, the NYSDEC and NCSWCD acknowledge the pivotal role of U.S. Geological Survey New York Water Science Center in reviewing and improving this document. For more information, please contact either the Remedial Action Plan (RAP) Coordinator at NCSWCD or the Area of Concern (AOC) Coordinator at NYSDEC.

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List of Abbreviations

AOC	Area of Concern
BAP	Biological Assessment Profile
BUI	Beneficial Use Impairment
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
GLRI	Great Lakes Restoration Initiative
GLWQA	Great Lakes Water Quality Agreement
IJC	International Joint Commission
NCSWCD	Niagara County Soil and Water Conservation District
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
OU	Operable Unit
PCBs	Polychlorinated Biphenyls
RAC	Remedial Advisory Committee
RAP	Remedial Action Plan
RIBS	Rotating Integrated Basin Studies
STA	Sediment Transition Area
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

1. Executive Summary

This Beneficial Use Impairment (BUI) removal report identifies the background, criteria, supporting data, and rationale to remove the *Degradation of Benthos* BUI designation from the Eighteenmile Creek Area of Concern (AOC). Benthic communities are widely used as an indicator of aquatic ecosystem health because they are abundant, sensitive to a variety of environmental stressors, and the collection and analysis of samples is relatively inexpensive and easy to perform. Sampling conducted between 1977 and 1994 suggested macroinvertebrate communities were adversely affected by contaminated surficial sediments leading to the BUI's impaired designation in the 1997 Stage I/II Remedial Action Plan (RAP) and subsequent updates (NYSDEC, 1997, NCSWCD, 2011). These assessments, however, relied heavily on inferred or expected impact to benthic communities based on elevated contaminant concentrations in bed sediments. Yet, in recent years, several new studies have been completed to assess the extent to which contaminants in Eighteenmile Creek are impairing beneficial uses, including the *Degradation of Benthos* BUI.

Benthic macroinvertebrate surveys conducted in 2012 and 2014 had generally favorable results and provided early evidence that the Degradation of Benthos BUI could be redesignated. However, these studies were inconclusive, in part because the 2012 study design did not include a reference area, as recommended by the International Joint Commission (IJC) delisting guidance (IJC, 1991), and a potential localized area of sediment toxicity associated with one sample location was identified in the 2014 study.

As a result, the New York State Department of Environmental Conservation (NYSDEC) and U.S. Geological Survey (USGS) conducted a comprehensive survey of macroinvertebrate community condition and toxicity of sediments from the Eighteenmile Creek AOC and a regional reference area in 2021. The results of this assessment indicate that the benthic communities in the AOC were in similar or superior condition to that of the reference area. Additionally, there was no evidence of sediment toxicity within the AOC and toxicity test results were similar or superior to that of the reference area.

Following an evaluation of the results from these studies and other applicable datasets, NYSDEC recommends the removal of the *Degradation of Benthos* BUI from the Eighteenmile Creek AOC. This recommendation is made with the full support of Niagara County Soil and Water Conservation District (NCSWCD) and the Eighteenmile Creek Remedial Advisory Committee (RAC).

2. Introduction and Background

Under Annex 1 of the Great Lakes Water Quality Agreement (GLWQA), the IJC identified 43 AOC in the Great Lakes Basin where pollution from past industrial production and waste disposal practices has caused significant ecological degradation. Up to fourteen BUIs could be impaired and are used as indicators of environmental degradation to evaluate the condition of an AOC.

Eighteenmile Creek flows through central Niagara County, New York from its headwaters in the Town of Lockport, to its discharge into Lake Ontario in Olcott approximately 18 miles east of the mouth of the Niagara River. The Eighteenmile Creek AOC includes the Olcott Harbor and extends upstream to the farthest point at which backwater conditions exist during Lake Ontario's highest monthly average lake level. This point is located just downstream of Burt Dam, approximately two miles south of Olcott Harbor (Figure 1).

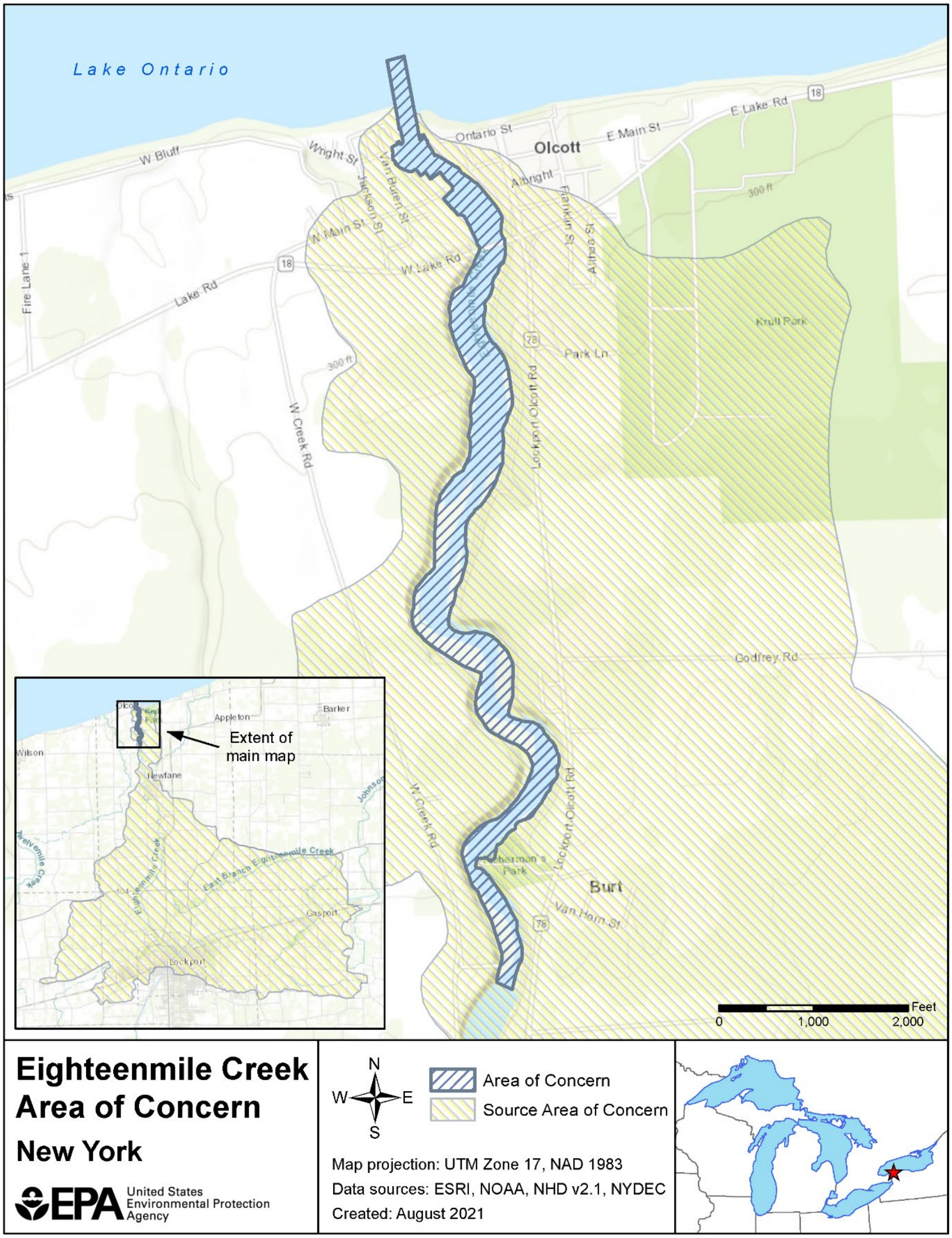

Figure 1 Eighteenmile Creek AOC boundary located in Niagara County, NY.

Eighteenmile Creek was designated as an AOC because water quality and bottom sediments were contaminated by past industrial and municipal discharge practices, the disposal of waste, and the use of pesticides. Numerous contaminants have been identified in creek sediments which have a detrimental effect on the AOC and Lake Ontario. As early as the 1997 Stage I/II RAP, the watershed upstream of the Eighteenmile Creek AOC, including the industrialized portions within the City of Lockport, have been identified as the likely source of contaminants impacting the AOC. The entire mainstem of Eighteenmile Creek, including upstream source areas and the AOC impact area, is now a designated site on the National Priorities List under the United States Environmental Protection Agency's (USEPA) Comprehensive Environmental Response, Compensation, and Liability Act (also known as Superfund).

Under Annex 1 of the GLWQA, AOCs are mandated to develop a RAP which identifies specific BUIs and their causes, and the restoration work needed to address the root problems and restore the identified BUIs. The Stage I/II RAP (NYSDEC, 1997) presented an array of water quality and sediment data that documented contaminant levels resulting in several BUI designations, including the *Degradation of Benthos* BUI, which is the focus of this report.

Eighteenmile Creek AOC had five of the fourteen BUIs designated due to legacy contaminants. The *Degradation of Benthos* is the third BUI recommended for removal following the *Restrictions on Dredging Activities* (NYSDEC, 2020) and *Degradation of Fish and Wildlife Populations* (NYSDEC and NCSWCD 2024). Efforts are ongoing to restore the *Restrictions on Fish and Wildlife Consumption* and *Bird or Animal Deformities or Reproduction Problems* BUIs.

2.1 Rationale for BUI Listing

The *Degradation of Benthos* BUI exists for an AOC when "benthic macroinvertebrate community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics" or "toxicity…of sediment associated contaminants at a site is significantly higher than controls" (IJC, 1991). This BUI was designated in the Eighteenmile Creek AOC as a result of assessments conducted between 1977 and 1994, which suggested macroinvertebrate communities were adversely affected by contaminated surficial sediments (NCSWCD, 2011; NYSDEC, 1997). These assessments, however, relied heavily on inferred or expected impact to benthic communities based on elevated contaminant concentrations in bed sediments. The limited direct sampling of benthic communities at that time indicated moderate or slight impairment based on community indices, and sediment toxicity analysis provided some limited evidence of toxicity (NYSDEC, 1997).

2.2 BUI Removal Criteria

To address the Eighteenmile Creek AOC BUIs, the RAC established restoration targets or "removal criteria" that determine when a BUI designation may be removed. Initial removal criteria for the *Degradation of Benthos* BUI were first introduced in a 2008 report (NCSWCD, 2008) and later included in the Eighteenmile Creek RAP Stage II Update (NCSWCD, 2011). In 2020, NCSWCD and NYSDEC, in consultation with technical experts representing federal and state partner agencies including the United States Army Corps of Engineers (USACE), United States Fish and Wildlife Service (USFWS) and USGS, evaluated the appropriateness of the removal criteria for each remaining BUI. Focus was placed on incorporating existing data and developing criteria which were measurable, representative, and attainable for the region, while still ensuring restoration and ecological objectives would be met. As a result of these efforts, the RAC approved modified removal criteria for all remaining BUIs (NCSWCD, 2020). The final removal criteria for the *Degradation of Benthos* BUI are:

1. Benthic macroinvertebrate communities are "non-impacted" or "slightly impacted" according to NYSDEC indices; OR
2. Benthic macroinvertebrate community condition is similar to unimpacted control sites of comparable physical and chemical characteristics; AND
3. Toxicity of sediment-associated contaminants is similar to unimpacted control sites of comparable physical and chemical characteristics.

The first criterion uses the NYSDEC Biological Assessment Profile (BAP) score to rank sites based on the condition of the resident macroinvertebrate community. If the first criterion cannot be reached, the BUI designation can be removed by meeting both the second and third criteria. The second criterion requires a comparison of macroinvertebrate community condition to a regional reference area with similar habitat characteristics. The third criterion requires a comparison of the toxicity of sediments to benthic organisms between the AOC and a regional reference area with similar habitat characteristics. The second and third criteria were included as an alternative option for removal of the BUI designation because it was recognized that low BAP scores could exist due to other regional stressors, including degraded habitat quality or seasonal eutrophication, and not due to the legacy pollutants from the AOC such as polychlorinated biphenyls (PCBs), heavy metals, or pesticides that were identified as the cause of the BUI (NCSWCD, 2020).

3. Monitoring and Assessments Supporting BUI Removal

This section provides a summary of all benthic macroinvertebrate community and sediment toxicity studies that provide weight of evidence upon which the recommendation to remove the *Degradation of Benthos* BUI is based.

3.1 Sediment-dwelling communities and sediment toxicity tests

For studies described in this section, macroinvertebrate communities were sampled directly from bed sediments. Sediments were obtained using petite ponar dredges in all instances except for two samples from riffle habitats that were collected using the traveling kick method during the 2012 survey. The 2014 and 2021 surveys did not sample riffle habitats, instead targeting depositional areas, or locations with fine sediments where contaminants are more likely to be found. Macroinvertebrates in the collected sediments were identified to the lowest practical taxonomic resolution (usually genus) following NYSDEC standard operating procedures (Smith et al., 2009, Duffy, 2021). The resulting identifications were then used to calculate five component metrics on a standardized scale from 0 to 10. The individual component metrics were then averaged to produce a BAP score for each site, a single value that is interpreted on a four-tiered scale of impact: severe (0.0–2.5); moderate (2.5–5.0); slight (5.0– 7.5); or non-impacted (7.5–10.0). Impact categories of moderate and severe are considered indicative of impaired conditions (Duffy, 2021). For each site, BAP scores were calculated for three replicate samples, and the average value then used as the overall score.

In the 2014 and 2021 surveys, an additional metric described as the "aggregate BAP" was also calculated due to the inability to obtain the full standard 100-organism count for each of the three replicate samples collected from each site. For the aggregate approach, the identification data from the three replicates at each site were combined, rarefied down to a random 100-organism subsample 30 times, and shown as the mean score of those 30 random subsamples for each site. The former approach (hereafter, 'standard BAP') represents a consistent level of sampling effort, incorporates the density of organisms present, is appropriate for comparisons between sites, and follows standard NYSDEC protocols. The aggregate approach, by generating the 100-organism target count, provides a community evaluation that may be more appropriate for evaluating the integrity of macroinvertebrate communities relative to the established NYSDEC impact classes and BUI removal criteria (George et al., 2017). The standard and aggregate BAP scores were each used as separate lines of evidence to determine if the first and second removal criteria were met. All BAP scores are presented to one decimal place except for those on the border of two impact categories which are presented to two decimal places.

Similarly, for all studies described herein, sediment toxicity testing was conducted using standard 10-day bioassays with the dipteran, *Chironomus dilutus*, and the amphipod, *Hyalella azteca*, following USEPA test methods 100.2 and 100.1, respectively (USEPA, 2000). In short, bioassays for each species were initiated using 8 laboratory replicates from each sample into which 10 test organisms were added. At the conclusion of the 10-day exposures, the percentage of surviving organisms (hereafter "survival") and the average weight of the surviving organisms (hereafter "growth") were assessed for each replicate (USEPA, 2000). The mean survival and growth data from these tests were then used to compare toxicity in sediments from the AOC with that of the reference area to determine if the third removal criterion was met.

In order to assess the second and third BUI removal criteria which require comparison to an "unimpacted control site", Oak Orchard Creek, another tributary to Lake Ontario that outlets to the lake approximately 40 kilometers east of Eighteenmile Creek, was selected as the reference area. This creek is well established as a reference area for assessments in the Eighteenmile Creek AOC. It has been included in prior assessments of the *Fish Tumors and Other Deformities* BUI, *Degradation of Fish and Wildlife Populations* BUI, and *Bird or Animal Deformities or Reproductive Problems* BUI (E&E, 2009; George et al., 2022). Oak Orchard Creek has also been selected by the USEPA as a suitable reference area for assessments of the Eighteenmile Creek Superfund site (E&E, 2017, 2019). Oak Orchard Creek is used as a reference area for Eighteenmile Creek based on their close proximity, similar surrounding geography, limited riparian development, flow impacts from hydroelectric dams, and comparable drowned river mouth habitat characterized by cattail beds and subject to backwater effects from Lake Ontario. Importantly, and unlike the AOC, Oak Orchard Creek is not known to have extensive legacy chemical contamination and in that regard serves as an ideal "unimpacted" reference waterbody. A more detailed comparison of the habitat and watershed characteristics of both streams is available in Table 1 of George et al. (2022) and George et al. (2023), including a standard suite of physical and chemical parameters including water depth, specific conductance, dissolved oxygen, pH, temperature, sediment grain size, and total organic carbon.

2012 Survey: A 2012 benthic survey was conducted that assessed macroinvertebrate community condition at five sites in the AOC and sediment toxicity at three of the sites (E&E, 2013). This survey was designed to address a prior set of BUI removal criteria and included separate assessments of riffle and pool habitats, and did not include a comparison to a reference area.

BAP scores from the two sites in riffle habitats ranged from 4.5 to 5.7, indicating moderate to slight impact while BAP scores from the three sites in pool habitats ranged from 6.7 to 7.4, indicating slight impact. Sediment toxicity testing using sediments from the three pool sites found no evidence of reduced survival or growth of *C. dilutus* or *H. azteca*.

2014 Survey: In 2014, a benthic survey assessed macroinvertebrate community condition and sediment toxicity at 3 sites in the AOC and 3 sites in the Oak Orchard Creek reference area (George et al., 2017).

Standard BAP scores at the three AOC sites ranged from 2.1 to 5.4 and averaged 3.8, indicating severe to slight impact. Aggregate BAP scores at the three AOC sites ranged from 3.9 to 7.51 and averaged 5.9, indicating moderate to no impact. These were generally similar to the BAP scores for the three sites within the reference area, where standard BAP scores ranged from 4.3 to 4.8 and averaged 4.6, while aggregate BAP scores ranged from 6.0 to 7.1 and averaged 6.4. Sediment toxicity test results were also similar between the AOC and reference area and provided little evidence of toxicity. Survival and growth of *C. dilutus* averaged 86.3% and 1.02 mg, respectively, across sites in the AOC compared to an average of 93.3% and 0.88 mg across all reference sites. Survival and growth of *H. azteca* averaged 93.3% and 0.13 mg, respectively, across sites in the AOC compared to an average of 93.8% and 0.14 mg across all reference sites (George et al., 2017). It was noted, however, that the upstream-most AOC site showed marginal evidence of toxicity, producing the lowest survival and growth of each test species. That same AOC site also produced the lowest standard and aggregate BAP scores.

Although the 2012 and 2014 benthic data did not suggest widespread degradation, the lack of a reference area in the 2012 survey, a low BAP score at one AOC site in the 2014 survey, and the relatively small number of AOC sites in each study caused sufficient uncertainty to prevent BUI removal. As a result, a comprehensive sampling effort with considerably more spatial coverage was designed, and implemented in 2021, to more decisively determine if the removal criteria have been met.

2021 Survey: The 2021 benthic survey is the most comprehensive and current survey conducted in the AOC and involved a comparison of 8 AOC sites and 6 reference sites (Figure 2) (George et al., 2023). Consequently, these results are presented in detail herein as the most authoritative data source for assessment of the BUI.

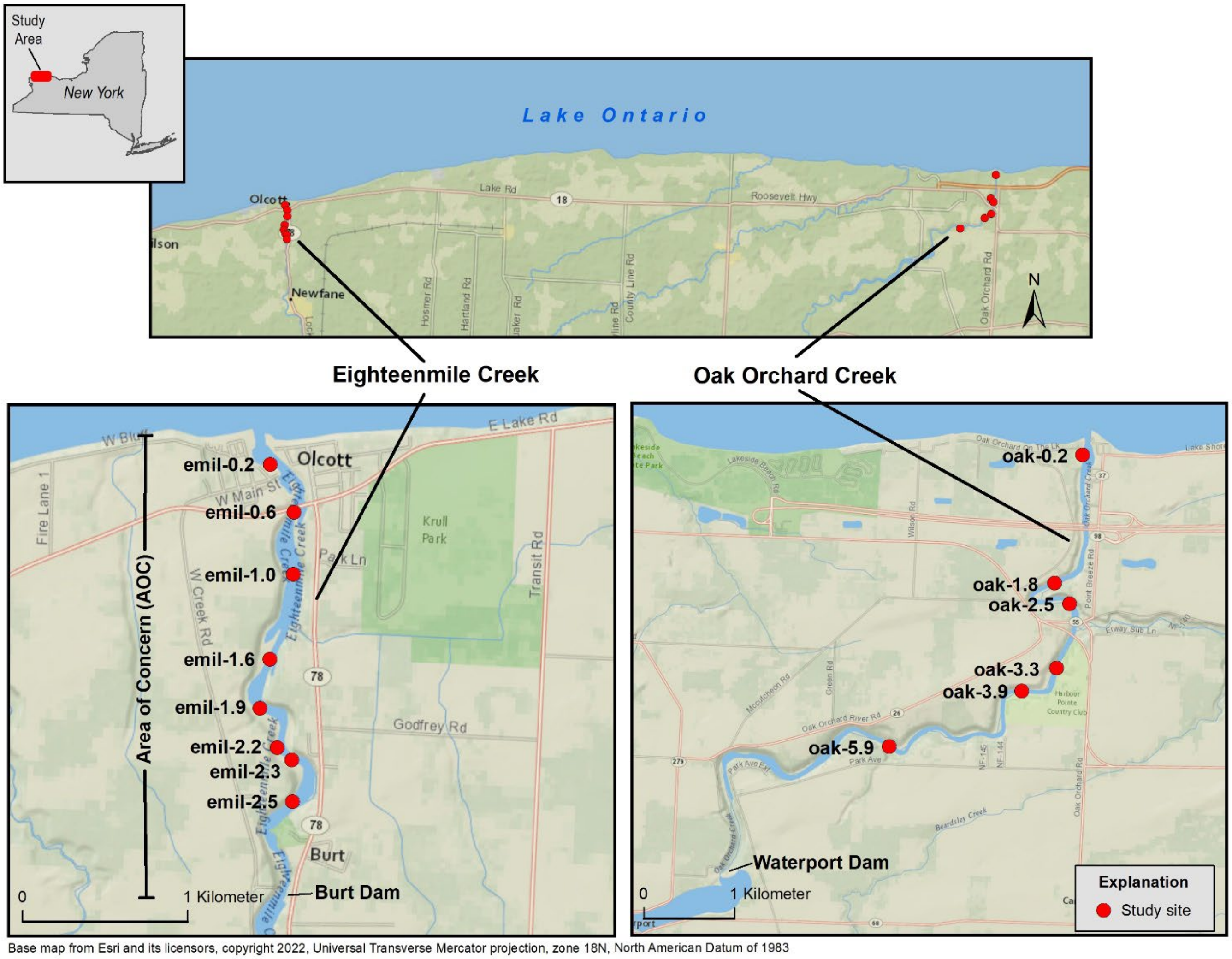

Figure 2: Location of benthic sampling sites in the Eighteenmile Creek AOC and Oak Orchard Creek reference area in the 2021 study (from George et al., 2023).

The standard and aggregate BAP scores indicated that community condition was similar between the AOC and reference area, but more variability was observed between sites in the AOC. Variability among and between sites is represented graphically by the standard error bars in Figure 3, and discussed in more detail in George et al., 2023. The standard BAP scores at AOC sites ranged from 2.2 to 8.1 and averaged 5.1, compared to the reference area where scores ranged from 3.9 to 6.0 and averaged 4.8 (Table 1). Standard BAP scores indicated that one of the eight AOC sites was classified as severely impacted, three of eight were moderately impacted, three of eight were slightly impacted, and one of eight was non-impacted, whereas four of the six reference sites were classified as moderately impacted and two of six were slightly impacted (Figure 3). The aggregate BAP scores at AOC sites ranged from 2.7 to 8.7 and averaged 6.6, compared to the reference area where scores ranged from 4.0 to 6.8 and averaged 5.5 (Table 1). Aggregate BAP scores indicated that two of the eight AOC sites were moderately impacted, three of eight were slightly impacted, and three of eight were non-impacted, whereas two of the six reference sites were classified as moderately impacted and four of six were slightly impacted (Figure 3). Both the standard BAP and aggregate BAP classified the average condition of the AOC as slightly impacted.

The standard and aggregate BAP classified the average condition of the Oak Orchard reference area as moderately and slightly impacted, respectively. Sites sampled in both 2014 and 2021 generally exhibited similar results, the exception being emil-2.2 (formerly emil-3) for which BAP scores notably increased in 2021 (Table 1).

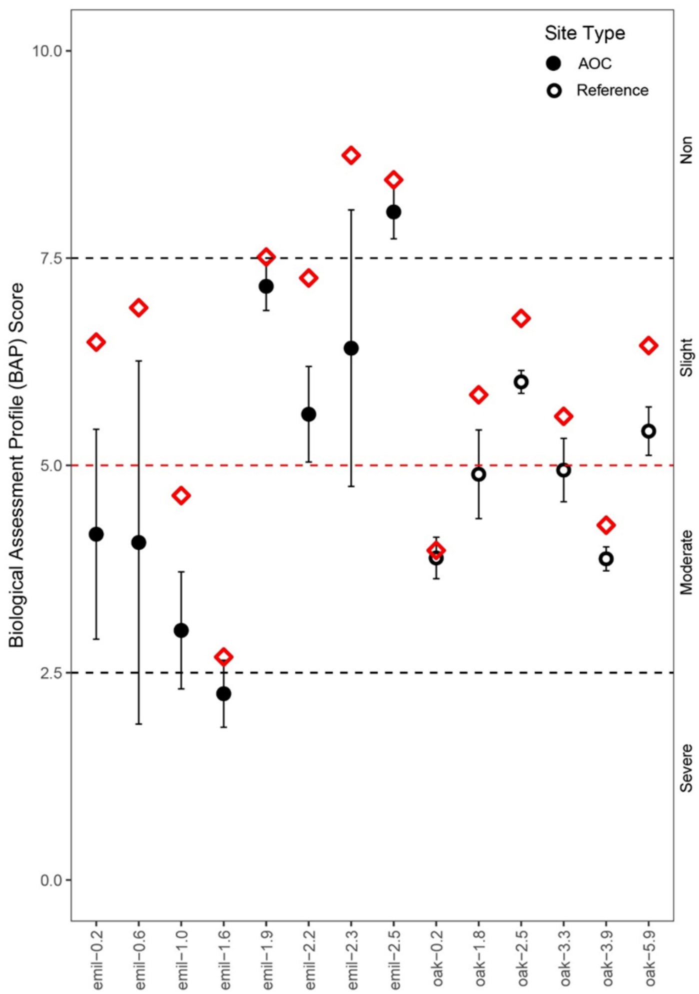

Figure 3: BAP scores of macroinvertebrate community integrity from the 2021 survey shown in black as the standard BAP score (mean ± one standard error, n = 3 replicates) and in red as the aggregate BAP score for eight sites in the Eighteenmile Creek AOC and six sites in the Oak Orchard Creek reference area.

Table 1: Standard and aggregate BAP scores from (a) the 8 AOC and 6 reference sites sampled in 2021 (from George et al., 2023) and (b) the 3 AOC and 3 reference sites that were also sampled in 2014 (from George et al., 2017). The primary site IDs are from the 2021 survey and indicate river kilometers upstream from Lake Ontario, while the site IDs listed parenthetically are those used for the same location in the 2014 survey. "-" indicates a site that was not sampled during a particular survey.

		2021 Survey		2014 Survey	
Site ID	Site Type	Standard BAP score	Aggregate BAP score	Standard BAP score	Aggregate BAP score
emil-0.2 (formerly emil-5)	AOC	4.2	6.5	5.4	7.51
emil-0.6	AOC	4.1	6.9	-	-
emil-1.0 (formerly emil-4)	AOC	3.0	4.6	3.9	6.4
emil-1.6	AOC	2.2	2.7	-	-
emil-1.9	AOC	7.2	7.51	-	-
emil-2.2 (formerly emil-3)	AOC	5.6	7.3	2.1	3.9
emil-2.3	AOC	6.4	8.7	-	-
emil-2.5	AOC	8.1	8.4	-	-
oak-0.2 (formerly orch-5)	Reference	3.9	4.0	4.3	6.0
oak-1.8 (formerly orch-4)	Reference	4.9	5.9	4.8	7.1
oak-2.5	Reference	6.0	6.8	-	-
oak-3.3 (formerly orch-3)	Reference	4.9	5.6	4.8	6.1
oak-3.9	Reference	3.9	4.3	-	-
oak-5.9	Reference	5.4	6.4	-	-

*BAP scores bordering two-impact categories are presented to two decimal places for clarity.

Sediment toxicity test results were generally similar between the AOC and reference area and provided no evidence that bed sediments in the AOC caused toxicity to either test species. A notable outlier in the dataset occurred with the *H. azteca* data from three reference sites where total or near-total mortality occurred. Survival and growth of *C. dilutus* averaged 94.4% and 1.23 mg, respectively, across sites in the AOC compared to an average of 95.0% and 1.03 mg across all reference sites (Figure 4). Survival and growth of *H. azteca* averaged 97.5% and 0.13 mg, respectively, across sites in the AOC compared to an average of 52.3% and 0.08 mg across all reference sites (Figure 4). Thus, the mean condition of all four toxicity endpoints was similar or superior in the AOC relative to the reference area.

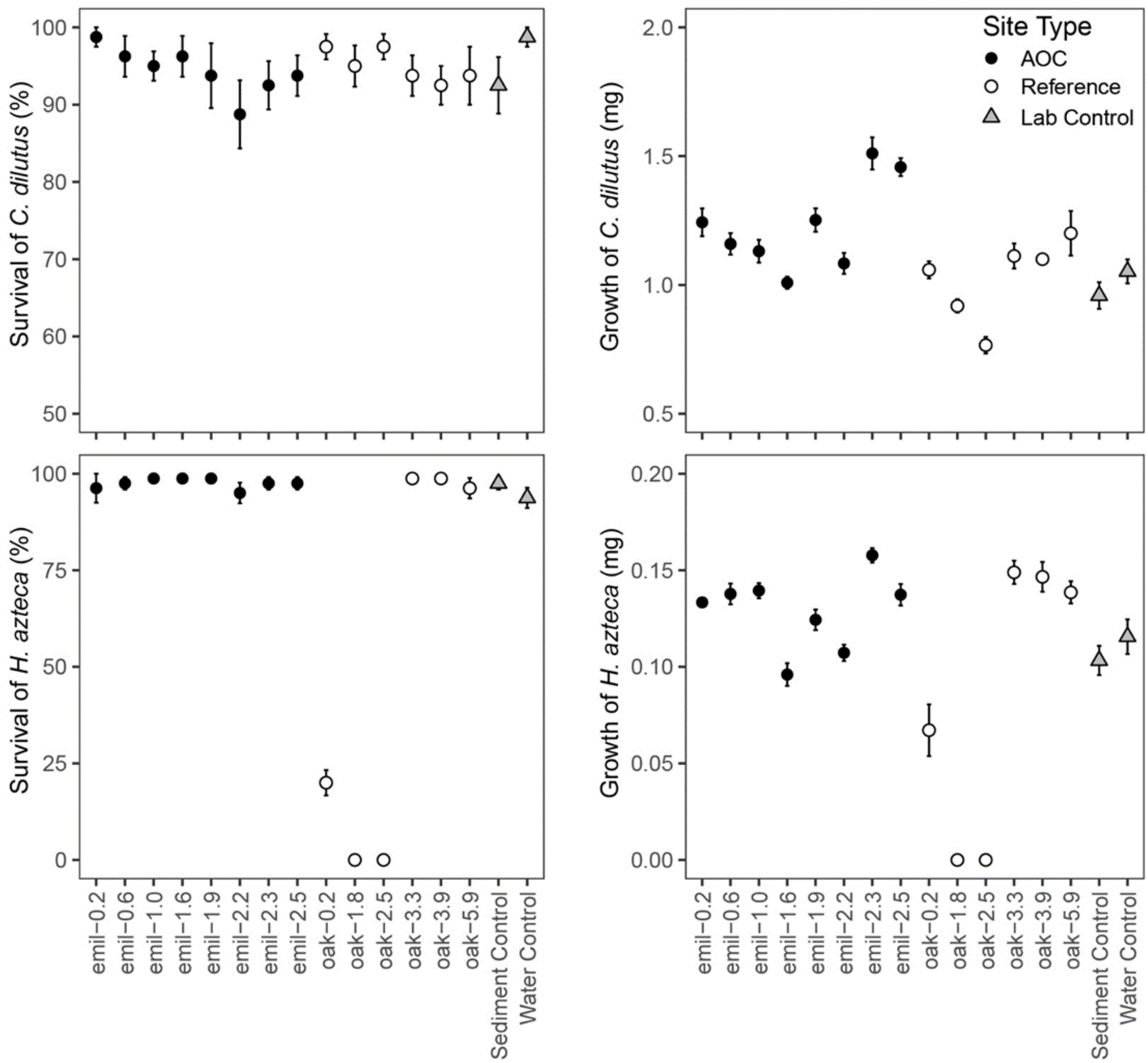

Figure 4: Survival and growth of C. dilutus and H. azteca (mean ± one standard error, n = 8) in 10-day sediment toxicity tests from the 8 AOC and 6 reference sites sampled in 2021.

When considered individually, none of the AOC sites met or even approached the USEPA and USACE standard criteria for toxicity used for sediment management decisions (USEPA and USACE, 1998), regardless of whether the Oak Orchard Creek reference sites or the laboratory test controls were used for the comparison. These criteria state that sediments are considered to be toxic if any of the following criteria are met:

-mortality of *C. dilutus* > 20% higher than in reference sediments and difference is statistically significant, OR

-mortality of *H. azetca* > 10% higher than in reference sediments and difference is statistically significant, OR

-mean dry weight (growth) of *C. dilutus* < 0.6 mg per organism, and difference between test and reference sediments > 10%, and difference is statistically significant.

3.2 NYSDEC Rotating Integrated Basin Studies (RIBS) Data

As part of the RIBS statewide water quality monitoring program, NYSDEC conducts routine monitoring across the state on a five-year rotating schedule of New York State watersheds. A single site in the Eighteenmile Creek AOC was sampled in 2015 and 2020 using Hester-Dendy artificial substrate samplers (multiplate). These samplers are positioned 1 meter below the surface and are colonized throughout a 5-week deployment. The organisms that colonize the substrates are then preserved, identified, and used to calculate a BAP score following standard NYSDEC methods (Duffy, 2021).

The study site, EMIL-1.1, is located 1.1 miles upstream from the confluence with Lake Ontario. Three replicate samples were taken in 2015 which produced an average BAP score of 6.6 and a classification of slightly impacted. Four replicate samples were taken in 2020 which produced an average BAP score of 7.49 and a classification of slightly impacted (NYSDEC, 2025). The 2015 and 2020 RIBS results were both within the range of the BAP scores from the AOC sites in the 2021 survey, and both were consistent with the "slightly impacted" average condition from the 2021 survey.

4. Sediment Management Actions

Historic investigations of the Eighteenmile Creek AOC have not identified significant sources of legacy contaminants originating from within the AOC boundaries. This has led to a significant amount of work completed by federal, state, and local partners to identify, characterize, and delineate upstream sources of contamination to Eighteenmile Creek. Extensive sediment sampling completed by the Great Lakes Legacy Act (GLLA) confirmed contaminants such as PCBs and metals exceeding state and federal superfund sediment guidance values in source areas upstream of the AOC (CH2MHill et al., 2015).

4.1 USEPA Superfund Site

Due to the extent of contamination in Eighteenmile Creek source areas and associated cost of remediation, the NYSDEC requested the Eighteenmile Creek Corridor and stream channel sediments be nominated to USEPA's Superfund program. The entire length of the creek, from the New York State (NYS) Barge Canal in Lockport to the outlet at Lake Ontario approximately 15 miles downstream in Olcott, New York was placed on the National Priorities List, or Superfund, in 2012. The main contaminants of concern are lead and PCBs.

The Superfund program divided the Eighteenmile Creek cleanup into at least four Operable Units (OUs) based on the type of remediation required and geographic area (Figure 5). The first phase of the cleanup (OU1), completed in 2016, included the demolition of the former Flintkote factory, which was a likely source of PCBs and metals to Eighteenmile Creek. The second phase of the cleanup (OU2) involves a combination of excavation and capping of contaminated sediment and soil, within the Creek Corridor, a 4,000-foot section of the creek and associated upland areas that span from the NYS Barge Canal to Harwood Street in the City of Lockport. A Record of Decision for OU2 was issued in 2017, with remedial work beginning in 2024. OU3 includes remediating creek sediments and floodplain soils from where OU2 ends (near Harwood Street in Lockport) and extending downstream 5.3 miles. This area is also referred to as the Sediment Transition Area (STA). In the Record of Decision for OU3 (USEPA, 2024), contaminated creek sediment that exceeds a remedial action level will be excavated and replaced with clean sand and a suitable habitat layer. In addition, the OU3 remedy will address PCB and lead contaminated floodplain soils in discrete areas adjacent to the STA. OU4 involves removing lead-contaminated soil at residential properties adjacent to the former Flintkote property in the City of Lockport. A Record of Decision for OU4 was issued in 2018 (USEPA, 2018), with cleanup beginning in 2024. Portions of the creek downstream of OU3 will be addressed in a future operable unit(s). It is anticipated that, once completed, the Superfund remedial efforts will result in conditions that allow for removal of the other remaining BUI designations within the Eighteenmile Creek AOC.

For more information about the Eighteenmile Creek Superfund Site, please visit: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0206456.

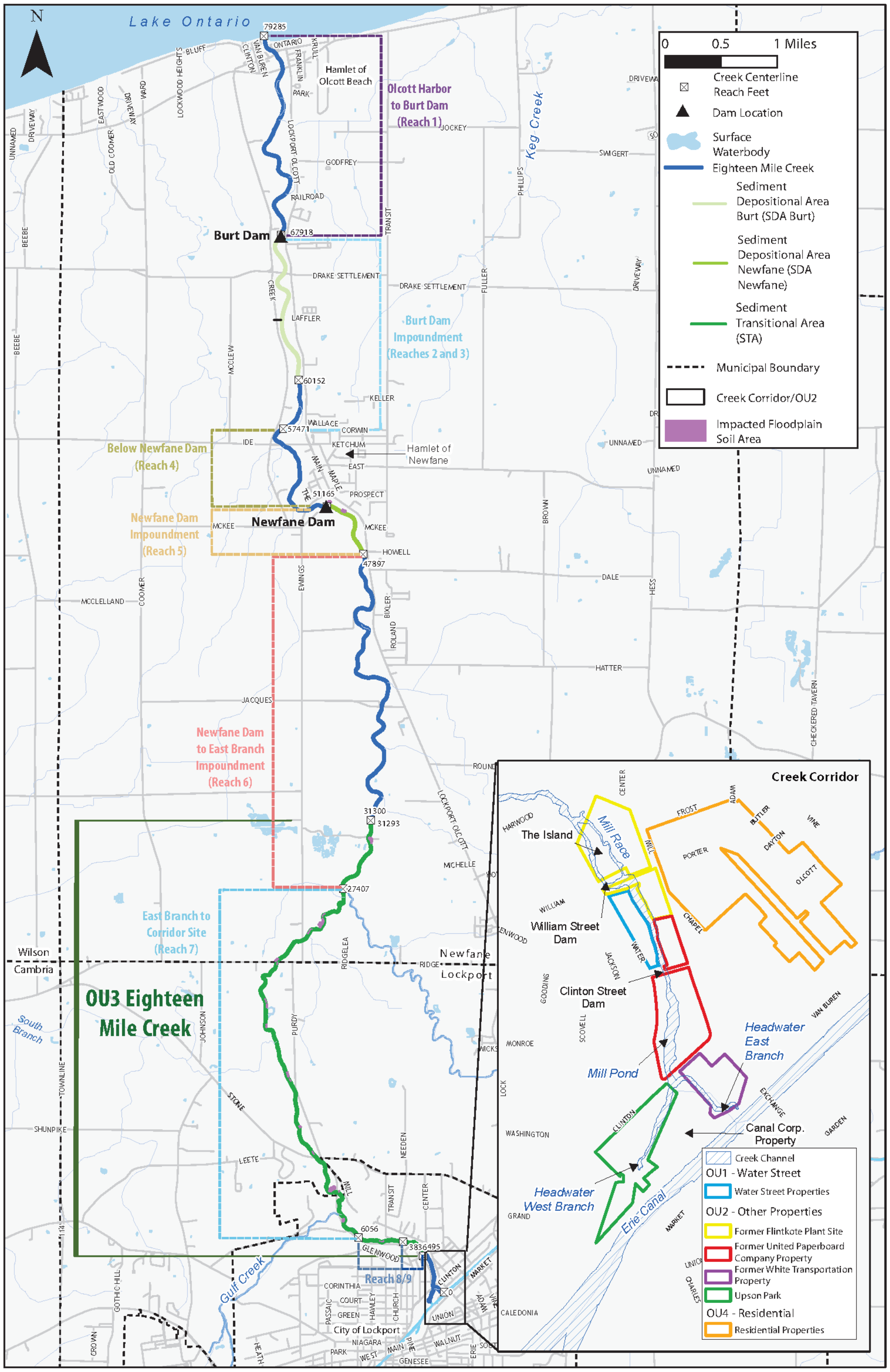

Figure 5: Eighteenmile Creek Superfund site overview map showing the locations of Operable Units 1-4. Portions of the creek downstream of OU3 will be addressed in a future operable unit(s). Eighteenmile Creek AOC comprises Reach 1 from Lake Ontario to Burt Dam (from USEPA, 2024).

4.2 Great Lakes Restoration Initiative Management Actions

In January 2020, the USACE completed a desktop review of available data for the Eighteenmile Creek AOC (Pickard et al., 2020). One of the primary objectives of this review was to determine if any additional sediment quality-related Management Actions were necessary to remove the remaining BUIs. The USACE evaluation concluded that no such sediment-related Management Actions were necessary within the AOC to address the BUIs, noting that poor benthic results at a single site (during the 2014 survey) should not be considered unusual and may not be related to contaminant levels in sediment. These findings were later confirmed by results from the 2021 benthic sampling which found AOC benthic communities are comparable to regional reference conditions, with only slight impact at the site that scored poorly in 2014.

In the context of the Great Lakes Area of Concern program, a “Management Action” is defined as a Great Lakes Restoration Initiative (GLRI) or GLLA funding commitment for a major project or strategic set of projects intended to bring about significant restoration of water quality and water dependent resources, consistent with the GLWQA. The primary examples of GLRI/GLLA Management Actions for AOCs typically fall into the general categories of water pollution source control, contaminated sediment remediation, and habitat restoration. Under this definition, assessments and monitoring projects to evaluate the status of BUIs are not considered to be Management Actions. Major habitat restoration, source control, and sediment remediation or sediment maintenance initiatives under separate federal, state, or local programs (such as the federal Superfund program) are also not considered to be Management Actions. Based on the recommendations made by the USACE, as well as the collective efforts achieved to date by local, state, and federal partners, Eighteenmile Creek AOC was designated as “Management Action Complete” in 2020. This determination was made by NYSDEC with support from NCSWCD and the Eighteenmile Creek RAC, and concurrence from USEPA.

The AOC program is collaborative and many of the goals outlined in the Eighteenmile Creek RAP are contingent upon the completion of remedial projects through federal Superfund programs. The Eighteenmile Creek AOC comprises Reach One of the Eighteenmile Creek federal Superfund site. It is imperative that pertinent planning, design, implementation, and ultimate completion of the Superfund remedies for all OUs support BUI restoration targets within the AOC to the greatest extent possible. While recent monitoring and assessment data may support the removal of some BUIs at this time, completion of the Superfund remedies will be necessary to ensure the full implementation of the Eighteenmile Creek RAP, removal of other BUIs, and ultimately delisting of the AOC.

5. Public Outreach

NYSDEC, in partnership with NCSWCD, USEPA, and the Eighteenmile Creek RAC, hosted a public meeting on ___________, to present the case for removing the *Degradation of Benthos* BUI to local stakeholders. The meeting was held during the 30-day period from ________ to __________, during which the public was invited to review and provide input on a draft version of this BUI removal report, which was hosted on the Eighteenmile Creek RAPs website.

(Placeholder/Possible Appendix 2 for summary of public engagement process, to be prepared after the 30-day period noted above.)

6. Conclusions

6.1 Removal Statement

In the Stage I/II RAP for the Eighteenmile Creek AOC, the *Degradation of Benthos* BUI was designated based on results of surveys conducted between 1977 and 1994 (NCSWCD, 2011, NYSDEC, 1997). These early assessments relied heavily on inferred or expected impact to benthic communities based on contaminant concentrations in sediments. Subsequent assessments conducted in 2012, 2014, and 2021 focused on direct sampling of benthic communities and sediment toxicity endpoints to directly assess the BUI removal criteria.

The current BUI removal criteria state "1. Benthic macroinvertebrate communities are "non-impacted" or "slightly impacted" according to NYSDEC indices; OR 2. Benthic macroinvertebrate community condition is similar to unimpacted control sites of comparable physical and chemical characteristics; AND 3. Toxicity of sediment-associated contaminants is similar to unimpacted control sites of comparable physical and chemical characteristics."

The 2021 survey, in addition to being the most recent, was by far the most comprehensive and therefore is the most authoritative source for determining if the BUI removal criteria have been met. The 2021 study design was consistent with similar surveys that addressed the *Degradation of Benthos* BUI in other New York AOCs, and included broad spatial coverage across both the AOC and a regional reference area. This study found that BAP scores at individual sites in the AOC and reference area were similar and ranged from severe to non-impacted. The first BUI removal criterion does not specify whether individual site or AOC average BAP scores should be considered. This is significant, because both the standard BAP (5.1) and aggregate BAP (6.6) mean scores from this study would classify the AOC as slightly impacted, meaning the first BUI removal criterion is likely met when considering the AOC as a whole. However, since there is variability across individual sites, with some falling into moderate or severe BAP impact tiers, it is appropriate to consider the second and third removal criteria as well. The data also show that the AOC macroinvertebrate community condition is similar or superior to that of the reference area, thereby meeting the second BUI removal criterion. Finally, sediment toxicity data from the AOC for both test species were similar or superior relative to the reference area, and exceeded established standards for survival and growth, thereby meeting the third BUI removal criterion. The results from the 2012 and 2014 studies, as well as routine samples collected under the NYSDEC RIBS program, provide additional weight of evidence in support of this conclusion. Although remedial action is ongoing in the Eighteenmile Creek watershed, the assessments summarized in this report have demonstrated that the removal criteria for the *Degradation of Benthos* BUI have been met. Pending remedial efforts by USEPA Superfund are expected to reduce upstream sources further improving the quality of sediments in Eighteenmile Creek including the AOC. Macroinvertebrate communities will continue to be monitored by NYSDEC's RIBS program to document current conditions on a five-year cycle.

For removal of the *Degradation of Benthos* BUI to occur, either the first BUI removal criterion must be met, or both the second and third BUI criterion must be met. As discussed above, recent data indicate that all three BUI removal criteria are satisfied, thus the weight of evidence suggests this beneficial use is restored. The NYSDEC has determined the *Degradation of Benthos* BUI designation can be removed for the Eighteenmile Creek AOC in accordance with USEPA guidance and the GLWQA. The Eighteenmile Creek RAC and NCSWCD fully support the removal of this BUI designation.

6.2 BUI Removal Steps

	Completed	*Date*	*Step Taken*
1.	✓	08/1997	BUI first designated as "impaired" in a delisting target report to USEPA.
2.	✓	08/2020	Final BUI removal criteria established with RAC consensus.
3.	✓	01/2024	RAC agreed to proceed with BUI removal.
4.	✓	5/19/2025	Initial Draft BUI removal recommendation provided to USEPA Technical Review Lead.
5.	✓	6/3/2025	Receive comments from USEPA Technical Review Lead and revise removal report accordingly.
6.			Hold public outreach meeting to present BUI removal rationale to local stakeholders (including a 30-day public comment period).
7.			NCSWCD/NYSDEC completes final modifications to the *Degradation of Benthos* BUI removal document, based on public comments received.
8.			Coordinate the formal transmittal of the BUI removal report with USEPA Great Lakes National Program Office (GLNPO).
9.			Communicate results to RAC for appropriate recognition and follow-up.

6.3 Post-Removal Responsibilities

6.3.1 New York State Department of Environmental Conservation

Through the RIBS program, NYSDEC staff will continue to monitor water quality and macroinvertebrate communities within Eighteenmile Creek on a routine basis. Staff also will continue to provide management and oversight support for active and inactive contaminated sites within the Eighteenmile Creek watershed.

6.3.2 United States Environmental Protection Agency

The USEPA GLNPO will continue to provide funding for RAP/RAC coordination and technical resources to support the removal of remaining BUIs and ultimately the delisting of the AOC. USEPA Region 2 will have continued responsibility for addressing the various Eighteenmile Creek Operable Units under the Federal Superfund program.

6.3.3 Niagara County Soil and Water Conservation District

NCSWCD will continue to serve as the RAP Coordinator for the Eighteenmile Creek AOC, facilitating RAC meetings, providing technical and administrative assistance for AOC documentation, serving as the primary point of contact for the AOC, and coordinating the overall implementation of the RAP for the Eighteenmile Creek AOC.

6.3.4 Remedial Advisory Committee

The RAC will continue to forward the objectives of the RAP by evaluating, supporting, and documenting the restoration of the Eighteenmile Creek AOC, until all the BUIs are restored and the long-term goal of delisting the AOC can be achieved.

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Appendix 1 – Benthos Assessments

1.A 2013 Study

1.B 2017 Study

1.C 2023 Study

Appendix 2 – Public Outreach Summary

Appendix 1.A

Eighteenmile Creek Baseline Benthic Community Sampling Report

April 2013

Prepared by Ecology and Environment

Eighteenmile Creek Baseline Benthic Community Sampling Report

April 2013

Prepared for:

NIAGARA COUNTY SOIL AND WATER CONSERVATION DISTRICT
Lockport, New York

Prepared by:

ECOLOGY AND ENVIRONMENT, INC.
368 Pleasant View Drive
Lancaster, New York 14086

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List of Abbreviations and Acronyms

AOC	Area of Concern
AVS	acid volatile sulfides
BAP	Biological Assessment Profile
BUI	Beneficial Use Impairment
COC	chain-of-custody
DDD	dichlorodiphenyl-dichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	chlorodiphenyl-trichloroethane
DOM-3	three most abundant taxa
E & E	Ecology and Environment, Inc.
EPT	Ephemeroptera, Trichoptera, and Plecoptera
GLRI	Great Lakes Restoration Initiative
HBI	Hilsenhoff Biotic Index
IJC	International Joint Commission
LEL	low effect level
NCSWCD	Niagara County Soil and Water Conservation District
NYSDEC	New York State Department of Environmental Conservation
PCB	polychlorinated biphenyl
PEC	probable effect concentrations
PMA	percent model affinity
RAC	Remedial Advisory Committee
RAP	Remedial Action Plan
REIC	REI Consulting Inc.
SEM	simultaneously extracted metals
SQT	Sediment Quality Triad
TEC	threshold effect concentration
USEPA	United States Environmental Protection Agency

Executive Summary

This report describes the results of a study designed to evaluate the current condition of the benthic macroinvertebrate community in the Eighteenmile Creek Area of Concern (AOC). The study results are to be used for two purposes: (1) as a baseline against which future changes in the benthic community can be measured; and (2) to reevaluate the status of Beneficial Use Impairment (BUI) Number (No.) 6 (Degradation of Benthos) within the Eighteenmile Creek AOC. In August 2012, the benthic macroinvertebrate community was sampled at two riffle/run habitat sites and three pool habitat sites in the AOC. In addition, sediment samples for contaminant analysis and sediment toxicity testing were collected from the three pool locations. The following findings are noteworthy:

- The benthic community in riffle and run/glide habitats in the AOC is not impaired or slightly impaired according to New York State Department of Environmental Conservation (NYSDEC) indices. This finding satisfies the first delisting criterion for BUI No. 6 for the Eighteenmile Creek AOC (i.e., benthic communities are not impacted or slightly impacted according to NYSDEC indices) and, therefore, supports delisting this BUI.

- The benthic community in pool habitats in the AOC is not impaired according to NYSDEC indices. Also, sediment bioassay and bioavailability data collected for this study found no sediment toxicity and low bioavailability of contaminants in sediment in the locations sampled. These findings satisfy the first and third delisting criteria for BUI No. 6 for the Eighteenmile Creek AOC and, therefore, support delisting this BUI.

Based on the findings of the current study, we recommend the following:

- The Niagara County Soil and Water Conservation District (NCSWCD) and Eighteenmile Creek Remedial Advisory Committee (RAC) should consider moving forward with delisting BUI No. 6.

- Another round of benthic community monitoring should be implemented in 2017 as suggested in the *Eighteenmile Creek Area of Concern (AOC) Strategic Plan for Beneficial Use Impairment (BUI) Delisting* (E & E 2011). Future monitoring data will provide insight into how sediment remedial actions and other activities upstream from the AOC affect the benthic community therein.

1 Introduction

This report describes the results of a study designed to evaluate the current condition of the benthic macroinvertebrate community in the Eighteenmile Creek Area of Concern (AOC). The study results are to be used for two purposes:

- As a baseline against which future changes in the benthic community can be measured; and
- To reevaluate the status of Beneficial Use Impairment (BUI) No. 6 (Degradation of Benthos) within the Eighteenmile Creek AOC.

The Sediment Quality Triad (SQT) approach was employed for the current investigation (USEPA 1994). This approach is based on concurrently evaluating sediment chemistry, sediment toxicity, and benthic community composition to draw a conclusion regarding the overall health of the benthic community.

The baseline sampling study described in this report was first identified in the *Eighteenmile Creek Area of Concern (AOC) Strategic Plan for Beneficial Use Impairment (BUI) Delisting* (E & E 2011) and described in detail in the *Quality Assurance Project Plan* (E & E 2012a) prepared to guide the work. This work was supported by a grant from the United States Environmental Protection Agency (USEPA) Great Lakes Restoration Initiative (GLRI) to the Niagara County Soil and Water Conservation District (NCSWCD).

This remainder of this report is organized as follows:

- Section 2 describes field and laboratory methods;
- Section 3 describes the study results;
- Section 4 provides a summary and recommendations; and
- Section 5 provides references.

Appendix A includes a copy of the final QAPP and Appendices B through F include field data collection forms and full analytical results from the laboratories that supported the project. A Data Usability Summary Report is included in Appendix G.

1.1 Background on Eighteenmile Creek AOC Status and BUIs

In 1987, the International Joint Commission (IJC) identified 43 AOCs in the Great Lakes Basin where the beneficial uses of the water body were considered impaired. Eighteenmile Creek was identified as one of the 29 United States AOCs. The creek has been polluted by past industrial and municipal discharges, the disposal of waste, and the use of pesticides. Currently, there are five documented BUIs at the Eighteenmile Creek AOC: (1) restrictions on fish and wildlife consumption; (2) degradation of fish and wildlife populations; (3) bird or animal deformities or reproductive problems; (4) degradation of benthos; and (5) restrictions on dredging activities (USEPA 2010). These five BUIs are largely driven by elevated levels of polychlorinated biphenyls (PCBs) in sediment and fish (E & E 2011), but elevated levels of metals and pesticides also are present in sediment throughout the creek (E & E 2012b). Table 1-1 lists the site-specific BUI delisting criteria developed by the NCSWCD for the Eighteenmile Creek system.

Table 1-1 Beneficial Use Impairments and Delisting Criteria for the Eighteenmile Creek AOC

BUI	BUI Status	Delisting Criteria
1. Restrictions on Fish and Wildlife Consumption	Impaired	There are no AOC-specific fish and wildlife consumption advisories issued by New York State; **AND**
		Contaminant levels in fish and wildlife must not be due to contaminant input from the watershed upstream of Burt Dam
3. Degradation of Fish and Wildlife Populations	Impaired	Fish and wildlife diversity, abundance and condition are statistically similar to diversity, abundance and condition of populations at non-AOC control sites; **AND**
		PCB levels in bottom-dwelling fish do not exceed the critical PCB tissue concentration for effects on fish (440 micrograms per kilogram of weight; Dyer et al. 2000)
5. Bird or Animal Deformities or Reproduction Problems	Impaired	No reports of wildlife population deformities or reproductive problems from wildlife officials above expected natural background levels; **AND**
		Contaminant levels in bottom-dwelling fish do not exceed the level established for the protection of fish-eating wildlife (NYSDEC Fish Flesh Criteria); **OR**
		In the absence of fish data, the toxicity of sediment-associated contaminants does not exceed levels associated with adverse effects on wildlife (NYSDEC Fish & Wildlife Bioaccumulation Sediment Criteria)

Table 1-1 Beneficial Use Impairments and Delisting Criteria for the Eighteenmile Creek AOC

BUI	BUI Status	Delisting Criteria
6. Degradation of Benthos	Impaired	Benthic macroinvertebrate communities are "non-impacted" or "slightly impacted" according to NYSDEC indices; **OR**
		In the absence of NYSDEC data, riffle habitats require benthic macroinvertebrate communities with a species richness higher than 20, EPT richness greater than 6, a biotic index value greater than 4.51, and a percent model affinity greater than 50; **OR**
		In the absence of benthic community data, this use will be considered restored when the level of toxic contaminants in sediments is not significantly higher than controls.
7. Restrictions on Dredging Activities	Impaired	When contaminants in AOC sediments (located within the actual or potential dredging areas identified for the improvement of ship navigation) do not exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities.

Source: USEPA 2010a

Key:

AOC = Area of Concern
BUI = Beneficial Use Impairment
EPT = Ephemeroptera, Plecoptera, and Trichoptera
NYSDEC = New York State Department of Environmental Conservation
PCB = Polychlorinated Biphenyl

Both human and ecological receptors using the Eighteenmile Creek system may be at risk from PCBs and other chemicals in fish and sediment based on recent investigations (E & E 2009a, E & E 2012b) and current fish consumption advisories (NYSDOH 2011). Elevated levels of PCBs in fish in Eighteenmile Creek appear to be the result of bioaccumulation from sediment (USACE 2004a, b; von Stackelberg and Gustavson 2012). Recent sediment data from the Remedial Investigation (RI) for Eighteenmile Creek show that surface sediment levels of PCBs and metals are greater in the portion of the creek near the source areas in Lockport, New York, compared with downstream reaches (E & E 2012b). Contaminant source areas along the creek in Lockport were characterized by NYSDEC (2006) and E & E (2009b). Remediation of these upstream sources areas and contaminated sediment throughout the creek is necessary to eliminate BUIs in the Eighteenmile Creek system and eventually delist this Great Lakes AOC (E & E 2011).

1.2 Site Location and Description

The Eighteenmile Creek AOC is located in Niagara County, New York (see Figure 1-1). The creek flows generally north through central Niagara County and discharges via Olcott Harbor into Lake Ontario, approximately 18 miles east of the mouth of the Niagara River. The AOC includes Olcott Harbor and extends upstream to the farthest point at which backwater conditions exist during Lake Ontario's highest monthly average lake level (see Figure 1-1). This point is located just downstream of Burt Dam, approximately 2 miles south of Olcott Harbor. This portion of the watershed is a unique gorge habitat that attracts recreational boaters, anglers, birders, and waterfowl hunters.

Only a small portion of the Eighteenmile Creek basin was originally designated an AOC by the IJC. However, for two reasons, since the Eighteenmile Creek Remedial Action Plan (RAP) process began, the AOC has been considered the impact area and the upper watershed as the source area (NYSDEC 1997). First, except for potential impacts from agricultural operations adjacent to the current AOC boundary, there are no documented sources or source areas of contamination within the AOC. Second, various investigations conducted over the past 35 years have suggested that contaminants may enter the AOC from upstream areas. Specifically, PCBs, copper, lead, and other metals have been found in creek sediment and bank fill in Lockport, New York, at concentration well above applicable New York State Department of Environmental Conservation (NYSDEC) standards, indicating that contaminant sources exist in this area (NYSDEC 2006, E & E 2009b and 2012b). Other contaminant source areas may exist along the creek between Lockport and the AOC (NYSDEC 2001).

Additional information regarding the characteristics of the Eighteenmile Creek AOC and watershed are available in the *Eighteenmile Creek State of the Basin Report* (E & E 2007), *Beneficial Use Impairment (BUI) Investigation Report for Eighteenmile Creek* (E & E 2009a), *Sediment Remedial Investigation Report* (E & E 2012b), and additional publications and factsheets available from the Eighteenmile Creek RAP Web site (http://www.eighteenmilerap.com/).

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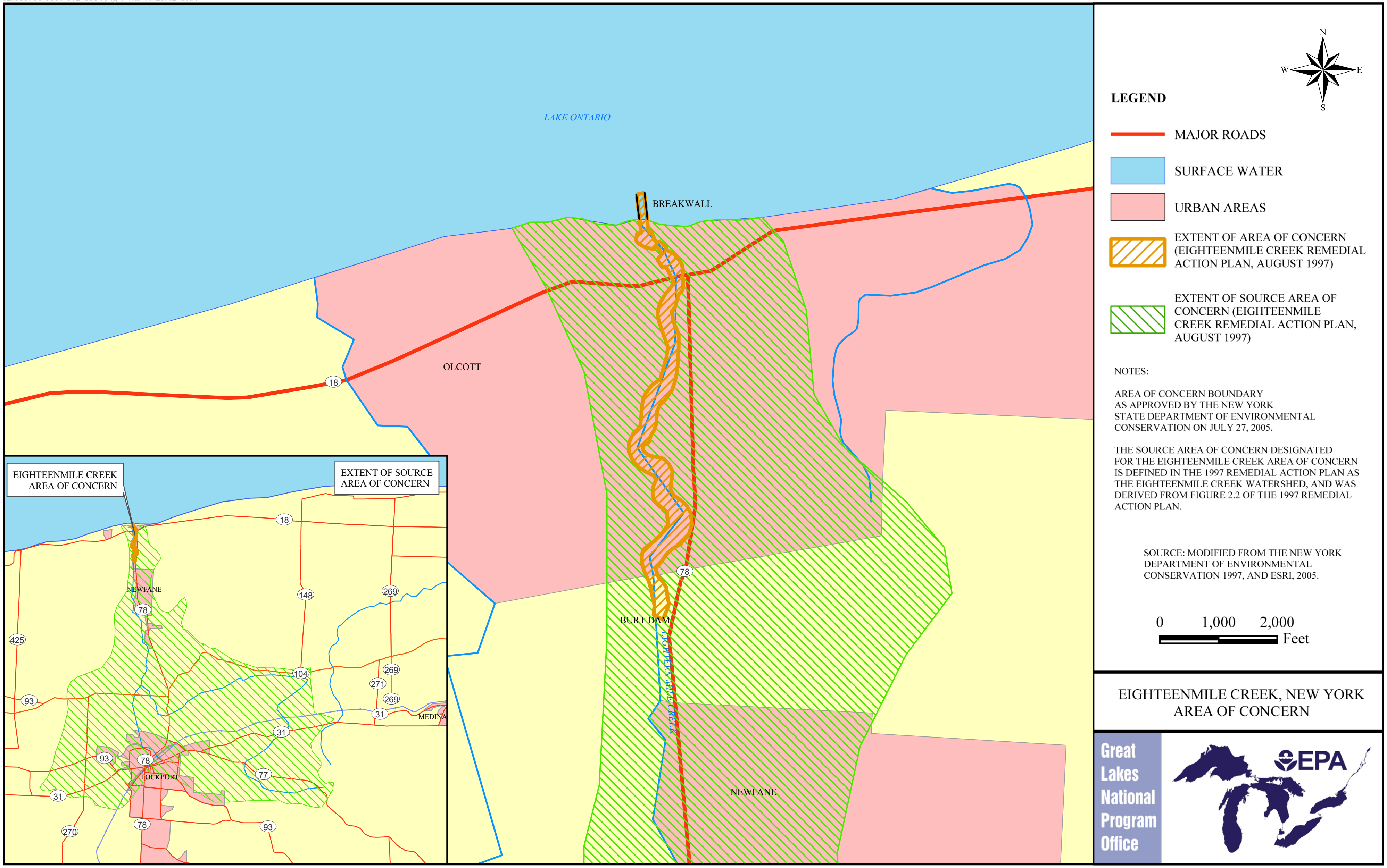

Figure 1-1 Eighteenmile Creek Area of Concern

2 Methods

2.1 Field Sampling Methods

Ecology and Environment, Inc. (E & E) biologists sampled the benthic community and associated chemical and physical parameters at two riffle/run habitat sites and three pool habitat sites in the Eighteenmile Creek AOC on August 21 and 22, 2012. In addition, sediment samples for chemical analysis and sediment toxicity testing were collected from the three pool locations. Table 2-1 provides a summary of the sample types collected at each location. As per the final QAPP (E & E 2012a), all sampling sites were located downstream of Burt Dam (see Figures 2-1 and 2-2). Riffle sample 1BR1 was located in the only area of true riffle habitat in this section of the creek, just downstream from Burt Dam. Because this riffle is relatively short (approximately 45 meters (~148 feet) long), the field team did not collect a second sample of riffle benthos from this area. Instead, a run /glide habitat (sample 1BR2) located approximately 200 meters (~656 feet) downstream from where 1BR1 was sampled (see Figure 2-1). Suitable pool habitats that could be sampled effectively with a petite Ponar dredge could not be located in the upstream portion of the AOC due to the presence of either gravelly substrate or dense submerged aquatic vegetation. E & E biologists were able to successfully collect benthos as well as sediment chemistry and bioassay samples in pool areas with finer substrates farther downstream, as shown on Figure 2-2.

Table 2-1 Summary of Baseline Benthic Community Samples

		Parameter		
Sample	Habitat Type	Benthic Community Composition[a]	Sediment Chemistry[b]	Sediment Toxicity[c]
1BR1	Riffle	X		
1BR2	Run/Glide	X		
1BP1	Pool	X	X	X
1BP2	Pool	X	X	X
1BP3	Pool	X	X	X

Notes:
[a] Macroinvertebrate abundance and diversity and metrics.
[b] PCB Aroclors and congeners, TAL inorganic analytes, AVS/SEM, TOC, grain size, and density.
[c] 10-day sediment bioassays with *Hyalella azteca* (amphipod) and *Chironomus dilutes* (midge).

Key:
AVS/SEM = Acid Volatile Sulfide/Simultaneously Extracted Metals
TAL = target analyte list
TOC = total organic carbon

2.1.1 Water Chemistry
Temperature, conductivity, pH, dissolved oxygen, and total dissolved solids were measured at all sites using a Horiba U-22 multi-parameter meter and probe. The unit was calibrated according to manufacturer's specifications at the beginning of each sampling day.

2.1.2 Physical and Benthic Sampling Procedures
Physical and benthic sampling procedures are described separately for riffle/glide and pool sample sites.

2.1.2.1 Riffle/Glide Habitat
Macroinvertebrate samples in riffle and run/glide habitats were collected according to standard procedures used by the NYSDEC Stream Biomonitoring Unit for riffle habitat (NYSDEC 2009). In addition, data for the following physical parameters were recorded:

- Water depth – using a meter stick;
- Wetted stream width – estimated using paces of one of the field biologists;
- Stream velocity/current – using Geopaks flow-averaging velocity meter;
- Embeddedness – visually estimated;
- Canopy cover – visually estimated; and
- Percent composition of substrate – visually estimated.

Copies of field data sheets are included in Appendix B. Benthic macroinvertebrates were collected using the "traveling kick method" using a rectangular-framed aquatic net with a 9 by 18-inch opening and 0.8 mm by 0.9 mm mesh. Samples were collected by the same person for consistency. The net was placed in the water approximately 0.5 meters (~1.6 feet) downstream from the sampler and the stream bottom was disturbed by foot, so that the dislodged organisms and debris were carried by the current into the net. Sampling was continued in a downstream direction along a diagonal transect for 5 minutes over a distance of 5 meters (~16 feet) (NYSDEC 2009). Once the sample was collected, the contents of the net were emptied and rinsed into an enamel pan. Invertebrates observed clinging to the sides of the net were removed and placed in the enamel pan. Large stones and debris were rinsed of organisms and returned to the water. Readily observable orders of invertebrates present in the pan were recorded on data sheets. Field personnel then poured the contents of the pan through a No. 30 mesh soil sieve, transferred the captured material into a plastic sample jar, and added enough 95% ethanol to achieve an approximately 70% final concentration of ethanol. The sample code was written on the side of the sample jar, and a small slip of Rite-in-the-Rain™ labeled with the sample code was placed inside the jar prior to closure.

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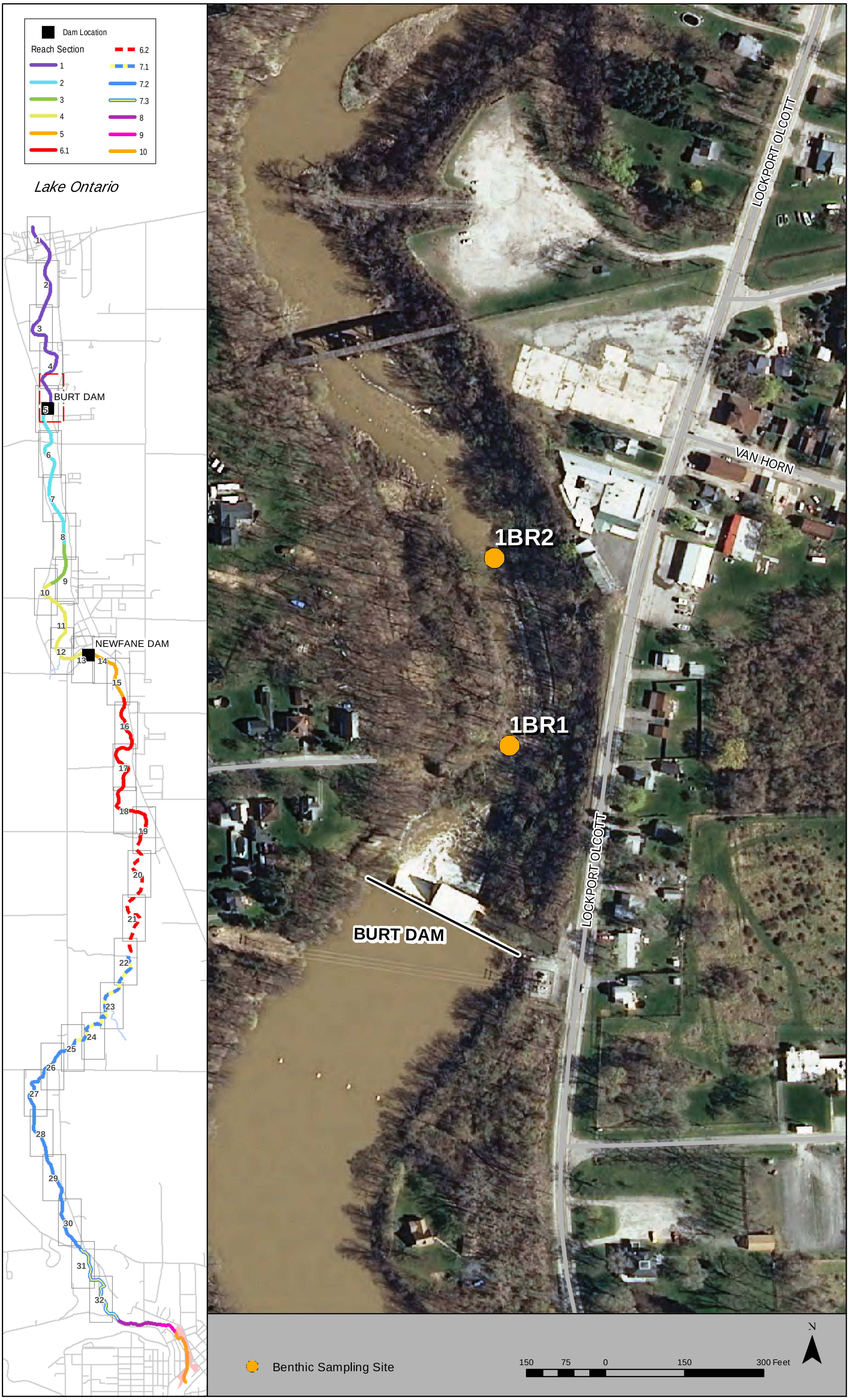

Figure 2-1 Riffle and Run/Glide Habitat Benthic Sites

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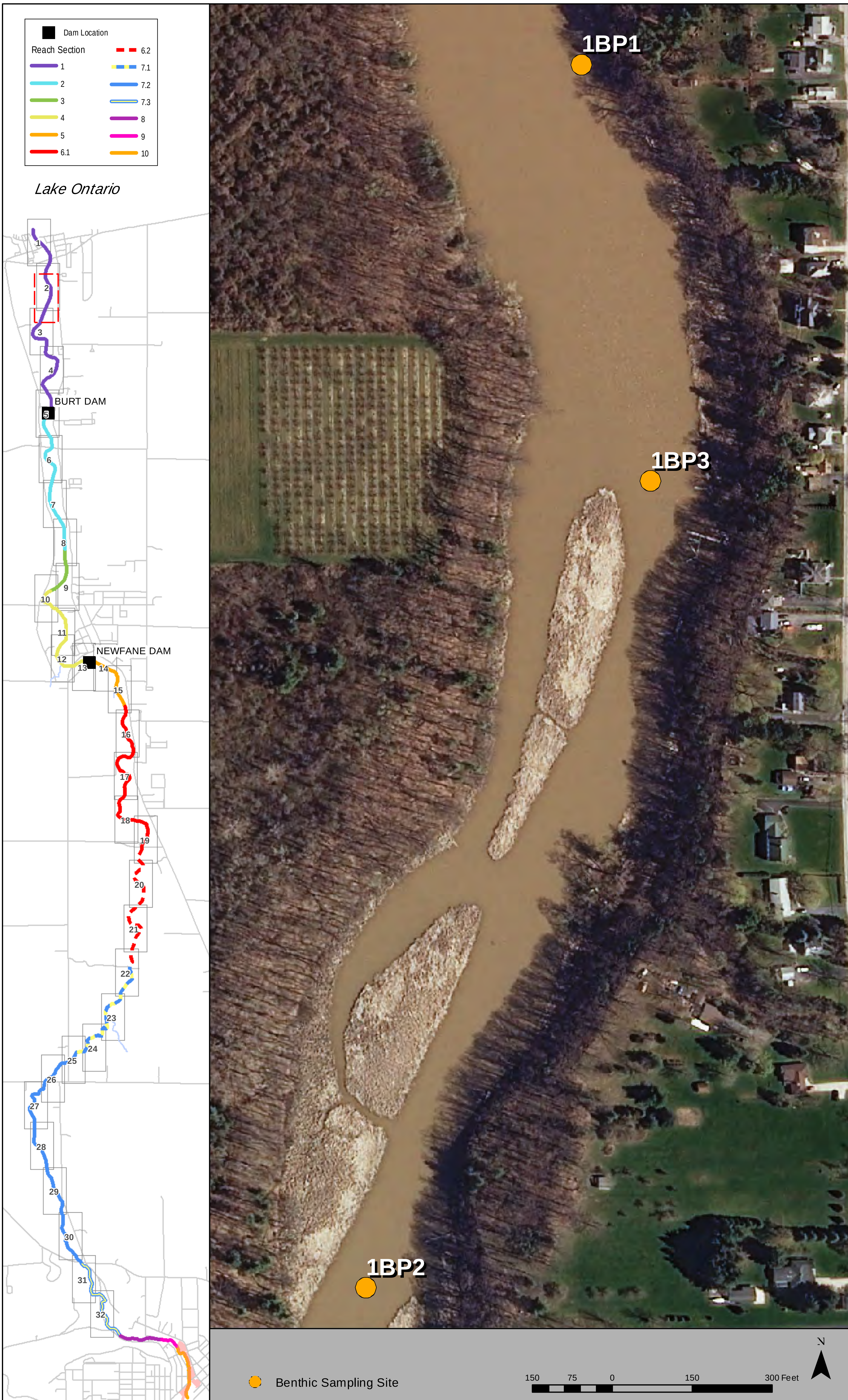

Figure 2-2 Pool Habitat Benthic Sites

2.1.2.2 Pool Habitat

Samples in the pool habitats were collected according to standard procedures used by the NYSDEC Stream Biomonitoring Unit for pool habitat (NYSDEC 2009). Also, data for the following physical parameters were recorded:

- Water depth – visually estimated using the length of rope attached to the petite Ponar dredge;
- Wetted stream width – visually estimated;
- Stream velocity/current – visually estimated;
- Canopy cover – visually estimated; and
- Percent composition of substrate – visually estimated based on material collected via the petite Ponar dredge.

Copies of field data sheets are included in Appendix B. Access to the pool sampling locations was made via a flat-bottomed Jon boat. Benthos was collected using a petite Ponar dredge (opening 6 by 6.5 inches or 0.0929 square meters) attached to a rope. The number of sediment grabs collected for samples 1BP1, 1BP2, and 1BP3, respectively, were 4, 2, and 3. The petite Ponar grabs for each sample were emptied into a rinsed 5-gallon plastic bucket, and the collected sediment screened through a No. 30 soil sieve to remove finer particles. Field personnel transferred the screened samples into jars and added enough 95% ethanol to achieve an approximately 50 to 70% final concentration of ethanol. The sample code was written on the side of the sample jar, and a small slip of Rite-in-the-Rain labeled with the sample code was placed inside the jar prior to closure. The dredge was rinsed thoroughly with stream water between each pool benthic sampling location.

2.1.3 Sediment Chemistry Sampling

Surface sediment (0 to 6 inches below the sediment water interface) was collected for chemical analysis in proximity to each of the pool benthos sampling locations. At each location, one or more sediment grabs with a petite Ponar dredge were emptied into a large pre-cleaned bucket, homogenized, and distributed to sample containers. Table 2-2 lists analytical parameters, number of samples, and sample-handling details. A field duplicate sample was collected for sediment chemistry at location 1BP1. The dredge was thoroughly cleaned and rinsed between sample areas.

Table 2-2 Analytical Parameters and Methods, Sample Containers, Preservatives, and Holding Times for Sediment Sampling at Eighteenmile Creek, Niagara County, New York

Sample Type	Preparation/Analysis	Method	Number of Samples	Sample Container	Preservation	Maximum Holding Time
Sediment[a]	Total Organic Carbon	ASTM D4129-05 modified.	4	Amber 4-oz glass jar with Teflon-lined cap	4°C	28 days
	Grain Size Distribution (percent sand, silt, clay)	ASTM D422	4	Amber 8-oz glass jar with Teflon-lined cap	4°C	28 days
	PCB Congeners and Aroclors (8082 list) and chlorinated pesticides	EPA 8082 and 8081B	4	Amber 8-oz glass jar with Teflon-lined cap	4°C	14 days to extraction; 35 days from extraction to analysis
	Density, wet	ASTM D854	4	Amber 4-oz glass jar with Teflon-lined cap	4°C	NA
	Total Metals (TAL list)	EPA 200.8, 6010B, 7471A	4	Amber 4-oz glass jar with Teflon-lined cap	4°C	180 days
	AVS/SEM (Cd, Cu, Ni, Pb, Hg, Zn, Ag)	EPA (1991) draft method for AVS/SEM in sediment and EPA 6010, 6020, and 7471 for metals.	4	Amber 4-oz glass jar filled to the brim with no air space	4°C	14 days for AVS
Sediment Toxicity	Toxicity - *Hyalella azteca* (10-day)	EPA 100.1	3	1-gal Ziploc bag (double bagged)	4°C	8 weeks
	Toxicity - *Chironomus dilutus* (10-day)	EPA 100.2	3	1-gal Ziploc bag (double bagged)	4°C	8 weeks

Notes:
[a] Three original samples and one field duplicate.

Key:
AOC = Area of Concern
ASTM = American Society of Testing and Materials
AVS = acid volatile sulfide
NA = not applicable
PCB = polychlorinated biphenyl
SEM = simultaneously extracted metal
TAL = target analyte list

2.1.4 Sample Handling and Shipping

Sediment samples were cooled to 4°C and shipped in coolers under chain-of-custody (COC) by overnight courier to ALS Environmental of Kelso, Washington, for chemical analysis and to Aquatic Biological Sciences of Williston, Vermont, for toxicity testing. Benthic macroinvertebrate samples were shipped under COC by overnight courier to REI Consulting Inc. (REIC) of Beaver, West Virginia, for processing.

2.2 Laboratory Methods

2.2.1 Benthic Macroinvertebrate Laboratory Methods

Benthic sample processing was performed by REIC. Sample 1BR1 was subsampled at a ratio of 6 to 100 (six cells of a 100-cell grid were selected for sorting and identification) to yield estimates of taxa in the entire sample. Sample 1BR2 was subsampled at a ratio of 2 to 100. The entirety of the benthic samples from the pool habitats were sorted and processed; subsampling was not performed. REIC identified macroinvertebrates to genus where possible for all insects. Clams and flatworms were only identified to family level. A full description of REIC's standard procedures for sorting and identifying benthic macroinvertebrates and for quality assurance/quality control is provided in the final Quality Assurance Project Plan (QAPP) (E & E 2012a, see Appendix A). Based on the numbers of each taxa of macroinvertebrates identified in a sample, REIC calculated 12 metrics, including family/generic richness; number of Ephemeroptera, Trichoptera, and Plecoptera (EPT) genera identified; percent of Chironomids in the sample; Shannon-Wiener Diversity index; and Hilsenhoff Biotic Index (HBI) (see Appendix F for full REIC report).

E & E calculated additional indices based on the reported results in order to assess impairment based on NYSDEC standards. These additional metrics included percent comprised by the three most abundant taxa (DOM-3), percent model affinity (PMA), and the Biological Assessment Profile (BAP) of index values, as described in NYSDEC's *Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State* (NYSDEC 2009).

The assessed level of impairment was then compared to the delisting criteria for BUI 6 (Degradation of Benthos) for the Eighteenmile Creek AOC (see Table 1-1). It should be noted that the assessed level of impairment reported for the riffle and run/glide habitats in the results section below includes an adjustment by one level of impairment to account for the effect of the impoundments upstream of the sample sites, as recommended by NYSDEC (2009).

2.2.2 Chemical and Toxicity Testing Methods

Sediment from pool sampling locations was submitted for chemical analysis and toxicity testing. Table 2-2 lists the methods used, numbers of samples, and sample-handling details.

3 Results and Discussion

The results of the present investigation are presented and discussed under three main headings: (1) Benthic Community Composition; (2) Sediment Chemistry; and (3) Sediment Toxicity Testing.

3.1 Benthic Community Composition

The benthic macroinvertebrate samples collected from the AOC indicate slight to no impairment of water quality based on NYSDEC criteria in the riffle and run/glide habitats, and moderate impairment in pool habitat (see Table 3-1). All samples were dominated by taxa moderately-tolerant to tolerant of pollution, and contained virtually no sensitive taxa (see Appendix F). More detail is provided below for the riffle and run/glide samples and pool samples. A summary of the physical and water chemistry parameters is provided in Table 3-2.

3.1.1 Riffle/Glide Habitat

The riffle community at 1BR1 was dominated by midge larvae (Chironomidae) of genera Chironomus, Polypedlium, and Tanytarsus, and *Cheumatopsyche* sp., a genus of filtering caddisflies. The run/glide community of 1BR2 was dominated by large numbers of *Cheumatopsyche* sp. and *Hydropsyche* sp., another genus of filtering caddisflies, and also midges of the genus *Polypedlium*. Interestingly, no mayfly species were collected at the run/glide habitat (1BR2). E & E biologists observed large numbers of zebra mussels on the rocks in both the riffle and run/glide locations. Incidental observations by E & E biologists indicated that zebra mussels attach to rock surfaces much more strongly than filtering caddisflies, making them less susceptible to dislodgement by simple foot-disturbance compared with other invertebrates. While some zebra mussels were collected in the kick samples, results indicate that perhaps they were not sampled as efficiently as other taxa using this collection method.

Much greater numbers of invertebrates, especially filtering caddisflies, were found at 1BR2 versus 1BR1. This difference may relate partly to the higher proportion of rock and rubble substrate at 1BR2; such substrates are necessary as stable attachment sites for filtering caddisflies (see Table 3-2). The difference may also be related to the presence of round goby (*Neogobius melanstomus*). Round goby were observed to be very common in the benthic environment of 1BR2, where the current is slower. Because round goby are known to feed on zebra

Table 3-1 Calculated Benthic Community Indices, Biological Assessment Profile of Index Values (BAP), and Assessed Impairment by Benthic Sample Location, Eighteenmile Creek Area of Concern, August 2012

Benthic Sample	Inv Density (per m^2)	PMA	PMA 1-10 scale	HBI	HBI 1-10 scale	EPT Rich-ness	EPT Rich-ness 1-10 scale	Generic Rich-ness	Generic Rich-ness 1-10 scale	DOM 3	DOM 3 1-10 scale	SHAN-WIENER	SHAN-WIENER 1-10 scale	BAP	Impact	Impact Corrected For Impoundment Effect
BR1	NA	48.4	4.82	6.23	5.34	7	5.91	24	6.76	65.41	NA	3.1	NA	5.71	slight	non-impacted
BR2	NA	26.6	1.14	5.1	6.75	3	3.61	23	6.47	91.25	NA	1.71	NA	4.49	moderate	slight impact
BP1	3,080	58.1	5.62	7.57	6.08	3	NA	23	9.04	58.71	7.72	3.32	8.30	7.35	non-impacted	NA
BP2	944	53.7	4.74	7.74	5.65	2	NA	19	7.50	61.05	7.33	3.26	8.15	6.67	non-impacted	NA
BP3	1,113	49.5	3.90	7.87	5.33	2	NA	21	8.27	52.38	8.77	3.6	9.00	7.05	non-impacted	NA

Key:

BAP = Biological Assessment Profile of index values for benthic macroinvertebrate communities (NYSDEC 2009, page 62). The BAP for a sample is determined by calculating the indices appropriate for the habitat type (riffle, pool, etc.), converting each index to a common 1-10 scale, and averaging those values. For riffle communities, the appropriate indices are species richness, HBI, EPT species richness, and PMA. For pool samples, the appropriate indices are species richness, HBI, Shannon-Wiener diversity, and PMA.
DOM 3 = Percentage of total number of animals in sample comprised by the three most numerous (dominant) taxa.
EPT = Number of genera of Ephemeroptera, Plecoptera, and Trichoptera in sample.
Inv Density = Density of benthic macroinvertebrates per square meter sampled.
HBI = Hilsenhoff Biotic Index,based on NYSDEC (2009) methodology.
NA = Not applicable.
PMA = Percent Model Affinity, based on NYSDEC (2009) methodology specific to riffle and pool habitats.
SHAN-WIENER = Shannon-Wiener Diversity index, based on NYSDEC (2009) methodology.

Table 3-2 Field Measured Physical and Chemical Parameters at Each Benthic Sample Location, Eighteenmile Creek Area of Concern, August 2012

Benthic Sample	Water Depth (meters)	Stream Width (meters)	Water Velocity (cm/s)	Canopy Cover (%)	Substrate Embeddedness (%)	Percent substrate Composition					Water Temp. (°C)	Conductance (mS/m)	pH	Dissolved Oxygen (mg/L)	Total Dissolved Solids (g/L)
						Rock	Rubble	Gravel	Sand	Silt					
BR1	0.33	10	100	40	10-20	30	30	30	10	0	18.1	70.8	7.2	14.7	0.45
BR2	0.315	30	23	20	20-25	25	50	15	5	5	18.1	70.4	7.4	14.4	0.35
BP1	4	60	0	0	NA	0	0	0	0	100	19	70.6	7.5	13.7	0.41
BP2	4	50	0	0	NA	0	0	0	15	85	18.1	74	7.06	12.1	0.47
BP3	4	65	0	0	NA	0	0	0	0	100	18.3	74.3	7.12	13.4	0.48

Key:

cm/s = centimeters per second
g/L = grams per liter
mg/L = milligrams per liter
mS/m = milliSiemens per meter

mussels, it is possible that they may suppress zebra mussel densities at 1BR2 enough to make a greater area of stable attachment sites available to filtering caddisflies.

In general, the benthic communities at 1BR1 and 1BR2 are consistent with assemblages found routinely by NYSDEC in surveys of other lake and impoundment outlets – such sites are characterized by lower diversity indices and dominance by filter feeders. NYSDEC protocols use species richness in calculations of BAP to assess impairment. Because the samples collected for this study were identified to the genus or family level, the richness levels reported herein may underestimate the true species richness, especially for Chironomidae. This may have resulted in a slight underestimate of BAP values calculated for the riffle and run/glide habitat samples. The BAP values of 5.71 and 4.49 for 1BR1 and 1BR2, respectively, would be classified by NYSDEC as slightly and moderately impaired if these samples were not collected from a lake-outlet stream. Because they were collected downstream from Burt Dam, samples 1BR1 and 1BR2 are classified as non-impaired and slightly impaired, respectively, after applying NYSDEC's lake-outlet adjustment (NYSDEC 2009). Consequently, locations 1BR1 and 1BR2 satisfy the first delisting criterion for BUI No. 6 (i.e., benthic macroinvertebrate communities are "non-impacted" or "slightly impacted" according to NYSDEC indices [see Table 1-1]).

3.1.2 Pool Habitat

Pool habitat benthic sample results show consistently high diversity scores (due to midge genera), and PMAs between 49.5 and 58.1 (see Table 3-1). Individuals from pollution tolerant taxa represented 96% to 99% of all invertebrates identified in the pool habitat samples (see Appendix F). Total invertebrate densities per square meter at 1BP1, 1BP2, and 1BP3 were 3,080, 944, and 1,113, respectively. Midges of tribe Chironomini and genus *Procladius*, and aquatic worms of family Naididae, were the dominant taxa. The three most common taxa represented between 52.4% and 61.0% of the invertebrates collected at each pool site. Calculated BAPs for the three pool sites ranged from 6.7 to 7.4, indicating non-impairment.

3.2 Sediment Chemistry

Metals, PCBs, and chlorinated pesticides as well as parameters to help with data interpretation were collected from the three pool locations (1BP1, 1BP2, and 1BP3) identified in Figure 2-1. A field duplicate sample was collected at 1BP1. A summary of the analytical data is provided in Table 3-3 along with sediment screening levels for protection of benthos. NYSDEC has indicated a preference for the threshold effect concentrations (TECs) and probable effect concentrations (PECs) from MacDonald et al. (2000), so these sediment screening levels were used preferentially. Chemical concentrations less than the TEC are presumed to pose no risk to benthos, whereas those greater than the PEC are presumed to have a high likelihood of causing an adverse effect. The TEC and PEC do not provide

Table 3-3 Eighteenmile Creek AOC Sediment Data (August 2012) Compared with Sediment Screening Levels.

	Sediment Screening Levels				Sample and Concentration			
Analyte[a]	TEC	PEC	Other[b]	Source	1BP1	1BP1 (R)	1BP2	1BP3
Metals (mg/kg)								
Aluminum	--	--	58,000	MacDonald et al. 1999	13,300	14,600	12,300	13,900
Antimony	--	--	2.9	MacDonald et al. 1999, PAETA	0.33 N	0.379 N	0.575 N	0.287 N
Arsenic	9.8	33	--	MacDonald et al. 2000	3.48	3.54	3.21	3.25
Barium	--	--	--	--	143	154	124	138
Beryllium	--	--	--	--	0.609	0.593	0.569	0.601
Cadmium	1	4.98	--	MacDonald et al. 2000	1.92	1.68	1.74	1.29
Chromium	43.4	111	--	MacDonald et al. 2000	88	89	88	55
Cobalt	--	--	50	MacDonald et al. 1999, criterion, Ont.	11	10	11	10
Copper	31.6	149	--	MacDonald et al. 2000	152	147	127	103
Iron	--	--	20,000	Persaud et al. 1993	22,400	24,000	22,200	22,900
Lead	35.8	128	--	MacDonald et al. 2000	217	211	265	141
Manganese	--	--	460	Persaud et al. 1993	516	529	551	529
Mercury	0.18	1.06	--	MacDonald et al. 2000	0.541	0.525	0.343	0.338
Nickel	22.7	48.6	--	MacDonald et al. 2000	**81**	**68**	**81**	39
Selenium	--	--	5	MacDonald et al. 1999, criterion, B.C.	0.9 J	0.9 J	0.8 J	1
Silver	--	--	0.5	USEPA 2003, ESL	0.596	0.893	0.439	0.399
Thallium	--	--	--	--	0.243	0.264	0.22	0.194
Vanadium	--	--	--	--	23	25	23	24
Zinc	121	459	--	MacDonald et al. 2000	**956**	**873**	**908**	**541**
Acid Volatile Sulides (AVS) and Simultaneously Extracted Metals (SEMs) (µmol/g)								
AVS	--	--	--	--	39	40	29	35
Sum of SEM Metals	--	--	--	--	7.2	5.4	6.7	3.8
ΣSEM / AVS ratio (unitless)	--	--	1	USEPA 1994	0.18	0.13	0.23	0.11
Ancillary Parameters								
Bulk Density (g/mL)	--	--	--	--	1.1	1.1	1.3	1.2
Solids (%)	--	--	--	--	34	32	42	35
Total Organic Carbon (%)	--	--	--	--	4.2	3.9	3.6	4.8
% Sand	--	--	--	--	23	21	40	28
% Silt	--	--	--	--	55	60	42	48
% Clay	--	--	--	--	22	18	18	24

Table 3-3 Eighteenmile Creek AOC Sediment Data (August 2012) Compared with Sediment Screening Levels.

Analyte[a]	Sediment Screening Levels TEC	PEC	Other[b]	Source	Sample and Concentration 1BP1	1BP1 (R)	1BP2	1BP3
Polychlorinated Biphenyls (µg/kg)								
Aroclor 1248	60	676	--	MacDonald et al. (2000)	390	320	420	320
Sum of Aroclors (ND = 0)	60	676	--	MacDonald et al. (2000)	390	320	420	320
Sum of Aroclors (ND = 0.5)	60	676	--	MacDonald et al. (2000)	399	330	428	329
Sum of Congeners (ND = 0)	60	676	--	MacDonald et al. (2000)	157	131	176	138
Sum of Congeners (ND = 0.5)	60	676	--	MacDonald et al. (2000)	162	134	176	138
Pesticides (µg/kg)								
Alpha Endosulfan	--	--	0.9	NYSDEC 1999 for endosulfan, 3% OC	2 P	1.6 JP	1.8 P	1.8 P
Alpha Chlordane	3.2	17.6	--	MacDonald et al. (2000) for chlordane	1.5 Ui	1.6 Ui	1.2 Ui	0.34 JP
Beta-Endosulfan	--	--	0.9	NYSDEC 1999 for endosulfan, 3% OC	1.7 P	0.77 JP	1.2 Ui	0.21 U
Dieldrin	1.9	61.8	--	MacDonald et al. (2000)	5.5 P	5.5 P	5.3 P	5 P
Endosulfan Sulfate	--	--	0.9	NYSDEC 1999 for endosulfan, 3% OC	0.17 Ui	0.2 JP	0.14 U	0.27 JP
Endrin	2.2	207	--	MacDonald et al. (2000)	1.1 J	0.91 J	0.97 J	0.85 J
Endrin Aldehyde	2.2	207	--	MacDonald et al. (2000) for endrin	1.1 Ui	0.92 Ui	0.87 J	0.75 J
Gamma-Chlordane	3.2	17.6	--	MacDonald et al. (2000) for chlordane	4.9 P	3.3 P	3.9 P	2.8 P
Hexachlorobenzene	--	--	20	Persaud et al. 1993	0.7 J	0.38 JP	0.76 JP	0.45 JP
p,p'-DDD	4.9	28	--	MacDonald et al. (2000)	3	2.5	1.8	2.8
p,p'-DDE	3.2	31	--	MacDonald et al. (2000)	16	13	11	14
p,p'-DDT	4.2	63	--	MacDonald et al. (2000)	9.3	7.5	8	8

Notes:
[a] Detected chemicals only are listed.
[b] Screening level analogous to TEC.

Key:
-- (double dash) = not available or not applicable
AOC = Area of Concern
AVS = Acid volatile sulfide
B.C. = British Columbia, Canada
GC = gas chromatograph
HPLC = high-performance liquid chromatography
i = detection limit elevated due to chromatographic interference
J = estimated value
N = matrix spike not within control limits
na = Not applicable
ND = Non-detect
OC = Organic carbon
Ont. = Ontario, Canada
P = GC or HPLC confirmation criteria exceeded. Relative % difference > 40% between results
PAETA = Probable apparent effect threshold approach
PCB = Polychlorinated biphenyl
PEC = Probable effect concentration (MacDonald et al. 2000)
SEM = Simultaneously extracted metals
TEC = Threshold effect concentration (MacDonald et al. 2000)
U = not detected
USEPA = United States Environmental Protection Agency
Value = Exceeds TEC or other benchmark.
Value = Exceeds PEC. Adverse effect possible.

guidance regarding possible adverse impacts when the concentration of a chemical lies between the TEC and PEC. Chronic freshwater sediment screening levels from NYSDEC (1999) and low effect level (LEL) screening levels from Persaud et al. (1993) were used for chemicals for which TECs and PECs were not available. The NYSDEC chronic screening levels and LELs are analogous to the TECs; that is, sediment chemical concentrations less than these screening levels are presumed to pose no risk. The following points are noteworthy regarding the August 2012 sediment sample data (see Table 3-3):

- Sediment concentrations of nine metals (cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc) exceeded the TEC, LEL, or NYSDEC chronic screening level in all samples. Nickel and zinc concentrations exceeded their respective PECs in all or most samples;

- Aroclor 1248 was the only Aroclor detected, consistent with previously collected data for Eighteenmile Creek (E & E 2012b). All samples collected in August 2012 contained PCBs in excess of the TEC. No samples exceeded the PEC; and

- Five pesticides (alpha-endosulfan, beta-ebdosulfan, gamma-chlordane, dichlorodiphenyl-trichloroethane [DDT], and dichlorodiphenyldichloroethylene [DDE]) exceeded the TEC or NYSDEC chronic screening level. No pesticides exceeded the available PECs.

Sediment data for acid volatile sulfides (AVS) and simultaneously extracted metals (SEM) were collected to help understand the bioavailability of divalent metals (cadmium, copper, lead, mercury, nickel, and zinc) in Eighteenmile Creek sediments. In brief, the AVS and SEM data indicate that there was more than ample AVS available to bind the available divalent metals (i.e., the ratio or SEM to AVS in the samples was less than one in all samples [see Table 3-3]). This result suggests that divalent metals in Eighteenmile Creek sediment, although present at concentrations above screening levels, are not bioavailable and, therefore, unlikely to adversely affect benthic life.

3.3 Sediment Toxicity Testing

Sediment bioassays are an important tool for evaluating sediment quality because they provide a direct measure of sediment toxicity, or the lack thereof. As part of the present study, 10-day sediment bioassays with *Hyalella azteca* (amphipod) and *Chironomus dilutus* (midge) were conducted with sediment from the three pool habitat locations downstream from Burt Dam (see Figure 2-2 for sample locations). Sediment from a clean reference stream near Aquatec Biological Sciences, where the bioassays were conducted, was tested concurrently and used as a point of comparison with the Eighteenmile Creek samples. Table 3-4 summarizes the results. Appendix E contains a copy of the bioassay testing report from Aquatec. There was no significant difference in midge or amphipod survival and growth between the Eighteenmile Creek samples and control (see Table 3-4). These results suggest that metals, PCBs, and pesticides in sediment in pool habitats downstream from Burt Dam, although in excess of screening levels (see Table 3-3), do not adversely impact benthic life. This finding agrees with the AVS/SEM results, which indicate that divalent metals in sediment in pool habitats below the dam are not bioavailable (see Section 3.2).

Table 3-4 Summary of Eighteenmile Creek Sediment Bioassay Results[a]

E & E Sample Number	Laboratory Sample Number	Mean Percent (%) Surviving	Significantly Different than Control ($p < 0.05$)?	Mean Weight (mg) per Surviving Organism	Significantly Different than Control ($p < 0.05$)?
10-day *Chironomus dilutus* (Midge) Test Results					
Control[b]	43434	95	--	1.65	--
1BP1	43435	93	No	1.73	No
1BP2	43436	96	No	1.67	No
1BP3	43437	90	No	1.79	No
10-day *Hyalella azteca* (Amphipod) Test Results					
Control[b]	43434	88	--	0.095	--
1BP1	43435	95	No	0.104	No
1BP2	43436	94	No	0.105	No
1BP3	43437	91	No	0.121	No

Notes:
[a] See Appendix E for complete bioassay laboratory report.
[b] Natural sediment collected from reference stream near bioassay laboratory.

Key:
E & E = Ecology and Environment, Inc.
p = probability

4 Summary, Conclusions, and Implications for BUI Delisting

Table 4-1 summarizes the findings of the present investigation and their implication for delisting BUI No. 6 (Degradation of Benthos) at the Eighteenmile Creek AOC. The following points are noteworthy:

- The benthic macroinvertebrate community in riffle and run/glide habitats in the AOC is not impaired or slightly impaired according to NYSDEC (2009) indices. This finding satisfies the first delisting criterion for BUI No. 6 for the Eighteenmile Creek AOC (see Table 1-1) and, therefore, supports delisting of this BUI.

- The benthic macroinvertebrate community in pool habitats in the AOC is non-impaired according to NYSDEC (2009) indices. Also, sediment bioassay and bioavailability data for pool habitats show no toxicity and low bioavailability of contaminants. These findings satisfy the first and third delisting criteria for BUI No. 6 for the Eighteenmile Creek AOC (see Table 1-1) and, therefore, support delisting this BUI.

Based on the findings of the current study, we recommend the following:

- The NCSWCD and Eighteenmile Creek Remedial Advisory Committee (RAC) should consider moving forward with delisting (re-designating) BUI No. 6.

- Another round of benthic community monitoring should be implemented in 2017 as suggested in the *Eighteenmile Creek Area of Concern (AOC) Strategic Plan for Beneficial Use Impairment (BUI) Delisting* (E & E 2011). Future monitoring data will provide insight into how anticipated sediment remedial actions and other activities upstream from the AOC affect the benthic community therein.

Table 4-1 Weigh-of-Evidence Regarding Benthic Community Impairment and Implications for BUI #6 Delisting

		Weight-of-Evidence Variables					
Sample	Habitat Type	Sediment Contamination[a]	SEM/AVS[b]	Sediment Toxicity[c]	Benthic Community Impairment[d]	Conclusions and Remarks	Implications for BUI #6 Status
1BR1	Riffle	ns	ns	ns	-	Benthic community not impaired according to NYSDEC indices (see Section 3.1.1).	First delisting criterion in Table 1-1 is satisfied. BUI may be delisted.
1BR2	Run/Glide	ns	ns	ns	+	Benthic community slightly impaired according to NYSDEC indices (see Section 3.1.1)	First delisting criterion in Table 1-1 is satisfied. BUI may be delisted.
1BP1	Pool	+	-	-	-	Benthic community non-impaired according to NYSDEC indices (see Section 3.1.2) and no sediment toxicity observed (see Section 3.3).	First and third delisting criteria in Table 1-1 are satisfied. BUI may be delisted.
1BP2	Pool	+	-	-	-	Same as above.	Same as above.
1BP3	Pool	+	-	-	-	Same as above.	Same as above.

Notes:

[a] Sediment Contamination:
+ = contaminant concentration > screening level
- = contaminant concentration < screening level

[b] SEM/AVS Ratio
+ = ratio > 1 (divalent metals are bioavailable)
- = ratio < 1 (divalent metals are not bioavailable)

[c] Sediment Toxicity
+ = measurable difference between site and control for survival or growth
- = no significant difference between site and control for survival or growth

[d] Benthic Community Impairment
- = no impairment according to NYSDEC indices
+ = slight impairment according to NYSDEC indices
++ = moderate impairment according to NYSDEC indices
+++ = severe impairment according to NYSDEC indices

Key:

AOC = area of concern
AVS = acid volatile sulfide
BUI = beneficial use impairment
ns = not sampled (no sediment deposition occurs at these locations)
NYSDEC = New York State Department of Environmental Conservation
SEM = simultaneously extracted metals

5 References

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A

Final Quality Assurance Project Plan

Provided on CD.

B Field Data Sheets

Provided on CD.

C Electronic Data Deliverable

Provided on CD.

D

Chemistry Lab Report

Provided on CD.

E

Toxicity Test Report

Provided on CD.

F

REIC Benthic Report

Provided on CD.

G Data Usability Summary Report

Provided on CD.

Appendix 1.B

Assessing the status of sediment toxicity and macroinvertebrate communities in the Eighteenmile Creek Area of Concern, New York

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Prepared by Scott George, Brian Duffy and Barry Baldigo

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Assessing the status of sediment toxicity and macroinvertebrate communities in the Eighteenmile Creek Area of Concern, New York

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ABSTRACT

In 1972, the governments of Canada and the United States committed to restoring the physical, chemical, and biological integrity of the Laurentian Great Lakes under the Great Lakes Water Quality Agreement. Through this framework, the downstream-most section of Eighteenmile Creek, a tributary to the south shore of Lake Ontario in New York, was designated as an Area of Concern (AOC) because water quality and bed sediments were contaminated by past industrial and municipal discharges, waste disposal, and pesticide usage. Five beneficial use impairments (BUIs) have been identified in the AOC including the degradation of the "benthos", or the benthic macroinvertebrate community. This investigation used sediment toxicity testing and macroinvertebrate community assessments to determine if the toxicity of bed sediments in the AOC differed from that of an unimpacted reference stream. Results from 10-day toxicity tests indicated that survival and growth of the dipteran *Chironomus dilutus* and the amphipod *Hyalella azteca* did not differ significantly between sediments from the AOC and reference area. Analyses of benthic macroinvertebrate community integrity and structure also indicated that macroinvertebrate communities, while impacted across most sites on both streams, were generally similar between the AOC and reference area. Despite these findings, the upstream-most AOC site consistently scored poorly in all analyses, which suggests that localized sediment toxicity may exist in the AOC, even if large scale differences between the AOC and a comparable reference stream are minimal.

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Introduction

In 1972, the governments of Canada and the United States committed to restoring the physical, chemical, and biological integrity of the Laurentian Great Lakes under the Great Lakes Water Quality Agreement (GLWQA). The purpose of this agreement, its successor agreement in 1978, and subsequent amendments, was to provide a framework for binational cooperation to restore, protect, and enhance the water quality of the Great Lakes in order to promote the ecological health of the Great Lakes basin (GLWQA, 2012). Through this framework, 43 Areas of Concern (AOCs) were subsequently identified in the Great Lakes basin. Areas of Concern are defined as geographic areas impacted by environmental degradation resulting from human activities at the local level, and exhibit impairment to one or more of 14 possible beneficial uses relating to chemical, physical, or biological integrity. For each AOC, a Remedial Action Plan is developed by a local remedial action committee to guide restoration efforts and the evaluation of recovery. Beneficial use impairments (BUIs) are then reevaluated over time, or following remedial efforts, to determine if they are still applicable to an AOC or if the BUIs may be removed and the entire AOC delisted.

Eighteenmile Creek, located in Niagara County of New York State, was designated as an AOC in 1985 because water quality and bed sediments were contaminated by past industrial and municipal discharges, waste disposal, and pesticide usage (CH2MHILL et al., 2015; NCSWCD, 2011; NYSDOH, 2015). In 2012, the AOC and areas upstream of it were also added to the Superfund National Priorities List of the country's most hazardous waste sites (USEPA, 2012b). Five BUIs have been identified in the Eighteenmile Creek AOC, including the degradation of the "benthos", or the benthic macroinvertebrate community. Assessments conducted by the U.S. Army Corps of Engineers and the New York State Department of Environmental Conservation (NYSDEC) between 1977 and 1994, which indicated that macroinvertebrate communities were adversely affected by contaminated surficial sediments, provided the rationale for this BUI (NCSWCD, 2011). The current status of the benthos BUI needs to be updated, however, because new inputs of contaminants have been largely eliminated (NCSWCD, 2011) and data from one recent investigation suggests that macroinvertebrate communities in the Eighteenmile Creek AOC may no longer be impaired (E&E, 2013).

The U.S. Geological Survey (USGS) and NYSDEC initiated the current study during 2014 to gather more extensive information on the toxicity

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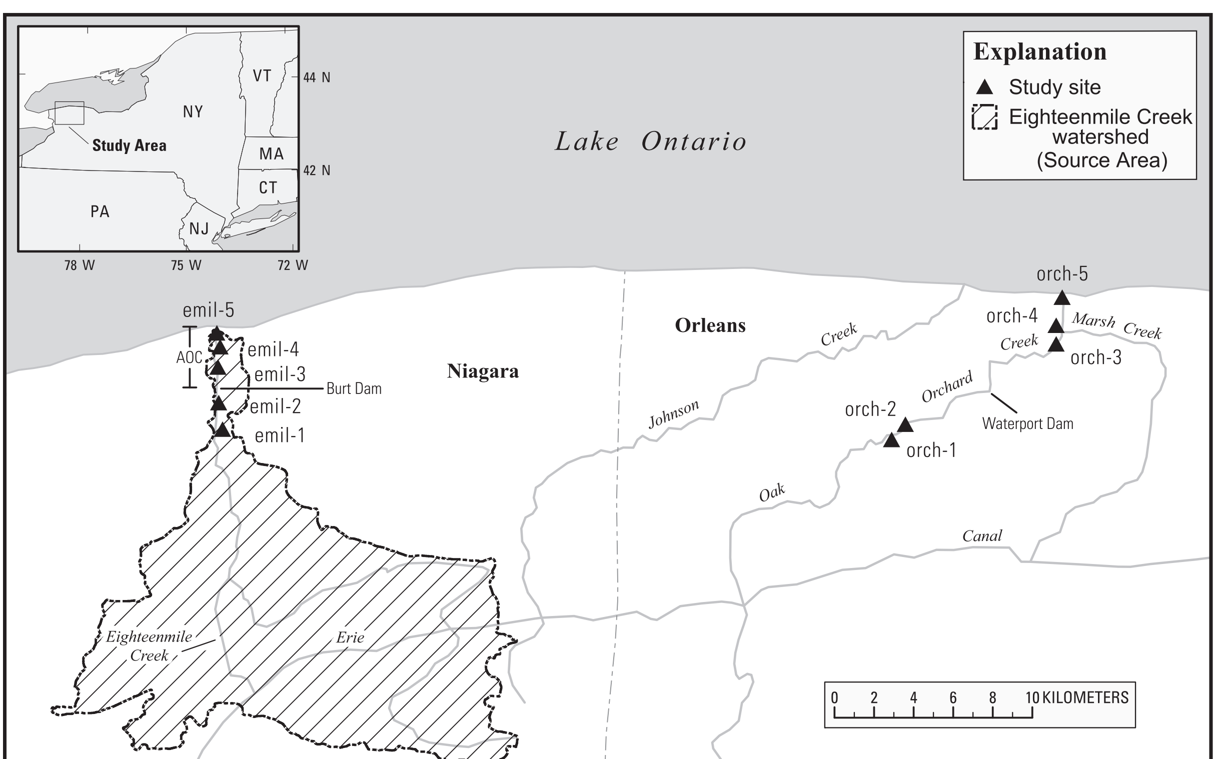
of sediments and condition of benthic macroinvertebrate communities needed to evaluate the benthos BUI in the Eighteenmile Creek AOC. The general delisting guidelines from the International Joint Commission (IJC), an independent binational organization charged with implementing the GLWQA, state that the benthos BUI may be removed from an AOC when benthic macroinvertebrate community structure or sediment toxicity do not differ from comparable unimpacted reference sites (IJC, 1991). Additionally, the Remedial Action Plan for the Eighteenmile Creek AOC provides specific criteria for removing the benthos BUI, most notably that benthic macroinvertebrate communities be classified as non-impacted or slightly impacted according to NYSDEC macroinvertebrate indices (NCSWCD, 2011). The primary objective of this study was to determine if the benthos BUI is still warranted in the Eighteenmile Creek AOC as defined by both the IJC guidelines and the Remedial Action Plan criteria. This was achieved by comparing the results of (a) laboratory sediment toxicity tests (survival and growth of two benthic macroinvertebrate species) and (b) benthic macroinvertebrate community assessments, at sites located within the AOC to reference sites located outside the AOC. This approach of assessing difference from comparable reference conditions is suggested by Grapentine (2009) and has been used in several other BUI assessments conducted in New York (Baldigo et al., 2012; Baldigo et al., 2016; Duffy et al., 2016) because it helps control for confounding regional stressors such as eutrophication and sedimentation. It is also consistent with a guidance document provided by the NYSDEC which describes the goal of the AOC remedial process in New York State as ensuring that conditions in an AOC are no worse than those in the surrounding area (NYSDEC, 2010).

Methods

Study area

The main branch of Eighteenmile Creek is approximately 24 km long and flows north from its headwaters near Lockport to its mouth at Lake Ontario in Olcott, N.Y. The AOC is defined as the downstream-most section, specifically the 3.5-km reach between a hydroelectric dam (Burt Dam) and Lake Ontario (Fig. 1). Additionally, the entire Eighteenmile Creek watershed has been designated as the source area of the contaminants that degraded the quality of sediments in the AOC because most point sources of sediment contamination were located upstream of the AOC (CH2MHILL et al., 2015; E&E, 2007; Makarewicz and Lewis, 2010; NCSWCD, 2011). Polychlorinated biphenyls (PCBs), chlorinated pesticides, and a number of heavy metals have been found in bed sediments at concentrations well above NYSDEC standards both inside and upstream of the AOC (CH2MHILL et al., 2015; NCSWCD, 2011; NYSDOH, 2015; Pickard, 2006; Stackelberg and Gustavson, 2012), and these contaminants are believed to be the primary cause of impairment to the macroinvertebrate community. Within the AOC, the highest concentrations of most toxic substances were found in the upstream-most 2 km closest to Burt Dam, but surficial sediments throughout the AOC contain contaminant levels of toxicological concern (Pickard, 2006).

Stream habitats within the Eighteenmile Creek AOC range from approximately 30–90 m in width and 0.5–3.5 m in depth (E&E, 2003), and the annual mean discharge below Burt Dam was 5.3 m^3/s in 2014 (USGS, 2014). Sediment samples were collected from five sites on Eighteenmile Creek; three of which were located within the AOC and two of which were located in the impounded section of the source area upstream of Burt Dam (Table 1, Fig. 1). Additionally, sediment samples were collected from five reference sites on Oak Orchard Creek, a comparable stream that enters Lake Ontario approximately 43 km east of Eighteenmile Creek. Oak Orchard Creek is of similar size and surrounding geography, also has a hydroelectric dam (Waterport Dam), and has been used as a reference stream for the assessment of other BUIs in the Eighteenmile Creek AOC because it is not known to have contaminated bed sediments (E&E, 2009). For example, the fish tumors BUI for the Eighteenmile Creek AOC, originally listed as unknown, was evaluated and determined to be not impaired using reference data from Oak Orchard Creek (E&E, 2009). Similar evaluations (which did not result in BUI removal) were conducted for the fish and wildlife



Base from *The National Map*, Universal Transverse Mercator projection, zone 18, WGS84, 1:1,000,000

Fig. 1. Map of the study area showing five study sites on Eighteenmile Creek and five reference sites on Oak Orchard Creek where bed sediments were sampled.

Table 1
Site information, locations (latitude and longitude - NAD83), and habitat characteristics for sediment samples collected August 27–28, 2014 for analysis of sediment toxicity and macroinvertebrate communities.

Stream name	Site ID	Site type	Latitude	Longitude	Grain size (phi units)	% TOC
Eighteenmile Creek	emil-1	Source area	43.29416	−78.71191	5.91	4.82
Eighteenmile Creek	emil-2	Source area	43.30613	−78.71502	6.81	3.67
Eighteenmile Creek	emil-3	AOC	43.32229	−78.71644	4.24	2.63
Eighteenmile Creek	emil-4	AOC	43.33157	−78.71570	4.73	2.43
Eighteenmile Creek	emil-5	AOC	43.33779	−78.71810	5.39	3.40
Oak Orchard Creek	orch-1	Upstream reference	43.30223	−78.29538	4.55	1.99
Oak Orchard Creek	orch-2	Upstream reference	43.30942	−78.28720	6.45	3.30
Oak Orchard Creek	orch-3	Downstream reference	43.34861	−78.19528	4.43	0.78
Oak Orchard Creek	orch-4	Downstream reference	43.35707	−78.19573	4.57	1.90
Oak Orchard Creek	orch-5	Downstream reference	43.36994	−78.19263	5.42	2.41

populations BUI and the bird or mammal deformities or reproductive impairment BUI (E&E, 2009). Three sites on Oak Orchard Creek were located downstream of the Waterport Dam and two sites were located upstream of it to account for potential confounding effects of Burt Dam on macroinvertebrate communities in the Eighteenmile Creek AOC (Table 1, Fig. 1). Hereafter, the four site types will be referred to as source area (emil-1 and emil-2), AOC (emil-3, emil-4, and emil-5), upstream reference (orch-1 and orch-2), and downstream reference (orch-3, orch-4, and orch-5).

Sample collection and processing

Bed-sediment grab samples were collected from depositional areas at each site using a petite Ponar (0.03 m^2) dredge on August 27–28, 2014 for use in sediment toxicity tests, macroinvertebrate community assessment, and assessment of habitat comparability. For sediment toxicity tests, five grabs were collected from each site, composited and mixed in a bucket, and a 4-L subsample was stored in a polyethylene container. Samples were kept on ice and shipped to Great Lakes Environmental Center, Inc., Traverse City, MI, where testing was initiated within five weeks of sample collection. For habitat comparability, 0.24-L and 0.12-L subsamples were collected from the unused composite for measurement of grain-size distribution and total organic carbon (TOC), respectively, and shipped to ALS Environmental, Rochester, NY. For macroinvertebrate identification, five replicate samples were collected from each site. Each replicate was composed of the detritus from four composited grabs that were sieved through a 500 μm mesh screen bottom bucket, placed in a 1-L container, preserved with 95% ethanol, and shipped to Watershed Assessment Associates, Schenectady, NY.

Samples for sediment toxicity tests were used to quantify acute and chronic toxicity to the dipteran, *Chironomus dilutus* (10–11 days old at test initiation), and the amphipod, *Hyalella azteca* (9–10 days old at test initiation), during 10-day survival and growth bioassays following USEPA test methods 100.2 and 100.1, respectively (USEPA, 2000). *Chironomus dilutus* and *H. azteca* are used as indicator species because they each inhabit broad geographic ranges, burrow in sediments, and have known sensitivities to common nutrients and toxins (ASTM, 2010; USEPA, 2000; USEPA and USACE, 1998). In short, bioassays for each species were initiated using 8 laboratory replicates (100 mL sediment and 175 mL overlying water) from each sample into which 10 test organisms were added. At the conclusion of the 10-day exposure, the percentage of surviving organisms (hereafter "survival") and the average ash-free dry weight of the surviving organisms (hereafter "growth") were assessed for each replicate. The quality of the data generated by the toxicity tests was assured by (a) testing two laboratory control samples (control 1: clean sediment and overlying water; control 2: water only) and (b) daily monitoring of temperature and dissolved oxygen in overlying water to verify that test conditions and organism responses generally met test acceptability criteria (USEPA, 2000). Additionally, the precision of test endpoints was assessed using duplicate samples from two sites. USEPA test methods 100.2 and 100.1 (USEPA, 2000) provide a full summary of the test conditions and procedures used.

A 100-organism subsample, or an exhaustive pick when <100 organisms were present, was sorted from each macroinvertebrate community replicate using a gridded tray and identified to the lowest possible taxonomic resolution (usually genus or species). The NYSDEC multi-metric index of biological integrity for Ponar samples was then calculated to assess the condition of macroinvertebrate communities (Smith et al., 2014). The index calculates five component metrics: species richness, Hilsenhoff Biotic Index (Hilsenhoff, 1987), Dominant-3, Percent Model Affinity (Novak and Bode, 1992), and Shannon-Weiner diversity, and converts them to a standardized value on a scale from 0 to 10. The five component metrics are then averaged to produce a Biological Assessment Profile (BAP) score, a single value for which a four-tiered scale of water quality impact (severe: 0.0–2.5; moderate: 2.5–5.0; slight: 5.0–7.5; or non-impacted: 7.5–10.0) has been established (Smith et al., 2014). Impact tiers of moderate and severe are indicative of impaired conditions.

Grain size was characterized using the ASTM D422–63 method (ASTM, 2007) for determining the distribution of particle sizes. The mid-point of each particle-size class was converted to phi units (Cummins, 1962), weighted by percent contribution to the total, and summed for each sample to obtain a simplified grain-size distribution for comparing physical habitat differences between sites. TOC was measured using the Lloyd Kahn Method (Kahn, 1998) to determine if the productivity of sediments, as well as the potential for sediments to accumulate contaminants and make them biologically available, was similar between sites. Although sediment toxicity tests using *C. dilutus* and *H. azteca* may not be strongly affected by small differences in grain size and TOC (USEPA, 2000), a number of field studies have shown these variables can influence the structure of macroinvertebrate community assemblages (Breneman et al., 2000; Reinhold-Dudok and den Besten, 1999).

Statistical analysis

An exploratory analysis of the response variables (survival and growth of *C. dilutus*, survival and growth of *H. azteca*, and BAP score) was conducted using a linear mixed model in Minitab v17. The use of a linear mixed model provides a robust statistical framework in which the effects of one factor can be tested while controlling for the effects of others, and also allows for a hierarchical nesting structure that includes the individual replicates from each sample. The primary objective of this analysis was to determine if the three sites within the Eighteenmile Creek AOC differed from the three downstream reference sites on Oak Orchard Creek while accounting for natural differences between the two creeks and the sites selected on each creek. The model was constructed using three factors with the following nesting structure: stream, type (nested within stream), and site (nested within type). Stream and type were treated as fixed factors while site was treated as a random factor in order to formulate broader conclusions about differences between site types rather than just the specific sites within each site type (Bolker et al., 2009). Histograms of the residuals and scatterplots of the fitted values versus the residuals were evaluated for each response variable to ensure there were no gross violations of normality or homoscedasticity. The results of all statistical analyses were considered significant at $\alpha = 0.05$ ($P \leq 0.05$).

Additionally, noninferiority testing using one-sided, one-sample equivalence tests was used to compare response variables at each of the three AOC sites to the mean value from the three downstream reference sites using Minitab v17. Noninferiority was established only if the entire 95% confidence interval around the difference between the test mean (average of the replicates of that site) and reference mean was greater than a lower limit of -0.2 multiplied by the reference mean (i.e. establish 95% confidence that the test mean was at least 80% of the reference mean). The use of 20% as a tolerance value is supported by numerous publications that have identified a 20% reduction in test sediments relative to control or reference sediments as a threshold for determining toxicity (Chapman and Anderson, 2005; Grapentine, 2009; USEPA, 2000, 2012a). Noninferiority testing improves the statistical inference of our analysis for two reasons. First, this approach enables a comparison of individual AOC sites to the mean reference condition, which was not possible using the linear mixed model while treating site as a random factor. Second, noninferiority testing puts the burden of proof on demonstrating equivalence, rather than difference (Mascha and Sessler, 2011; Walker and Nowacki, 2011). Such an approach is appropriate when the goal of management action is to restore the condition of an impacted area to that of the surrounding area and has recently been applied to the BUI-assessment framework (Rutter, 2010).

The structure of macroinvertebrate communities was also evaluated using multivariate techniques with PRIMER-E v7 software (Clarke and Gorley, 2015). The raw taxa counts from each replicate were $\log(x + 1)$ transformed and used to form a resemblance matrix of Bray-Curtis similarities. A one-way analysis of similarities (ANOSIM) test was used to assess differences in assemblages between the four site types (Clarke and Gorley, 2015; Clarke et al., 2014). Although the ANOSIM test produces a *P*-value, the value of the *R*-statistic is considered more important for assessing differences between groups (Clarke and Gorley, 2015). An *R* value of >0.75 indicates well separated groups, whereas an *R* value 0.5–0.75 indicates separate but abutting or slightly overlapping groups, and an *R* value of 0.25–0.5 indicates distinguishable but overlapping groups (K.R. Clarke, Plymouth Marine Laboratory, 2016, personal communication)(Ramette, 2007). Similarity percentages (SIMPER) analysis was then used to identify the taxa that contributed most strongly to observed differences between sites or site types. Additionally, a non-metric multidimensional scaling (nMDS) ordination plotting the Bray-Curtis similarities of combined (summing all replicates from each site) $\log(x + 1)$-transformed taxa counts was used to visually assess differences in macroinvertebrate community structure between sites and site types (Clarke and Gorley, 2015; Clarke et al., 2014).

Results and discussion

Sediment toxicity test quality assurance

The survival and growth of *C. dilutus* exceeded the minimum test acceptability criteria of 70% and 0.48 mg (USEPA, 2000), respectively, in both laboratory controls. Similarly, the survival and growth of *H. azteca* exceeded the minimum test acceptability criteria of 80% and exhibiting measurable growth, respectively, in both laboratory controls. The overlying water quality measurements were also within the acceptable limits for each test method with the exception of a few brief decreases in dissolved oxygen during *C. dilutus* tests, which are generally considered not to affect the quality of test data (USEPA, 2000). Toxicity test results from the two sets of duplicate sediment samples indicated that relative percent difference between duplicates was small and averaged 3.4% for survival of *C. dilutus*, 4.2% for growth of *C. dilutus*, 2.1% for survival of *H. azteca*, and 8.1% for growth of *H. azteca*. Overall, these quality assurance data indicate that test acceptability criteria were met, and therefore the test results can be considered valid assessments of sediment toxicity.

Sediment toxicity test results

The data for each endpoint of the sediment toxicity tests are summarized as mean values herein and are reported as the individual laboratory replicates in George et al. (2016). Survival of *C. dilutus* ranged from 76% at emil-3 to 98% at control-1 and differed significantly by site, but not by type or stream (Fig. 2). Noninferiority (relative to the mean value of the three downstream reference sites) was established for sites emil-4 and emil-5 but not for emil-3. Growth of *C. dilutus* ranged from 0.77 mg at orch-3 to 1.19 mg at emil-5 and differed significantly by site, but not by type or stream. Noninferiority was established for all three AOC sites. Survival of *H. azteca* ranged from 83% at emil-1 to 99% at emil-4 and differed significantly by site but not by type or stream (Fig. 3). Noninferiority was established for all three AOC sites. Growth of *H. azteca* ranged from 0.11 mg at emil-3 to 0.20 mg at control-1 and differed significantly by site but not by type or stream. Noninferiority was established for sites emil-4 and emil-5 but not for emil-3.

The combined results of the sediment toxicity tests indicate that sediments within the AOC generally were not significantly more toxic to the survival and growth of *C. dilutus* and *H. azteca* than sediments from the downstream reference area or the other site types. The linear mixed model indicated that none of the toxicity endpoints differed significantly between the AOC and the downstream reference area, and noninferiority of two of the three AOC sites (emil-4 and emil-5) was established for each endpoint. However, the model identified site as a significant factor for all four endpoints, which indicates that sediment toxicity varied between individual sites. The survival and growth of both test species was at or near its lowest levels at emil-3, the upstream-most AOC site. It is possible that longer-duration sediment toxicity tests such as USEPA test methods 100.4 and 100.5 (USEPA, 2000) might have been more effective at identifying chronic growth effects at sites with marginally toxic sediments (Crane et al., 2005; Ingersoll et al., 2001). However, 10-day tests remain the standard for assessments of sediment toxicity (USEPA and USACE, 1998) and have been used extensively within the AOC framework (CH2MHILL, 2012; Crane et al., 2005; Hoke et al., 1993).

Macroinvertebrate community integrity and structure

The use of Oak Orchard Creek as a comparable reference stream and the validity of comparing macroinvertebrate community integrity and structure between sites were strengthened by the relatively similar grain-size distributions and TOC values. Phi units ranged from 4.24 at emil-3 to 6.81 at emil-2 and averaged 5.08 on Oak Orchard Creek and 5.42 on Eighteenmile Creek (Table 1). The percentage of TOC ranged from 0.78% at orch-3 to 4.82% at emil-1 and averaged 2.1% on Oak Orchard Creek and 3.4% on Eighteenmile Creek (Table 1). While these habitat data suggest that comparisons of macroinvertebrate communities are appropriate and valid, a low relative abundance of organisms in both streams complicated the assessment of macroinvertebrate community integrity. Despite compositing the sieved contents from four grabs into each replicate, the desired 100-organism subsample could not be achieved for many replicates even after an exhaustive sort of the detritus. Although the low relative abundance of organisms may itself be a reflection of sediment toxicity at some sites or broad (non-AOC) regional stressors, the BAP scores derived from small subsamples may underestimate the true condition of macroinvertebrate communities. Therefore, BAP scores are presented (a) as originally intended using

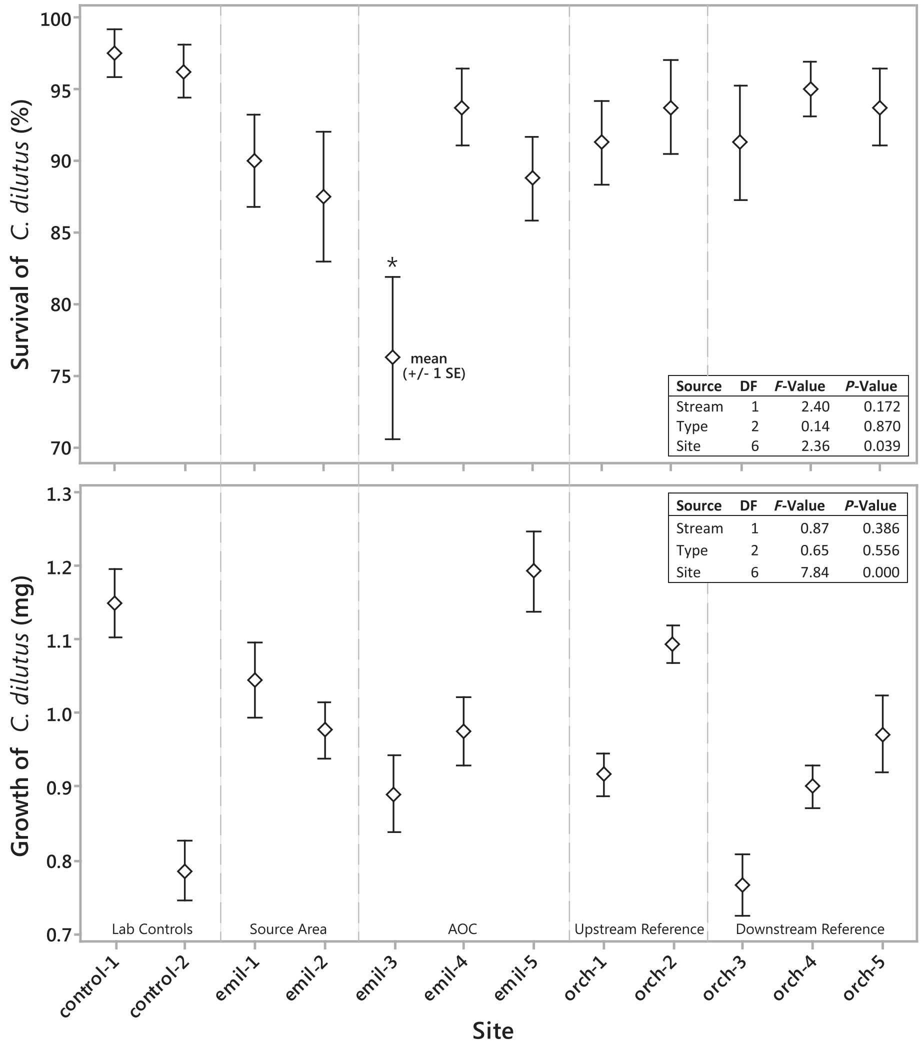


Fig. 2. Interval plots (mean ± one standard error, n = 8) showing the survival and growth of *C. dilutus* in 10-day sediment toxicity tests from ten study sites and two laboratory controls. Results of the linear mixed model show the significance of stream, type, and site on survival and growth of *C. dilutus*. Asterisk denotes an AOC site for which noninferiority could not be established with the mean downstream reference condition.

the means of the five replicates at each site (regardless of sample size) and (b) as an aggregated score (herein termed the aggregate BAP) in which the organisms from all five replicates from each site were combined, rarefied down to a random 100-organism subsample 30 times, and shown as the mean score of those 30 random subsamples. The former approach represents a consistent level of sampling effort, incorporates the density of organisms present, is appropriate for comparisons between sites, and follows standard NYSDEC protocols (Smith et al., 2014). The latter approach, by simulating the 100-organism target count, provides a community evaluation that may be more appropriate for evaluating the integrity of macroinvertebrate communities relative to the established NYSDEC impact classes and BUI removal criteria.

The integrity of macroinvertebrate communities, presented as the mean BAP score from the five replicates at each site, ranged from 2.1 at emil-3 to 5.9 at orch-2 (Table 2) and differed significantly by site but not by type or stream (Fig. 4). Similar to the results of the sediment toxicity tests, differences between sites were highly significant, and BAP score was lowest at emil-3. Noninferiority was established for site emil-5 but not for emil-3 and emil-4. For biological monitoring of surface waters in New York State, the BAP score is interpreted on a four-tiered scale of water quality impact ranging from severely impacted to non-impacted (Smith et al., 2014). The aggregate BAP scores ranged from 3.9 at emil-3 to 7.5 at emil-5, and emil-2 and emil-3 were classified as moderately impacted, emil-1, emil-4, orch-1, orch-2, orch-3, orch-4 and orch-5 were classified as slightly impacted, and emil-5 was classified as non-impacted (Fig. 4). Together, the results of the mean BAP scores and the aggregate BAP scores indicate that community integrity was poorest immediately upstream and downstream of Burt Dam and that macroinvertebrate communities across most sites on both streams showed some degree of departure from the expected unimpacted condition.

Multivariate analysis of the macroinvertebrate assemblages indicated that community structure differed between the four site types. The ANOSIM test indicated that type was a significant factor (Global $R = 0.430$, $P = 0.001$) and pairwise comparisons were significant between all site types (Fig. 5). However, the relatively small R-values indicate that differences between site types, while significant, were minimal and should be interpreted cautiously. It is noteworthy that the AOC sites on Eighteenmile Creek were actually more similar to the downstream reference sites on Oak Orchard Creek than to the source area sites on Eighteenmile Creek, which are located <2.5 km upstream of the AOC. The nMDS ordination showed that two of the AOC sites, emil-4 and emil-5, grouped closely with the three downstream reference sites, while emil-3 separated from these five sites (Fig. 5). The SIMPER analysis indicated that the most discriminating taxa between emil-3 and the three downstream reference sites were three chironomid genera, *Chironomus* sp., *Microchironomus* sp., and *Procladius* sp., and one oligochaete species, *Limnodrilus hoffmeisteri*, which

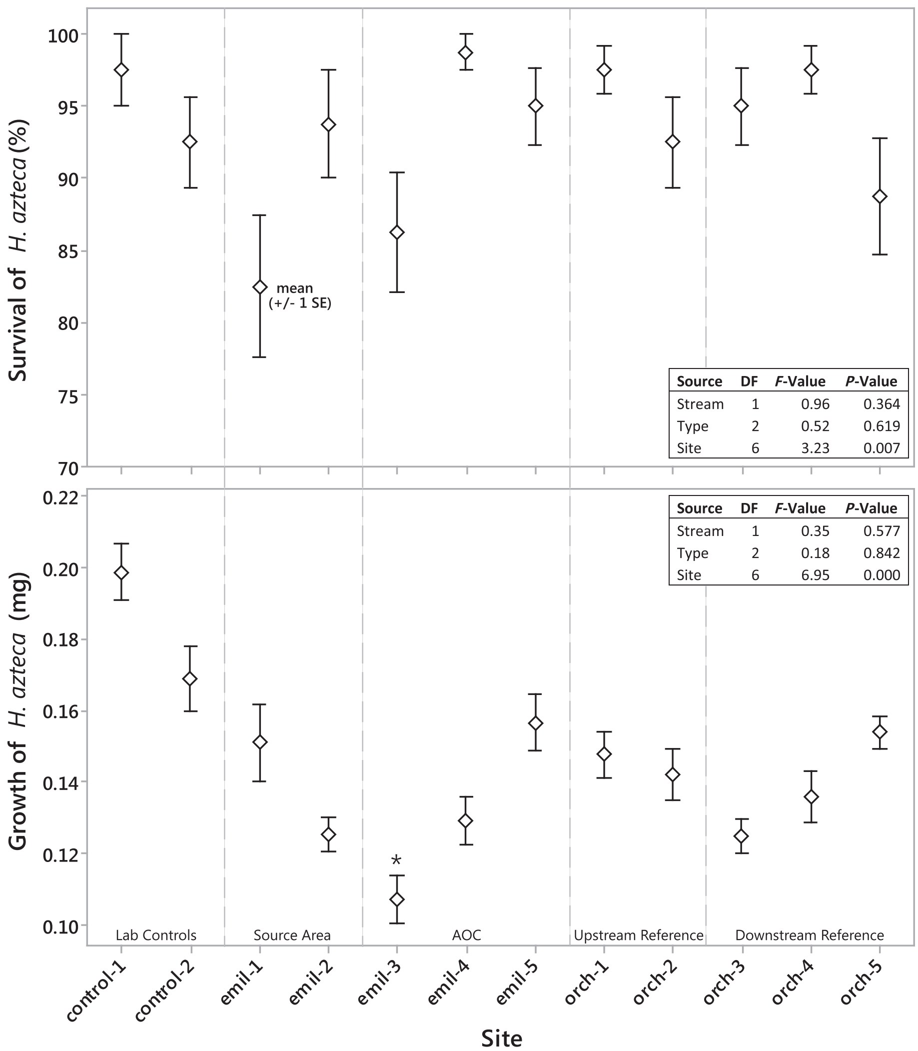


Fig. 3. Interval plots (mean ± one standard error, n = 8) showing the survival and growth of *H. azteca* in 10-day sediment toxicity tests from ten study sites and two laboratory controls. Results of the linear mixed model show the significance of stream, type, and site on survival and growth of *H. azteca*. Asterisk denotes an AOC site for which noninferiority could not be established with the mean downstream reference condition.

together contributed 30.8% of the overall dissimilarity. *Chironomus* sp. and *Microchironomus* sp. were completely absent from emil-3 while *L. hoffmeisteri* was present at emil-3 but in low abundances. In contrast, *Procladius* sp. had a greater mean abundance at emil-3 than at the downstream reference sites and was the most abundant taxon in four of the five replicates from emil-3. The genus *Procladius* is known to be extremely tolerant of environmental contamination (Warwick, 1989), and its dominance at emil-3 may be further evidence of sediment toxicity at this site.

Conclusions

The results of the sediment toxicity tests and analyses of macroinvertebrate community integrity and structure consistently supported

Table 2
Macroinvertebrate community information including the mean values for subsample size, component metrics of the Biological Assessment Profile (BAP) score, and the final (10-scaled) BAP score for the five replicates collected from each site. The aggregate BAP score presents the mean score of 30 random 100-organism subsamples from the combined replicates at each site.

Site ID	Subsample size (no. organisms)	Species richness	Hilsenhoff Biotic Index	Shannon-Weiner diversity	Percent model affinity	Dominant-3	BAP score	Aggregate BAP score
emil-1	65	11.0	8.6	2.7	60.5	68.4	4.9	5.2
emil-2	31	6.6	9.0	1.9	46.3	83.6	2.4	4.9
emil-3	15	5.4	8.6	1.8	24.6	82.0	2.1	3.9
emil-4	26	9.4	8.7	2.6	42.4	68.6	3.9	6.4
emil-5	19	10.6	8.0	3.1	42.3	51.7	5.4	7.5
orch-1	32	12.6	8.0	3.2	37.6	52.4	5.4	7.2
orch-2	81	15.2	8.4	3.2	48.6	55.3	5.9	6.6
orch-3	25	10.4	8.2	3.0	34.7	56.8	4.8	6.1
orch-4	40	11.4	8.5	3.0	36.2	56.3	4.8	7.1
orch-5	25	9.4	8.8	2.6	48.8	64.2	4.3	6.0

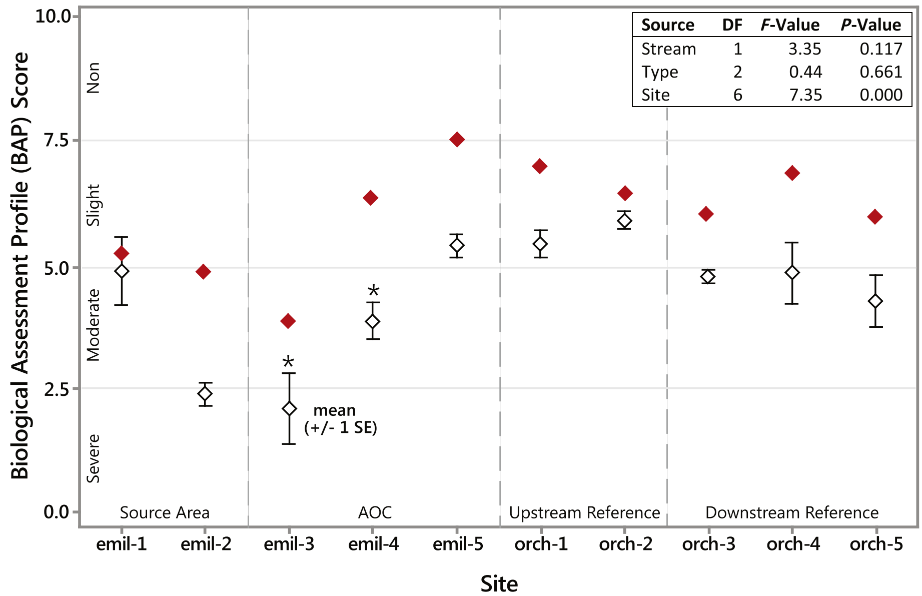


Fig. 4. Biological Assessment Profile (BAP) scores of macroinvertebrate community integrity from ten study sites shown as hollow diamonds for the mean values (±one standard error, n = 5) and as solid diamonds for the aggregate BAP values. Results of the linear mixed model show the significance of stream, type, and site on the BAP score. Asterisk denotes an AOC site for which noninferiority could not be established with the mean downstream reference condition.

two important conclusions. First, both analyses indicated that the overall quality of bed sediments in the AOC was not significantly worse than that of the downstream reference sites on Oak Orchard Creek. This finding was supported by the results of four endpoints from two toxicity tests and by a multi-metric index of macroinvertebrate community integrity. The only analysis to find a significant difference between AOC and downstream reference sites was a multivariate analysis of macroinvertebrate community structure using an ANOSIM test. This difference was relatively small and does not necessarily imply that conditions were worse in the AOC, only that communities were slightly different. Second, although our results indicated that the overall quality of sediments in the AOC was no worse than at a comparable reference stream, one site within the AOC, emil-3, consistently scored poorly in all analyses. Sediments from emil-3 had the lowest or among the lowest survival and growth of both test species in the toxicity tests, the lowest BAP scores of macroinvertebrate community integrity, the lowest density of organisms, and emil-3 was somewhat isolated in the nMDS ordination of macroinvertebrate community structure. Additionally, noninferiority could not be established at emil-3 for survival of *C. dilutus*, growth of *H. azteca*, and BAP score, relative to the respective mean values of the three downstream reference sites. These results suggest that sediment toxicity may be adversely affecting macroinvertebrate communities at emil-3 which is the upstream-most AOC site, located approximately 1.2 km downstream from Burt Dam. This is somewhat consistent with findings by Pickard (2006) indicating that the concentrations and bioavailability of most toxic substances were generally greater in the upper 2 km of the AOC. However, the nearest individual sampling point from that study, located approximately 40 m from emil-3, was not among the most contaminated of the 15 sites examined (Karn et al., 2004; Pickard, 2006). This may reflect the patchy nature of

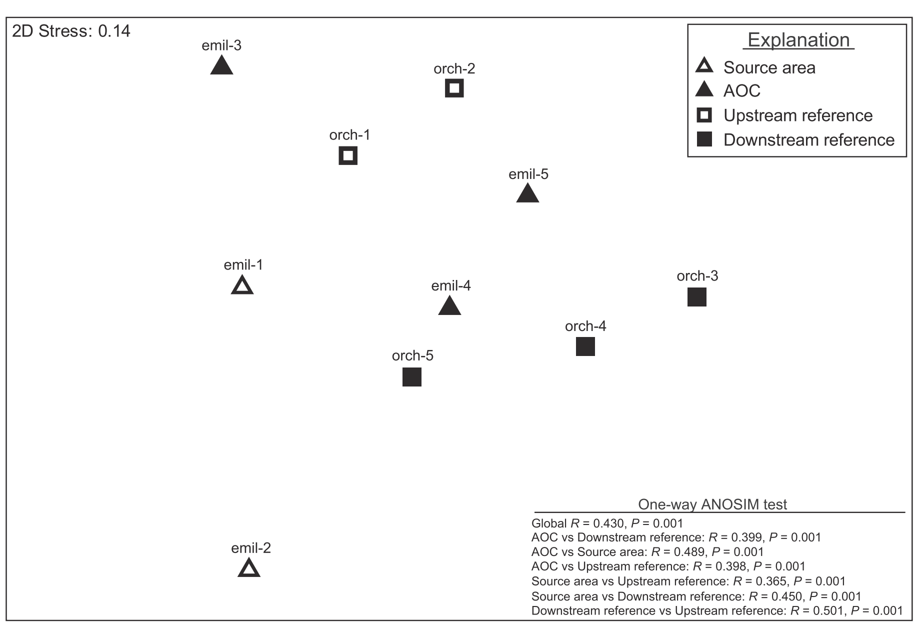


Fig. 5. Non-metric multidimensional scaling ordination and analysis of similarities (ANOSIM) results comparing macroinvertebrate community structure between site types. The ANOSIM test was run using each replicate from each site while the ordination shows the combined assemblage (sum of all replicates) from each site.

sediment contamination, particularly in lotic environments (Batley et al., 2002; Burton and Johnston, 2010; Crane and MacDonald, 2003), and underscores the importance of extensively evaluating sediments prior to remedial efforts (Batley et al., 2002). Together, the results from this study coupled with those of Pickard (2006) may identify emil-3 and the upper 2 km as a potentially impacted reach that could be targeted for more intensive sampling or future remedial efforts. Two recent studies, however, found that the concentrations of many toxic substances including PCBs and metals were at least 10–20 times higher in the source area upstream of Burt Dam (CH2MHILL et al., 2015; Stackelberg and Gustavson, 2012) than in the AOC. Given this, it is somewhat surprising that similar or more severe toxicity was not apparent in sediments from the source area at sites emil-1 and emil-2.

The results of the present study have important implications for assessing the current status of the benthos BUI in the Eighteenmile Creek AOC. The general delisting guidelines from the International Joint Commission state that the benthos BUI may be removed from an AOC when benthic community structure or sediment toxicity do not differ from comparable unimpacted reference sites (IJC, 1991; NCSWCD, 2011). These or similarly structured criteria that assess difference from comparable reference conditions (Grapentine, 2009) have been used effectively to evaluate, or justify removal of, BUIs in other AOCs, including the degradation of benthos and plankton BUIs in the St. Lawrence River at Massena (Baldigo et al., 2012; Duffy et al., 2016) and Rochester Embayment (Baldigo et al., 2016) AOCs, and the fish tumors BUI in the Presque Isle Bay AOC (Rutter, 2010). The absence of notable significant differences in sediment toxicity and macroinvertebrate communities between the Eighteenmile Creek AOC and the downstream reference area in Oak Orchard Creek suggests that the quality of bed sediments inside and outside the AOC are not dissimilar. Thus, if broadly applied, the IJC BUI-removal guideline might support the removal of the benthos BUI in this AOC. Such a recommendation, however, would be complicated by the apparent sediment toxicity observed at one AOC site, emil-3. The Remedial Action Plan for the Eighteenmile Creek AOC also provides specific removal criteria for the benthos BUI, most notably that benthic macroinvertebrate communities be classified as non-impacted or slightly impacted according to NYSDEC macroinvertebrate indices (NCSWCD, 2011). The aggregate BAP scores at the three AOC sites on Eighteenmile Creek indicated that emil-3 was moderately impacted, emil-4 was slightly impacted, and emil-5 was non-impacted, thus narrowly failing to meet the specific removal criteria. However, BAP scores from the reference sites on Oak Orchard Creek also showed some degree of impact which suggests that confounding regional factors such as eutrophication or sedimentation may also be contributing to lower BAP scores. Together, the combined results from the sediment toxicity tests and assessments of macroinvertebrate community integrity and structure suggest that AOC and reference conditions are not dissimilar but some localized effects of sediment toxicity may exist.

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Appendix 1.C

Comprehensive assessment of macroinvertebrate community condition and sediment toxicity in the Eighteenmile Creek Area of Concern, New York, 2021

August 2023

Prepared by Scott George, Barry Baldigo, Scott Collins, David Clarke and Brian Duffy

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Comprehensive assessment of macroinvertebrate community condition and sediment toxicity in the Eighteenmile Creek Area of Concern, New York, 2021

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ABSTRACT

The degradation of benthic communities (benthos) is one of four remaining beneficial use impairments (BUIs) in the Eighteenmile Creek Area of Concern (AOC), located on the south shore of Lake Ontario in New York. The historical rationale for listing this BUI as impaired relied heavily on inferred or expected impact to benthic communities based on elevated contaminant concentrations in bed sediments from past industrial and municipal discharges, hazardous-waste disposal, and pesticide usage. Previous assessments of macroinvertebrate community condition in the AOC have produced inconclusive results, and it remains unclear if contaminated sediments are impairing benthic communities. In 2021, a comprehensive assessment of macroinvertebrate community condition and sediment toxicity was conducted at eight sites in the AOC and six sites in a reference area on Oak Orchard Creek to determine if the removal criteria for this BUI have been met or if additional remedial measures are needed. The New York multi-metric index of biological integrity classified the mean community condition across AOC sites as slightly impacted, and 10-day toxicity tests with *Chironomus dilutus* and *Hyalella azteca* found no evidence of toxicity in AOC sediments. Equivalence testing indicated that community condition, and survival and growth of both test species, were not inferior in the AOC relative to the reference area. The weight of evidence from this study and other relevant datasets indicate that sediment contamination is not causing measurable impairment to benthic communities in the Eighteenmile Creek AOC.

1. Introduction

Eighteenmile Creek, a tributary to Lake Ontario in Niagara County of New York State, was designated as an Area of Concern (AOC) in 1985 under the Great Lakes Water Quality Agreement between the United States and Canada. Areas of Concern are defined as geographic areas impacted by environmental degradation resulting from human activities at the local level and have one or more of 14 possible beneficial use impairments (BUIs) relating to chemical, physical, or biological integrity. Eighteenmile Creek received this designation because water quality and bed sediments were contaminated by past industrial and municipal discharges, hazardous-waste disposal, and pesticide usage (CH2MHILL et al., 2015; NCSWCD, 2011; NYSDEC, 1997; NYSDOH, 2015). In 2012, the AOC and areas upstream of it were also added to the Superfund National Priorities List of the country's most hazardous waste sites (USEPA, 2012). Five beneficial use impairments were originally identified in the Eighteenmile Creek AOC, including BUI #6, "degradation of benthos" (NCSWCD, 2011).

The degradation of benthos BUI exists for an AOC when "*benthic macroinvertebrate community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics*" or "*toxicity…of sediment associated contaminants at a site is significantly higher than controls*" (IJC, 1991). The status of this BUI was listed as impaired in the Eighteenmile Creek AOC as a result of assessments conducted between 1977 and 1994, which suggested macroinvertebrate communities were adversely affected by contaminated surficial sediments (NYSDEC, 1997; NCSWCD, 2011). These assessments, however, relied heavily on inferred or expected impact to benthic communities based on elevated contaminant concentrations in bed sediments. The limited direct sampling of benthic communities indicated moderate or slight impairment based on community indices, and sediment toxicity tests only suggested evidence of toxicity in one end point for one test species (Abele et al.,

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1998; NYSDEC, 1997). More recent assessments of benthic community condition have also produced inconclusive or inconsistent results. A study conducted in 2012 at five sites in the AOC found that community condition ranged from moderately impacted to slightly impacted, and sediment toxicity tests indicated no evidence of toxicity (E&E, 2013). This study did not include a comparison to a reference area, however, which is necessary to meet the most recent BUI removal criteria. A separate study conducted in 2014 that included three sites in the AOC found community condition ranged from severely impacted to non-impacted and possible evidence of sediment toxicity was observed at one site (George et al., 2017). This study included a comparison to a reference area on Oak Orchard Creek which indicated the condition of benthic communities and the toxicity of sediments were similar between the reference area and the AOC. In 2019, chronic sediment toxicity testing was conducted at three sites in the AOC, as well as upstream source areas and a reference area on Oak Orchard Creek as part of the Remedial Investigation for the Superfund Program. The test endpoints indicated little or no chronic toxicity associated with AOC sediments when compared to the reference site or control sediment samples, although sediments in the source areas of Eighteenmile Creek upstream of the AOC were toxic to test species (WSP, 2021, 2022). Together, the limited amount of community information, age of the data, and inconclusive nature of the findings from these studies has confounded efforts by the Remedial Advisory Committee for the Eighteenmile Creek AOC to determine the status of the benthos BUI. Thus, a more comprehensive investigation was planned to obtain a robust suite of data on the condition of benthic communities to conclusively determine if the removal criteria for the benthos BUI have been met.

The U.S. Geological Survey (USGS) and New York State Department of Environmental Conservation (NYSDEC) initiated the current study during 2021 to address this uncertainty and gather a comprehensive suite of information on the condition of benthic macroinvertebrate communities needed to fully evaluate the status of the Degradation of Benthos BUI in the Eighteenmile Creek AOC. Revised BUI removal criteria adopted in 2020 (NCSWCD, 2020; Pickard et al., 2020) by the Remedial Advisory Committee for the Eighteenmile Creek AOC state that this BUI can be removed when:

-Benthic macroinvertebrate communities are “non-impacted” or “slightly impacted” according to NYSDEC indices; OR

-Benthic macroinvertebrate community condition is similar to unimpacted control sites of comparable physical and chemical characteristics; AND

-Toxicity of sediment-associated contaminants is similar to unimpacted control sites of comparable physical and chemical characteristics

The primary objective of this investigation was to assess benthic community condition to determine if (a) the first removal criterion has been achieved, or (b) both the second *and* third removal criteria have been achieved. This effort involved sampling macroinvertebrate communities to characterize community condition and collecting bed sediments to assess toxicity at sites in the AOC as well as at reference sites located outside of the AOC where chemical contamination is at background levels. Data from nearby reference area(s) are crucial to BUI assessments because they provide a benchmark for gauging the status of any given BUI in the AOC relative to conditions across the region. Grapentine (2009) defined reference as “the conditions representative of the natural, background, or hypothetically expected state of a descriptor of benthic conditions in the absence of the stressor(s) of concern”. This approach of assessing difference from comparable reference conditions has been used successfully in numerous other BUI assessments across New York (Baldigo et al., 2012; Baldigo et al., 2016; Duffy et al., 2016; Duffy et al., 2017; George et al., 2022b) and elsewhere (Scudder Eikenberry et al., 2019; Stevack et al., 2020) because it helps control for confounding regional stressors such as eutrophication, hydrologic modification, and invasive species. It is also consistent with the International Joint Commission guidelines (IJC, 1991), and a NYSDEC guidance document (NYSDEC, 2010), which describes the goal of the AOC remedial process in New York as ensuring that conditions in an AOC are no worse than those in the surrounding area.

2. Methods

2.1. Study area

Predominant land use in the Eighteenmile Creek watershed consists of agriculture, forest, and developed land, and the vast majority of high-intensity land use takes place near the City of Lockport. The main branch of Eighteenmile Creek is approximately 24 km long and flows north from its headwaters near Lockport to its mouth at Lake Ontario in Olcott, New York. The AOC is defined as the downstream-most section, specifically the 3.5-km reach between a hydroelectric dam (Burt Dam) and Lake Ontario (Fig. 1). Stream habitats in the AOC range from approximately 30–90 m in width and 0.5–3.5 m in depth (E&E, 2003) and the annual mean discharge below Burt Dam averaged 3.95 m^3/s between 2012 and 2021 (U.S. Geological Survey, 2022).

The entire Eighteenmile Creek watershed has been designated as the source area of the contaminants that degraded the quality of sediments in the AOC because most point sources of sediment contamination were located upstream of the AOC (CH2MHILL et al., 2015; NCSWCD, 2011). As a result, chemical contamination of the sediment in Eighteenmile Creek generally increases in concentration moving from downstream (AOC) to upstream (source) areas. Polychlorinated biphenyls (PCBs), chlorinated pesticides, and heavy metals have been found in bed sediments at concentrations well above NYSDEC standards both within and upstream of the AOC (CH2MHILL et al., 2015; NCSWCD, 2011; NYSDOH, 2015; Pickard, 2006; Stackelberg and Gustavson, 2012). PCB and lead concentrations follow a similar spatial distribution in creek sediments, increasing from downstream to upstream, but a greater percentage of lead samples (85% and 35%, respectively) exceed the NYSDEC Class C screening criteria (NYSDEC, 2014), indicating these sediments are likely to pose a risk to aquatic life. Additionally, a paired evaluation of metal concentrations and toxicity suggest that metals in sediment may be a causative agent of toxicity to benthic invertebrates in the upper reaches of Eighteenmile Creek (WSP, 2022). In 2017, the U.S. Environmental Protection Agency (USEPA) issued a Record of Decision to remove contaminated sediments within Operable Unit Two (USEPA, 2017), an approximately 1.6 km section of the source area (upstream of the AOC). The USEPA subsequently completed the Remedial Investigation of the remaining sections of the creek (WSP, 2022), including the AOC, but sediment remediation had not yet occurred in any Eighteenmile Creek operable unit at the time this study was conducted.

Sediment samples were collected from eight sites in the Eighteenmile Creek AOC and at six sites in a reference area on Oak Orchard Creek, a comparable stream that enters Lake Ontario approximately 43 km to the east (Fig. 1, Table 1). Oak Orchard Creek is similar in surrounding geography to Eighteenmile Creek and also has a hydroelectric dam (Waterport Dam) near its mouth but is not known to have extensive point source legacy chemical contamination (WSP, 2022; E&E, 2009). The downstream reaches of Eighteenmile Creek and Oak Orchard Creek are both drowned river mouth habitat subject to backwater from Lake Ontario and are characterized by cattail beds and little riparian development. The reach of Oak Orchard Creek downstream of Waterport Dam is well established as a reference location for assessments in the Eighteenmile Creek AOC and has been included in prior assessments of the fish tumors and other deformities, fish and wildlife populations, bird or animal deformities or reproductive problems, and benthos BUIs (E&E, 2009; George et al., 2022a; George et al., 2017). This reach has also been selected by the USEPA as a suitable reference area for assessments of Eighteenmile Creek Superfund Operable Unit 3 (E&E, 2017, E&E, 2019). A more detailed comparison of the habitat and watershed characteristics of both streams is available in Table 1 of George et al. (2022a). Of the eight sites in the AOC, five were randomly selected from a gridded map using a random number generator and the remaining three repeated the

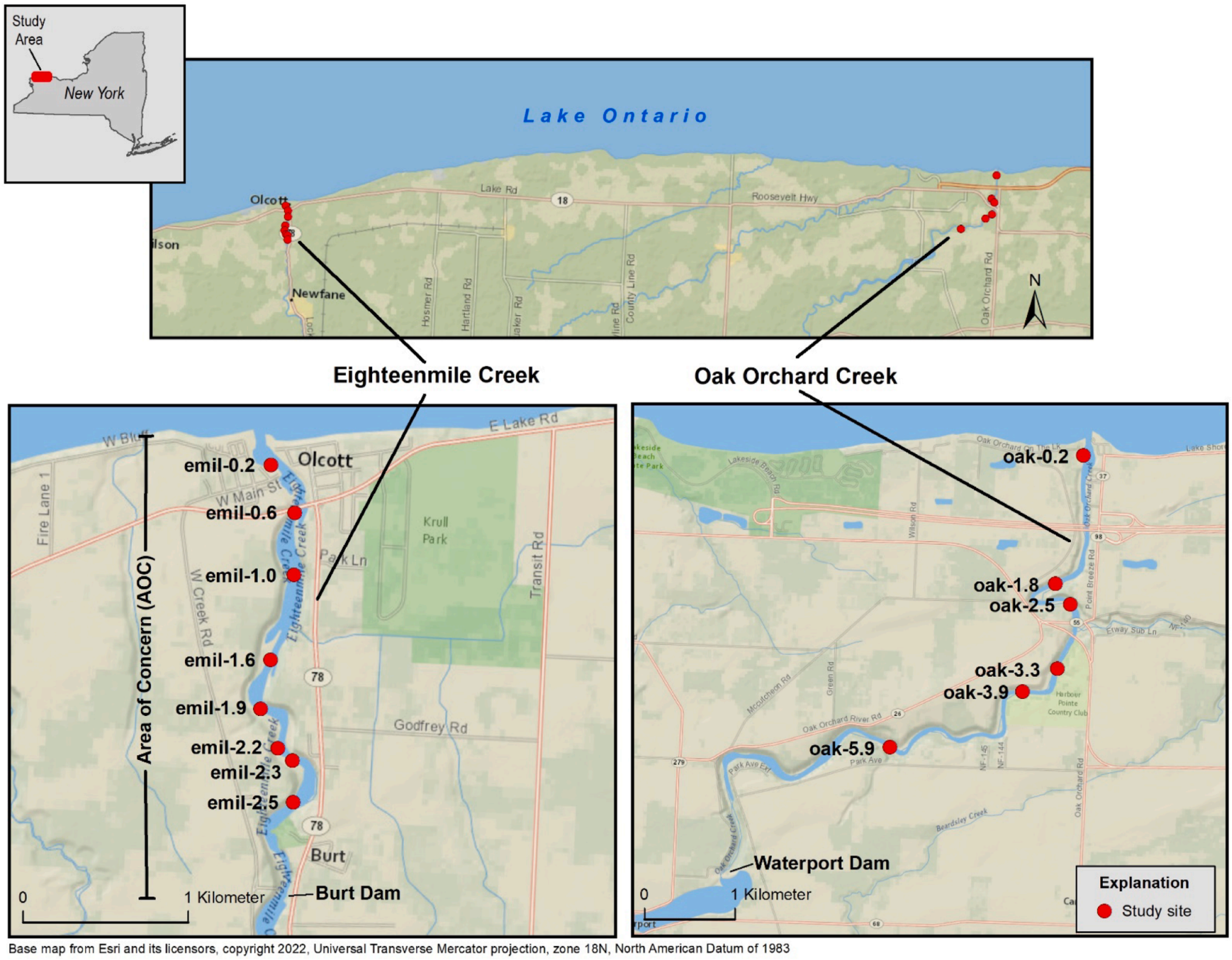

Fig. 1. Map of the study area showing eight sites in the Eighteenmile Creek AOC and six reference sites on Oak Orchard Creek where bed sediments were sampled in 2021.

Table 1
Site information and habitat measurements for eight sites in the Eighteenmile Creek AOC and six sites in the Oak Orchard Creek reference area where sediment samples were collected between August 3–5, 2021. Site IDs are an alphanumeric code that include an approximate measure of river kilometers upstream from Lake Ontario. Data from George and Baldigo (2022).

Water Body	Site ID	Type	Latitude	Longitude	Depth (m)	Temperature (°C)	Specific Conductance (μS/cm)	pH	Dissolved Oxygen (mg/L)	Fine Sediment (%)	Total Organic Carbon (%)
Eighteenmile Creek	emil-0.2	AOC	43.33755	−78.71780	2.2	22.0	757	8.40	8.51	73.0	2.3
Eighteenmile Creek	emil-0.6	AOC	43.33501	−78.71586	4.0	21.0	756	7.91	6.51	76.2	5.1
Eighteenmile Creek	emil-1.0	AOC	43.33162	−78.71571	3.5	20.9	756	8.02	5.90	75.5	6.0
Eighteenmile Creek	emil-1.6	AOC	43.32692	−78.71717	3.4	21.1	673	8.20	6.16	65.2	4.5
Eighteenmile Creek	emil-1.9	AOC	43.32423	−78.71775	1.9	22.1	703	8.74	5.52	31.2	2.7
Eighteenmile Creek	emil-2.2	AOC	43.32212	−78.71635	2.0	21.8	768	8.80	4.34	39.6	5.6
Eighteenmile Creek	emil-2.3	AOC	43.32148	−78.71521	2.0	23.0	768	9.06	7.98	42.5	8.8
Eighteenmile Creek	emil-2.5	AOC	43.31921	−78.71502	1.2	24.2	758	9.16	10.20	39.5	4.3
Oak Orchard Creek	oak-0.2	Reference	43.36998	−78.19265	1.9	23.0	648	8.00	6.30	60.0	4.4
Oak Orchard Creek	oak-1.8	Reference	43.35710	−78.19576	2.7	23.7	647	8.27	7.81	41.6	3.9
Oak Orchard Creek	oak-2.5	Reference	43.35510	−78.19363	1.8	23.6	647	8.16	7.43	38.0	3.5
Oak Orchard Creek	oak-3.3	Reference	43.34867	−78.19507	3.2	22.8	647	7.80	5.05	37.6	1.5
Oak Orchard Creek	oak-3.9	Reference	43.34625	−78.19968	3.8	23.3	660	7.89	5.60	60.3	3.5
Oak Orchard Creek	oak-5.9	Reference	43.34023	−78.21744	1.7	23.1	660	7.82	6.90	45.6	2.6

AOC sites sampled in the 2014 study (George et al., 2017). Similarly, of the six reference sites on Oak Orchard Creek, three were randomly selected and the other three repeated the reference sites sampled in 2014.

2.2. *Sample collection and processing*

Bed sediments were collected from depositional areas at each site using a petite Ponar (0.03 m^2) dredge on August 3–5, 2021 for use in macroinvertebrate community assessment, sediment toxicity tests, and assessment of habitat comparability. For macroinvertebrate identification, three replicate samples were collected from each site. A large quantity of sediment was processed for macroinvertebrate samples because past benthic community assessments of non-wadeable habitats in the AOC have struggled to reach the 100-organism target for calculating NYSDEC indices (E&E, 2013; George et al., 2017). Each replicate was composed of the detritus from eight composited grabs that were sieved through a 500 μm mesh screen bottom bucket. The volume of detritus retained by the sieve from the eight composited grabs typically ranged from 1 to 4 L. All detritus was retained for each replicate, preserved with 95% ethanol, and shipped to Watershed Assessment Associates (Schenectady, NY) for identification. For sediment toxicity tests, six grabs were collected from each site, composited and mixed in a bucket, and a 4-L subsample was stored in a polyethylene container. Samples were kept on ice and shipped to Great Lakes Environmental Center, Inc. (Traverse City, MI) where testing was initiated within five weeks of sample collection. For habitat characterization, sediment subsamples were collected from the unused toxicity composite and shipped to RTI Laboratories (Livonia, MI) for measurement of grain-size distribution and total organic carbon (TOC) concentration. Sediment contaminant concentrations (PCBs, metals, etc.) were not analyzed as part of this project because other recent studies had already provided an extensive assessment (WSP, 2022).

Macroinvertebrates were identified following NYSDEC Standard Operating Procedures (Duffy, 2021). A 100-organism subsample, or an exhaustive pick when < 100 organisms were present, was randomly sorted from each macroinvertebrate community replicate using a gridded tray and identified to the lowest practical taxonomic resolution (usually genus). The NYSDEC multi-metric index of biological integrity for Ponar samples was then calculated to assess the condition of macroinvertebrate communities (Duffy, 2021). The index calculates five component metrics: species richness, Hilsenhoff Biotic Index (Hilsenhoff, 1987), Dominant-3, Percent Model Affinity (Novak and Bode, 1992), and the Shannon Diversity Index, and converts them to a standardized value on a scale from 0 to 10. The five component metrics are then averaged to produce the Biological Assessment Profile (BAP) score, a single value for which a four-tiered scale of water quality impact (severe: 0.0–2.5; moderate: 2.5–5.0; slight: 5.0–7.5; or non-impacted: 7.5–10.0) has been established (Duffy, 2021). Impact categories of moderate and severe are considered indicative of impaired conditions (Duffy, 2021). The BAP score (and associated impact tiers) is used to assess water quality and ecosystem condition in surface waters across New York and has been used as the primary metric for assessing benthic condition in the six AOCs in the state (Baldigo et al., 2023; Duffy et al., 2016; Duffy et al., 2017; George et al., 2022b).

Samples for sediment toxicity tests were used to quantify acute and sublethal toxicity to the dipteran, *Chironomus dilutus*, and the amphipod, *Hyalella azteca*, during 10-day survival and growth bioassays following USEPA test methods 100.2 and 100.1, respectively (USEPA, 2000). *Chironomus dilutus* and *H. azteca* are used as indicator species because they each inhabit broad geographic ranges, burrow in sediments, and have known sensitivities to common nutrients and toxins (ASTM, 2010; USEPA and USACE, 1998b; USEPA, 2000). Porewater testing for ammonia (total ammonia as N) was conducted on all samples upon receipt at the testing facility to determine if mitigation was necessary to reduce ammonia concentrations below the 20 mg/L threshold for test initiation following standard procedures (USEPA and USACE, 1998a). Porewater ammonia concentrations in all samples were < 20 mg/L and no mitigation measures were taken. Bioassays for each species were initiated using 8 laboratory replicates (100 mL sediment and 175 mL overlying water) from each sample into which 10 test organisms were added. At the time of test initiation, *C. dilutus* were approximately nine days old with an average ash-free dry weight of 0.220 mg and *H. azteca* were 11–12 days old with an average dry weight of 0.022 mg. At the conclusion of the 10-day exposure, the percentage of surviving organisms (hereafter "survival") and the average weight (ash-free dry weight for *C. dilutus* and dry weight for *H. azteca*) of the surviving organisms (hereafter "growth") were assessed for each replicate (USEPA, 2000). The quality of the data generated by the toxicity tests was assured by: (a) testing two laboratory control samples (control 1: clean sediment and overlying water; control 2: water only) and (b) daily monitoring of temperature and dissolved oxygen in overlying water to verify that test conditions and organism responses met test acceptability criteria (USEPA, 2000). Additionally, a duplicate sample from one site was collected and analyzed to assess the precision of test endpoints.

2.3. Habitat characterization

A standard suite of habitat and water-quality parameters were measured at each site to evaluate habitat comparability between sites and potential influences on community composition and sediment toxicity tests. Water quality parameters including specific conductance, dissolved oxygen, pH, and temperature were measured at 1 m above the river bottom at the time of sample collection using a YSI Professional Plus Multiparameter Water Quality Meter following quality assurance and calibration procedures described in NYSDEC (2023b). Grain size was characterized using the ASTM D422–63 method (ASTM, 2007) for determining the distribution of particle sizes. The percentage of each sample that was composed of fine sediments (the silt and clay fractions), was calculated as percent by mass able to pass through a No. 200 (75 μm) sieve. Total organic carbon was measured using method 9060A (USEPA, 2004) and is reported here as a percentage of the total sample by dry weight. The raw data from macroinvertebrate identification, sediment toxicity tests, and grain-size and total organic carbon analyses are available in a USGS data release (George and Baldigo, 2022).

2.4. Statistical analysis

A preliminary inspection of the macroinvertebrate identification data indicated that 30 of the 42 community replicates (71%) did not reach the target subsample size of 100-organisms despite the large quantity of sediment processed. Thus, two different approaches were used to calculate BAP scores from this dataset. For the first approach, differences in subsample sizes were ignored and BAP scores were calculated for all replicates following standard procedures described in Duffy (2021) and are presented as the average of the scores from the three replicate samples. For the second approach, a technique described in George et al. (2017) was used in which the data from all three replicates were combined for each site and then rarefied (without replacement) to produce a random 100-count subsample. This procedure was repeated for 30 consecutive iterations and BAP scores were then calculated and are presented as the mean score of those 30 random subsamples for each site. The former approach represents a consistent level of sampling effort, accounts for the density of organisms present, and follows standard NYSDEC protocols (Duffy, 2021). The latter approach, by simulating the 100-organism target count, provides an assessment that may be more appropriate for evaluating the integrity of macroinvertebrate communities relative to the established NYSDEC impact categories and BUI removal criteria. Hereafter, the results of the first approach are referred to as 'standard BAP scores' and the results of the second approach are termed 'aggregate BAP scores'.

The standard BAP scores, aggregate BAP scores, and endpoints from the toxicity tests were compared between the AOC and reference areas using a noninferiority testing framework. This type of statistical approach reverses the typical hypothesis testing structure and puts the burden of proof on demonstrating equivalence, rather than difference (Lakens, 2017; Mascha and Sessler, 2011; Walker and Nowacki, 2011). Although the results of this approach can be more difficult to communicate to managers and stakeholders, this type of analysis is warranted in the AOC-framework where the goal of management action is to restore the condition of an impacted area to that of the surrounding area (Rutter, 2010). This type of hypothesis testing is particularly necessary for evaluating the specific removal criteria for the benthos BUI in the Eighteenmile Creek AOC which state that community condition and sediment toxicity should be "similar" to reference sites. One of the main challenges with this type of analysis is determining the degree of departure from the reference condition that is acceptable. There is little consensus regarding the effect size that monitoring programs should target for detecting change in aquatic assemblages (Janz et al., 2010). Consequently in this analysis, 25% was used because it has been recommended as appropriate for many ecological monitoring applications (Munkittrick et al., 2009). Noninferiority testing was performed using one-sided, two-sample equivalence tests (not assuming equal variance) using Minitab v17. Noninferiority was established only if the entire 95% confidence interval around the ratio of the test mean (AOC) to the reference mean (Oak Orchard Creek) was greater than a lower limit of 0.75 (i.e., establish 95% confidence that the test mean was at least 75% of the reference mean).

The structure of macroinvertebrate communities was also evaluated using multivariate techniques with PRIMER-E v7 software (Clarke and Gorley, 2015). Although such analyses do not produce output directly related to the BUI removal criteria, they provide a robust assessment of community composition and can identify key taxa or groups of taxa responsible for patterns in the dataset. The raw taxa counts from all three replicates were summed for each sample, square-root transformed, and used to form a resemblance matrix of Bray-Curtis similarities comparing all samples. A non-metric multidimensional scaling (nMDS) ordination was used to plot the Bray-Curtis similarities and visually assess differences in macroinvertebrate community structure between sites (Clarke and Gorley, 2015; Clarke et al., 2014). Similarity percentages (SIMPER) analysis was then used to identify the taxa that contributed most strongly to any observed differences in the composition of communities between the AOC and reference area.

3. Results

3.1. Macroinvertebrate communities

Macroinvertebrate communities in the Eighteenmile Creek AOC were composed of organisms from 15 taxonomic orders and were dominated by chironomids in the order Diptera (primarily genera *Procladius* and *Chironomus*). Macroinvertebrate communities in the Oak Orchard Creek reference area were composed of organisms from nine taxonomic orders and were also dominated by chironomid-family Diptera (primarily genus *Procladius*). Eight orders were present in both the AOC and reference area, while seven orders were found exclusively in the AOC (Amphipoda, Basommatophora, Hoplonemertea, Lumbriculida, Megaloptera, Odonata, and Trichoptera) and one order (Coleoptera) was found exclusively in the reference area (Table 2). Within the sensitive EPT (Ephemeroptera, Plecoptera, Trichoptera) orders, Ephemeroptera (mayfly larvae) were present at six AOC sites, reaching a peak relative abundance of 13.0% at emil-2.5, Plecoptera (stonefly larvae) were not found at any AOC site, and Trichoptera (caddisfly larvae) were present at two AOC sites reaching a peak relative abundance of 3.0% at emil-0.6 (Table 2). In the reference area, Ephemeroptera were found at the four upstream-most sites, reaching a peak relative abundance of 4.5% at oak-5.9, while Trichoptera and Plecoptera were not found at any reference site.

Multivariate analyses indicated the composition of macroinvertebrate communities differed considerably between the AOC and reference area. The nMDS ordination revealed tight clustering of the reference sites while the AOC sites exhibited more within-group dissimilarly and were widely distributed through ordination space (Fig. 2). The similarity percentages analysis indicated the three most discriminating taxa responsible for differences between AOC and reference sites were 'undetermined Tubificidae without cap. setae' (Tubificidae) and *Paralauterborniella nigrohalteralis* (Chironomidae) which both had considerably greater abundance in the reference area, and genus *Chironomus* (Chironomidae) which had greater abundance in the AOC.

The standard and aggregate BAP scores indicated that community condition was similar between the AOC and reference area but considerably more variability was observed between sites in the AOC. The standard BAP scores at AOC sites ranged from 2.2 at emil-1.6 to 8.1 at emil-2.5 and averaged 5.1, compared to the reference area where scores ranged from 3.9 at oak-0.2 and oak-3.9 to 6.0 at oak-2.5 and averaged 4.8 (Table 3). Standard BAP scores indicated that one of the eight AOC sites was classified as severely impacted, three of eight were moderately impacted, three of eight were slightly impacted, and one of eight was non-impacted, whereas four of the six reference sites were classified as moderately impacted and two of six were slightly impacted (Fig. 3). The aggregate BAP scores at AOC sites ranged from 2.7 at emil-1.6 to 8.7 at emil-2.3 and averaged 6.6, compared to the reference area where scores ranged from 4.0 at oak-0.2 to 6.8 at oak-2.5 and averaged 5.5 (Table 3). Aggregate BAP scores indicated that two of the eight AOC sites were moderately impacted, three of eight were slightly impacted, and three of eight were non-impacted; two of the six reference sites were classified as moderately impacted and four of six were slightly impacted (Fig. 3). Noninferiority was established for the AOC with both the standard BAP ($T = 1.905$, $P = 0.045$, $df = 9$) and aggregate BAP ($T = 3.102$, $P = 0.005$, $df = 11$) as the lower bound of the 95% confidence interval about the ratio of the Eighteenmile Creek and Oak Orchard Creek means did not

Table 2
Percent contribution (relative abundance) of all taxonomic orders from eight sites in the Eighteenmile Creek AOC and six sites in the Oak Orchard Creek reference area where macroinvertebrate communities were sampled in 2021. Percentages were calculated by summing the counts of all taxa from the three replicates at each site (George and Baldigo, 2022) and then determining the relative abundance of each taxonomic order to the entire sample.

	emil-0.2	emil-0.6	emil-1.0	emil-1.6	emil-1.9	emil-2.2	emil-2.3	emil-2.5	oak-0.2	oak-1.8	oak-2.5	oak-3.3	oak-3.9	oak-5.9
Amphipoda	26.9	12.6	0.8	–	1.3	2.1	5.1	24.0	–	–	–	–	–	–
Basommatophora	–	4.8	–	–	0.7	–	0.6	–	–	–	–	–	–	–
Coleoptera	–	–	–	–	–	–	–	–	–	–	0.3	–	–	0.6
Diptera	50.3	65.3	77.4	94.4	73.6	87.6	38.0	44.0	55.1	74.5	71.7	78.0	77.1	77.6
Ephemeroptera	1.2	1.2	–	–	7.4	1.0	11.4	13.0	–	–	0.3	1.0	0.5	4.5
Hirudinida	0.6	0.6	19.4	4.0	4.7	–	9.5	2.7	–	0.5	0.7	–	–	–
Hoplonemertea	–	–	–	–	–	–	1.3	–	–	–	–	–	–	–
Isopoda	0.6	–	–	–	0.7	–	13.3	4.0	–	–	–	–	–	0.6
Lumbriculida	–	–	–	–	–	–	–	0.3	–	–	–	–	–	–
Megaloptera	–	4.8	–	–	–	–	–	–	–	–	–	–	–	–
Mesogastropoda	1.8	4.2	–	0.8	2.0	–	0.6	–	1.8	–	0.3	0.5	–	–
Odonata	0.6	1.2	–	0.8	1.0	–	1.9	1.7	–	–	–	–	–	–
Trichoptera	–	3.0	–	–	–	–	1.3	–	–	–	–	–	–	–
Tubificida	13.5	1.8	2.4	–	8.7	9.3	17.1	10.0	42.5	25.0	26.0	20.5	22.4	16.0
Unionida	–	–	–	–	–	–	–	0.3	–	–	0.3	–	–	–
Veneroida	4.7	0.6	–	–	–	–	–	–	0.7	–	0.3	–	–	0.6

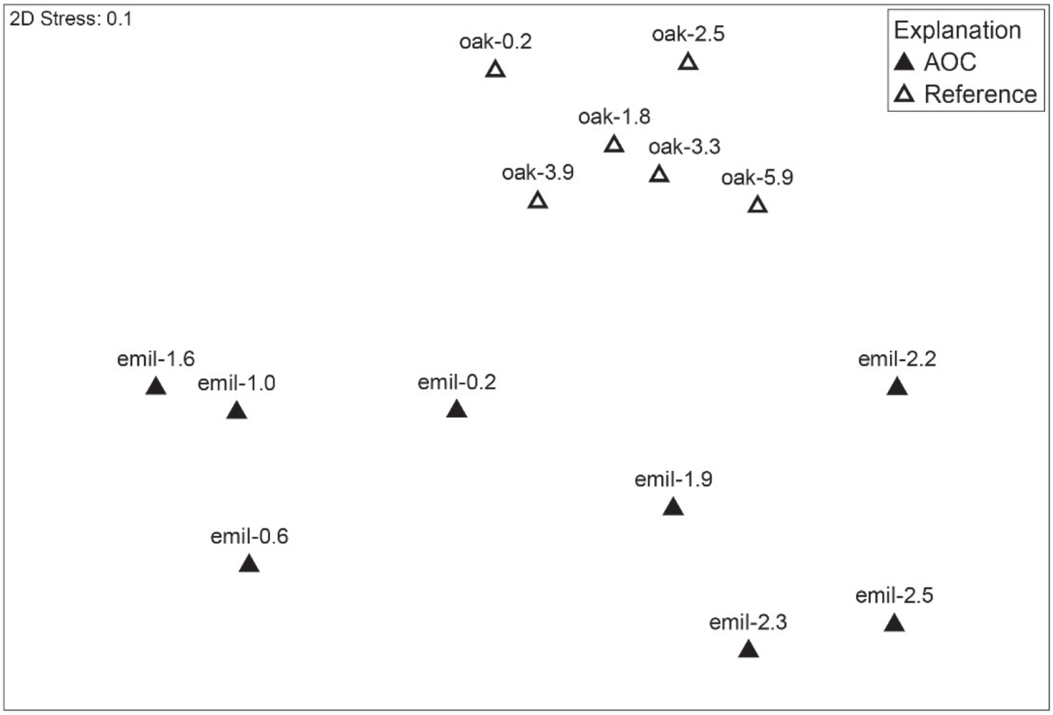

Fig. 2. Non-metric multidimensional scaling (nMDS) ordination of macroinvertebrate community composition. The ordination plots Bray-Curtis similarities derived from square-root transformed community data summed across the three replicates for each sample.

Table 3
Macroinvertebrate community information including subsample size, component metrics of the Biological Assessment Profile (BAP) score, and the final (10-scaled) standard BAP score presented as mean (standard error) for the three replicates collected at each site (George and Baldigo, 2022). The aggregate BAP score presents the mean (standard error) BAP score of 30 random 100-organism subsamples from the combined replicates at each site.

Site ID	Subsample size (no. of organisms)	Species richness	Hilsenhoff Biotic Index	Percent model affinity	Shannon Diversity Index	Dominant-3	Standard BAP score	Aggregate BAP score
emil-0.2	57 (26)	11.3 (3.7)	8.2 (0.3)	47.0 (7.2)	2.5 (0.4)	76.6 (8.6)	4.2 (1.3)	6.5 (0.1)
emil-0.6	56 (24)	10.7 (4.8)	8.2 (0.6)	48.7 (12.9)	2.4 (0.6)	75.6 (13.3)	4.1 (2.2)	6.9 (0.1)
emil-1.0	41 (15)	6.0 (2.1)	7.8 (0.6)	41.7 (7.6)	1.9 (0.5)	83.3 (8.3)	3.0 (0.7)	4.6 (0.0)
emil-1.6	42 (5)	7.0 (0.6)	8.9 (0.1)	37.3 (3.8)	2.1 (0.1)	85.1 (2.0)	2.2 (0.4)	2.7 (0.1)
emil-1.9	100 (0)	22.3 (0.7)	7.8 (0.4)	47.3 (8.3)	3.6 (0.1)	50.5 (1.8)	7.2 (0.3)	7.5 (0.1)
emil-2.2	32 (5)	11.7 (1.3)	7.2 (0.2)	39.0 (4.7)	3.1 (0.1)	56.4 (3.3)	5.6 (0.6)	7.3 (0.0)
emil-2.3	53 (19)	16.0 (6.2)	8.0 (0.1)	68.3 (9.2)	3.1 (0.6)	57.8 (12.0)	6.4 (1.7)	8.7 (0.0)
emil-2.5	100 (0)	24.0 (1.7)	7.7 (0.2)	64.0 (1.2)	3.8 (0.2)	48.7 (4.5)	8.1 (0.3)	8.4 (0.0)
oak-0.2	95 (5)	13.0 (0.6)	9.3 (0.1)	42.3 (1.5)	2.6 (0.1)	73.7 (2.0)	3.9 (0.3)	4.0 (0.1)
oak-1.8	61 (10)	14.3 (2.6)	8.7 (0.3)	35.7 (4.3)	3.1 (0.2)	59.4 (2.9)	4.9 (0.5)	5.9 (0.0)
oak-2.5	100 (0)	17.0 (0.6)	8.0 (0.2)	41.0 (1.5)	3.3 (0.0)	56.3 (1.5)	6.0 (0.1)	6.8 (0.0)
oak-3.3	67 (11)	11.7 (1.5)	8.2 (0.1)	40.3 (2.2)	3.0 (0.1)	58.9 (3.5)	4.9 (0.4)	5.6 (0.1)
oak-3.9	64 (11)	12.0 (0.6)	8.8 (0.1)	38.0 (1.2)	2.6 (0.1)	69.9 (0.6)	3.9 (0.1)	4.3 (0.1)
oak-5.9	52 (14)	12.7 (1.5)	8.1 (0.3)	40.0 (3.0)	3.2 (0.1)	55.0 (1.0)	5.4 (0.3)	6.4 (0.0)

extend below the threshold value of 0.75 for either metric.

3.2. Sediment toxicity test results

The survival and growth of *C. dilutus* exceeded the minimum test acceptability criteria of 70% and 0.48 mg (USEPA, 2000), respectively, in both laboratory controls. Similarly, *H. azteca* met the minimum test acceptability criteria of 80% survival and exhibited measurable growth in both laboratory controls. The daily measurements of overlying water quality were all within the acceptable ranges (temperature: 23 °C ± 1, dissolved oxygen > 2.5 mg/L) for each test method with no deviations observed (USEPA, 2000). Similarly, parameters measured at test initiation and termination (hardness, alkalinity, ammonia, pH, and conductivity) exhibited negligible variability and met the test acceptability criteria of not varying by > 50% (USEPA, 2000). Toxicity test results from the duplicate sediment samples collected at emil-1.6 indicated high precision with the survival endpoint and more variability around the growth endpoint for both species. The relative percent difference between the duplicate samples was 4.0% for survival of *C. dilutus*, 11.8% for growth of *C. dilutus*, 0% for survival of *H. azteca*, and 29.2% for growth of *H. azteca*. Overall, these quality assurance data indicate that test acceptability criteria were met, and therefore, the test results can be considered valid assessments of sediment toxicity.

Survival and growth of *C. dilutus* and *H. azteca* were generally similar between the AOC and reference area (Fig. 4). A notable outlier in the dataset occurred with the *H. azteca* data from three reference sites where total or near-total mortality occurred. Survival and growth of *C. dilutus* averaged 94.4% and 1.23 mg, respectively, across sites in the AOC compared to an average of 95.0% and 1.03 mg across all reference sites (Table 4). Survival and growth of *H. azteca* averaged 97.5% and 0.13 mg, respectively, across sites in the AOC compared to an average of 52.3% and 0.08 mg across all reference sites (Table 4). Noninferiority was established for the AOC with both *C. dilutus* endpoints (survival: $T = 18.753$, $P < 0.001$, $df = 11$, growth: $T = 5.862$, $P < 0.001$, $df = 11$) and

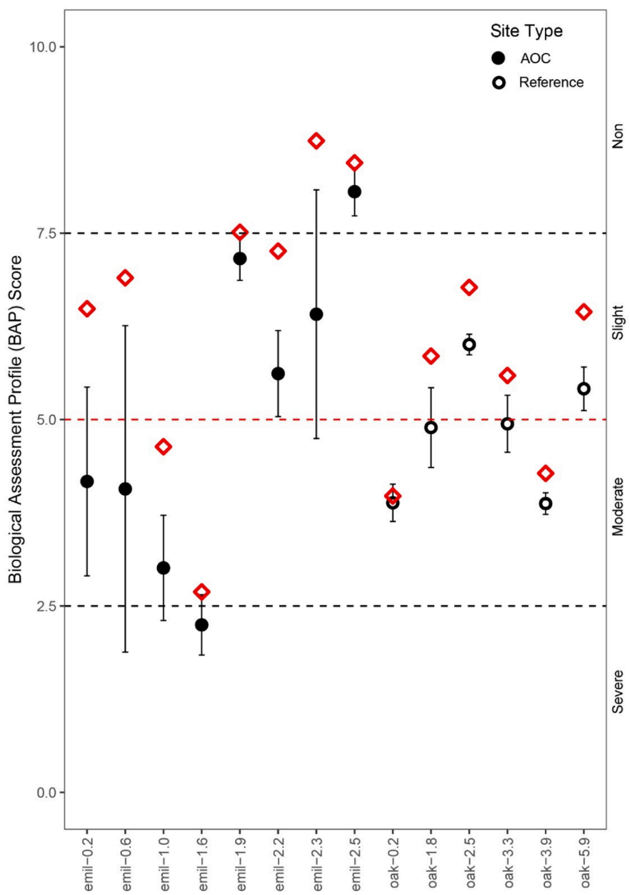

Fig. 3. Biological Assessment Profile (BAP) scores of macroinvertebrate community integrity shown in black as the standard BAP score (mean ± one standard error, n = 3) and in red as the aggregate BAP score for eight sites in the Eighteenmile Creek AOC and six sites in the Oak Orchard Creek reference area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

both *H. azteca* endpoints (survival: $T = 3.764$, $P = 0.007$, $df = 5$, growth: $T = 2.882$, $P = 0.017$, $df = 5$).

4. Discussion

The primary objective of this study was to assess the current status of macroinvertebrate communities and sediment toxicity in the Eighteenmile Creek AOC to determine whether legacy sediment contamination is causing impairment to the benthic component of the aquatic ecosystem. The results from macroinvertebrate community assessment at eight sites in the AOC during 2021 indicate that community condition spanned a wide range, but the mean condition was similar to that of a reference area on Oak Orchard Creek. Additionally, sediment toxicity tests using *C. dilutus* and *H. azteca* found no evidence that bed sediments in the AOC caused toxicity to either test species. The results of non-inferiority tests indicated that the standard and aggregate BAP scores, as well as the survival and growth endpoints for both toxicity-test species, were not inferior in the AOC relative to the reference area. For most of these comparisons, the mean value of the metric or endpoint in the AOC was higher than the corresponding value from the reference area. Despite these largely positive findings, there were several noteworthy patterns in the data, and informative comparisons with prior data from this AOC and from other systems, that warrant further discussion.

The condition and composition of macroinvertebrate communities in the AOC were considerably more variable than that observed in the reference area. This increased variability in the AOC was evident both between sites, where standard BAP scores ranged from 2.2 to 8.1 among AOC sites compared with 3.9 to 6.0 among reference sites, and within sites where variability between the three replicates was markedly higher at the AOC sites compared to the reference sites as shown by the standard error bars in Fig. 3. This indicates that at both the minute spatial scale of 1–2 m between replicates within a site, and at the broad spatial scale of both systems (multiple kilometers), the condition of macroinvertebrate communities was far more variable in the AOC than the reference area. Some of the within-site variability may be attributable to large differences in subsample sizes between replicates at some AOC sites. For example, at site emil-0.6 where the standard BAP scores ranged widely between the three replicates, the number of organisms obtained from the detritus of the three respective replicates was 100, 16, and 51 (George and Baldigo, 2022). However, even when the three replicates were pooled for each site in the multivariate analysis, the nMDS ordination showed that the structure or composition of communities varied considerably between AOC sites while the six reference sites grouped closely together. Without additional sampling and comprehensive comparisons of habitat heterogeneity between the AOC and reference area, it is not possible to confidently determine if the increased variability observed in macroinvertebrate communities at AOC sites is an indicator of stress. Despite the uncertainty as to the source of the variability, the removal criteria for the benthos BUI do not require direct consideration of variability.

The high mortality of *H. azteca* at three of the six reference sites was unexpected and difficult to interpret but does not alter the overall conclusions from this study or prohibit an assessment of whether the benthos BUI removal criteria have been met. Exposure to sediments from the three downstream-most reference sites, oak-0.2. oak-1.8, and oak-2.5, caused total or near-total mortality of *H. azteca*, while comparable *C. dilutus* tests from the same sites indicated no effect on survival and potentially a slight reduction of growth. All associated laboratory controls indicated that the starting batch of test organisms was healthy, and daily monitoring of overlying water in the test chambers found no deviations of temperature or dissolved oxygen outside the test acceptability criteria (USEPA, 2000). Similarly, porewater ammonia concentrations were within the ranges observed in other samples and were well below the 20 mg/L threshold that would require mitigation (USEPA and USACE, 1998a). There was also no evidence that indigenous organisms were responsible for the mortality as the 100 mL-sediment aliquots used in each test chamber were visually screened for their presence during test initiation and test takedown. Habitat data collected from the three sites including particle size, TOC, depth, and dissolved oxygen also were not atypical and were within ranges observed at the other AOC and reference sites (Table 1). The NYSDEC Division of Environmental Remediation's Spill Incidents Database (NYSDEC, 2023a) was also queried to investigate if the toxicity observed at the three downstream-most reference sites could be the result of a known discharge. There were no records of chemical or petroleum spill incidents impacting the lower section of Oak Orchard Creek in the 10 years prior to this study. Thus, the most obvious explanation for this mortality is the presence of some unidentified stressor or contaminant in the sediment to which *H. azteca* has greater sensitivity than *C. dilutus*. However, the limited sediment chemistry data available from Oak Orchard Creek does not provide any additional insight into a possible cause. Analysis of a sediment sample collected in 2019 from an area near the reference sites in this study with *H. azteca* mortality did not detect the presence of PCB Aroclors, PAHs, or pesticides (WSP, 2021, 2022). Metals were detected, but not at concentrations exceeding NYSDEC Class A screening criteria (indicating little or no potential risk to aquatic life) (NYSDEC, 2014), and acid volatile sulfide / simultaneously extracted metals (AVS/SEM) analysis suggested that metals at this site were unlikely to be bioavailable. Three additional sediment samples collected from the same area on Oak Orchard Creek in 2020 yielded similar results (WSP, 2022). Additionally, prior sediment toxicity testing in Oak Orchard Creek has consistently

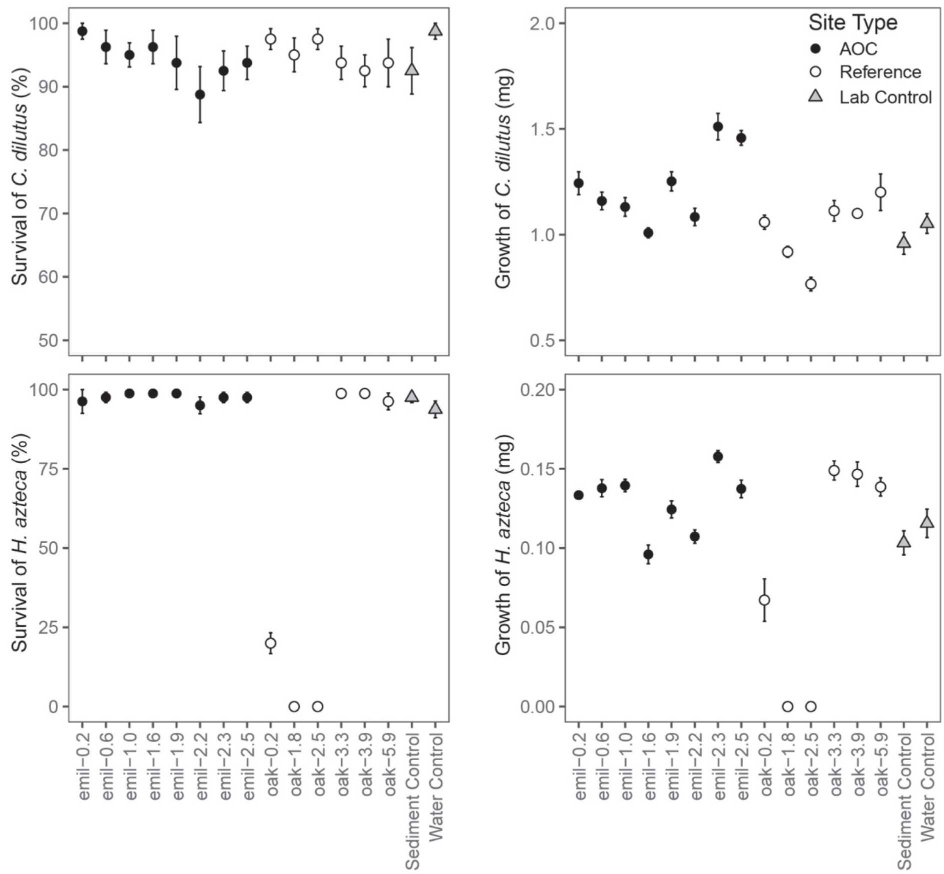

Fig. 4. Interval plots (mean ± one standard error, n = 8) showing the survival and growth of *C. dilutus* and *H. azteca* in 10-day sediment toxicity tests from study sites and laboratory controls.

Table 4
Results from 10-day sediment toxicity tests (George and Baldigo, 2022) presented as mean (standard error) for survival and growth of *C. dilutus* and *H. azteca* from the eight test replicates conducted for each field sample and laboratory control.

Site ID	*C. dilutus* survival (%)	*C. dilutus* growth (mg)	*H. azteca* survival (%)	*H. azteca* growth (mg)
emil-0.2	98.8 (1.2)	1.243 (0.054)	96.3 (3.7)	0.133 (0.002)
emil-0.6	96.3 (2.6)	1.159 (0.042)	97.5 (1.6)	0.138 (0.005)
emil-1.0	95.0 (1.9)	1.131 (0.044)	98.8 (1.2)	0.139 (0.004)
emil-1.6	96.3 (2.6)	1.008 (0.024)	98.8 (1.2)	0.096 (0.006)
emil-1.9	93.8 (4.2)	1.252 (0.045)	98.8 (1.2)	0.124 (0.005)
emil-2.2	88.8 (4.4)	1.083 (0.041)	95.0 (2.7)	0.107 (0.004)
emil-2.3	92.5 (3.1)	1.511 (0.063)	97.5 (1.6)	0.158 (0.004)
emil-2.5	93.8 (2.6)	1.457 (0.035)	97.5 (1.6)	0.137 (0.006)
oak-0.2	97.5 (1.6)	1.059 (0.033)	20.0 (3.3)	0.067 (0.013)
oak-1.8	95.0 (2.7)	0.918 (0.026)	0.0 (0)	no survival
oak-2.5	97.5 (1.6)	0.766 (0.032)	0.0 (0)	no survival
oak-3.3	93.8 (2.6)	1.112 (0.049)	98.8 (1.2)	0.149 (0.006)
oak-3.9	92.5 (2.5)	1.100 (0.018)	98.8 (1.2)	0.147 (0.008)
oak-5.9	93.8 (3.7)	1.200 (0.087)	96.3 (2.6)	0.139 (0.006)
Duplicate (emil-1.6)	92.5 (2.5)	1.134 (0.057)	98.8 (1.2)	0.129 (0.004)
Lab control (sediment and water)	92.5 (3.7)	0.959 (0.052)	97.5 (1.6)	0.103 (0.007)
Lab control (water only)	98.8 (1.2)	1.052 (0.047)	93.8 (2.6)	0.116 (0.009)

found no evidence of toxicity to *C. dilutus* and *H. azteca* (George et al., 2017; WSP, 2021) and numerous past and ongoing efforts in the AOC and Superfund programs have deemed it a suitable reference area indicative of typical regional conditions (E&E, 2009, 2017, 2019; George et al., 2022a).

Despite the challenges posed by the unexplained mortality of *H. azteca* in sediments from three reference sites, numerous lines of evidence support the conclusion that sediments in the AOC are not toxic to benthic macroinvertebrates. First, if the three anomalous reference sites are removed from the comparisons of the toxicity endpoints, the mean values from the three remaining reference sites were nearly identical to the corresponding endpoints from the eight AOC sites. Conversely, if these results were not excluded, most analyses would indicate that sediments from the AOC were less toxic than those from the reference area. Second, none of the AOC sites met the USEPA and U.S. Army Corps of Engineers standard criteria for toxicity used for sediment disposal decisions (USEPA and USACE, 1998b). These criteria state that sediments are considered to be toxic if any of the following criteria are met:

-mortality of *C. dilutus* > 20% higher than in reference sediments and difference is statistically significant, OR

-mortality of *H. azetca* > 10% higher than in reference sediments and difference is statistically significant, OR

-mean dry weight (growth) of *C. dilutus* < 0.6 mg per organism, and difference between test and reference sediments > 10%, and difference is statistically significant

None of the eight AOC sites in this study met, or even approached, these criteria regardless of whether the Oak Orchard Creek reference sites or the laboratory test controls were used for the comparison. Finally, the results of the 10-day toxicity tests from the eight AOC sites in Eighteenmile Creek were generally similar to or showed less toxicity than results from other reference areas used in past AOC assessments in New York. The survival of *C. dilutus*, growth of *C. dilutus*, survival of *H. azteca*, and growth of *H. azteca* at the eight sites in the Eighteenmile Creek AOC averaged 94.4%, 1.23 mg, 97.5%, and 0.13 mg, respectively. Comparable data for the four toxicity endpoints from six reference sites on the Buffalo River averaged 82.9%, 1.58 mg, 97.1% and 0.07 mg, respectively in 2017, and 97.0%, 1.37 mg, 93.3% and 0.13 mg, respectively in 2020 (George et al., 2022b). Similarly, at ten reference sites on the upper Niagara River sampled in 2019, the toxicity endpoints averaged 84.6%, 1.64 mg, 95.2%, 0.12 mg, respectively (Baldigo et al., 2023). Thus, the toxicity test results from the eight sites in the Eighteenmile Creek AOC sampled in 2021 appear to be consistent with regional reference conditions and provide no indication that sediments were toxic to macroinvertebrates.

While it is difficult to ascertain with much confidence, the macroinvertebrate data collected in Eighteenmile Creek during 2021 and in prior efforts generally indicate that benthic communities have not changed much or improved only slightly over the past three decades. It is challenging to assess changes in community condition and structure over time due to inconsistent sampling methods, locations, and number of sites, and levels of taxonomic resolution between datasets, but some comparisons are possible. The percentage of communities (relative abundance) composed of chironomids (non-biting midges) and oligochaetes (worms), which are generally considered to be pollution tolerant, was 83.4% at one location sampled with a standard Ponar in 1994 (Abele et al., 1998), compared to an average of 86.2% from three petite Ponar sites in 2012 (E&E, 2013), 92.7% from three petite Ponar sites in 2014 (George et al., 2017), and 66.9% from the eight petite Ponar sites in 2021 described in this study (George and Baldigo, 2022). In a similar comparison of the sensitive EPT orders, the relative abundance of mayfly, stonefly, and caddisfly larvae was 0.0, 0.0, and 0.6% in the 1994 dataset, 1.4, 0.2, and 1.6% in the 2012 data, 0.0, 0.0, 0.8% in the 2014 data, and 4.4, 0.0, 0.5% in the 2021 data. Standard and aggregate BAP scores from the three 2014 samples averaged 3.8 and 5.9 respectively (George et al., 2017), compared to 4.3 and 6.1, at the same three sites resampled in 2021 as part of this study (emil-0.2, emil-1.0, and emil-2.2). Together, these data indicate that the condition of macroinvertebrate communities has remained fairly static over the past three decades.

The results from this assessment of macroinvertebrate community condition and sediment toxicity, when interpreted in conjunction with other studies described above, have important implications for assessing the status of the benthos BUI in the Eighteenmile Creek AOC. The mean condition of macroinvertebrate communities, as calculated using both the standard BAP and aggregate BAP score, was 5.1 and 6.6 respectively, thus falling into the slightly impacted category and meeting the first criterion of being '*"non-impacted" or "slightly impacted" according to NYSDEC indices*'. Although the mean condition met this criterion, four and two of the eight individual AOC sites, using the two respective indices, did not meet this criterion. Thus, it may be appropriate to consider the second and third criterion, which together, require that community condition and sediment toxicity in the AOC be similar to that of a comparable reference area. The data collected during this study and corresponding noninferiority tests indicate that condition of macroinvertebrate communities and the quality of sediments in the AOC were similar or potentially superior to that of the reference area. These results corroborate findings from three recent studies which produced similar conclusions (George et al., 2017; WSP, 2022; E&E, 2013). Therefore, the weight of evidence from the existing suite of data from all sources indicates that benthic macroinvertebrate communities in the Eighteenmile Creek AOC are similar to the regional condition and are not impaired by chemical contamination of sediments. While the decision whether to remove the benthos BUI ultimately lies with the Eighteenmile Creek AOC Remedial Advisory Committee and associated state and federal agencies, the findings presented in this manuscript are an important contribution towards that action and for informing approaches to assessing this BUI in other AOCs across the Great Lakes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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