NORTHEAST OHIO REGIONAL SEWER DISTRICT

2011 Mill Creek Environmental Monitoring: Biological, Water Quality, and Habitat Survey Results

Prepared by
The Water Quality and Industrial Surveillance Division

Introduction

During 2011, the Northeast Ohio Regional Sewer District (NEORSD) conducted electrofishing, benthic macroinvertebrate surveys, water chemistry sampling, and habitat assessments at ten headwater sites on Mill Creek. Mill Creek is an intensely urbanized tributary to the Cuyahoga River. Mill Creek has a natural waterfall, Mill Creek Falls (also known as Cataract Falls), that is a fish migration barrier at River Mile (RM) 2.80. The purpose of the 2011 monitoring was to gain an overall picture of the health of the stream using a watershed approach and evaluate the impact of Combined Sewer Overflows (CSOs), construction of the Mill Creek Tunnel, and other environmental factors on the stream. Ten sites spaced along the entire length of the Mill Creek Main Branch were assessed. The last comprehensive survey of Mill Creek was conducted in 1995 as a part of the Mill Creek Watershed Management Project. Many of the sites from that project were revisited in the 2011 study.

The study site at RM 0.12 was required under the District's CSO permit, Ohio Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Permit No. 3PA00002*FD. This site is downstream of all NEORSD-owned CSOs that discharge into Mill Creek. According to the permit (1997), "discharges from combined sewer overflows shall not cause or significantly contribute to violations of water quality standards or impairment of designated uses."

The 2011 surveys were also in support of several NEORSD capital improvement projects designed to provide wet weather flow relief, stormwater storage capacity, and reduction/elimination of CSOs for several communities in the Mill Creek watershed. The Miles Avenue Relief Sewer (MARS) was completed in June 2010 and connects to the Lee Road Relief Sewer (LRRS). The LRRS connects to the Mill Creek Tunnel, the third leg of which was constructed in Phase Three of the Mill Creek Tunnel Project (MCT-3C). The Mill Creek Tunnel and LRRS were completed in 2012. The stream monitoring surveys conducted in 2011, which were considered pre-construction monitoring for LRRS and MCT-3C and post-construction monitoring for MARS, will enable future evaluations of the effectiveness of the capital improvement projects in restoring the chemical and biological health of Mill Creek.

Stream monitoring activities were conducted at RMs 10.70 and 11.52 in the upstream and downstream sections of the project area, respectively, of a proposed restoration project in a degraded stretch of Mill Creek through Highland Park Golf Course. The project, Highland Park Stream Restoration (Project number 392938-01), will be funded by a 2008 grant awarded to NEORSD through Ohio EPA's Water Resource Restoration Sponsor Program (WRRSP) (Ohio EPA 2009a). The restoration project is a joint effort between NEORSD and the City of Cleveland, and is anticipated to begin in November 2012 and be completed by December 31, 2013. The purpose of the project is to improve riparian conditions and instream habitat, and stabilize lateral and vertical instability in the channel (NEORSD Engineering Consultant Dave Anthony, personal correspondence). The 2011 monitoring data augments the pre-restoration baseline monitoring data gathered in 2009 and will be utilized once restoration activities are complete to evaluate any changes to water quality and biological community health.

Sampling was conducted by NEORSD Level 3 Qualified Data Collectors certified by Ohio EPA in Fish Community and Benthic Macroinvertebrate Biology, and Chemical Water Quality and Stream Habitat Assessments as explained in the NEORSD Study Plan *2011 Mill Creek Environmental Monitoring*, approved by Ohio EPA on June 14, 2011.

Figure 1 is a map of the sampling locations on Mill Creek, and Table 1 lists the sampling locations and their respective RM, latitude/longitude, site description, and surveys conducted. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD Water Quality and Industrial Surveillance Division.

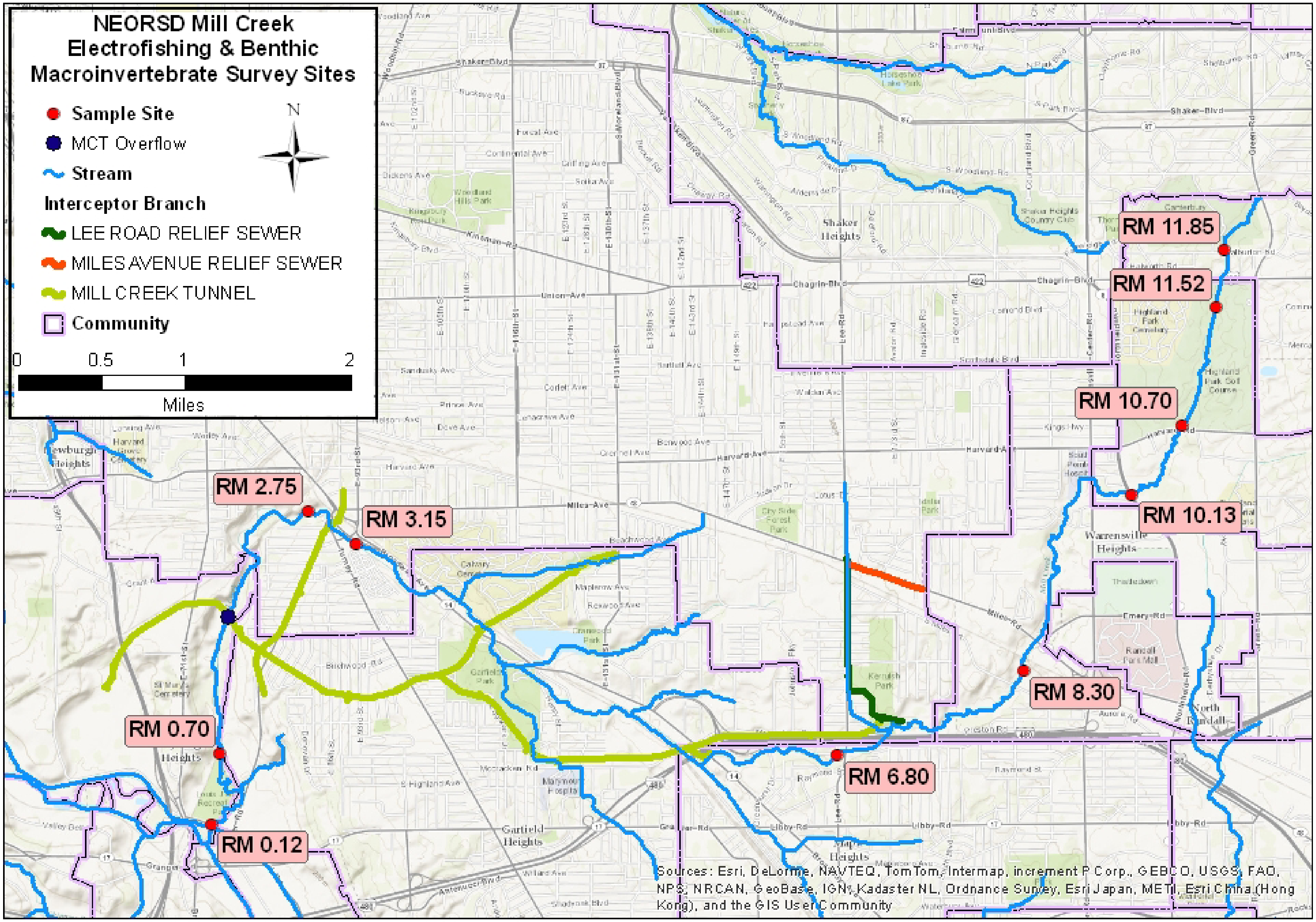

Figure 1. Sampling Locations

Table 1. Sampling Locations						
River Mile	Latitude	Longitude	Description	Quadrangle	Purpose*	Historical Site Name
11.85	41.4671	-81.5203	Upstream of Halburton Road, in Canterbury Golf Course	Shaker Heights	Upstream of Capital Improvement projects, evaluate overall watershed health	35.2
11.52	41.4621	-81.5214	Upstream section of restoration at Highland Park Golf Course	Shaker Heights	Evaluate overall watershed health, conduct required pre-restoration monitoring	n/a
10.70	41.4518	-81.5255	Downstream section of restoration at Highland Park Golf Course	Shaker Heights	Evaluate overall watershed health, conduct required pre-restoration monitoring	n/a
10.13	41.4460	-81.5312	Northfield Road	Shaker Heights	Evaluate overall watershed health, monitor in support of capital improvement projects	35.0
8.30	41.4305	-81.5442	Upstream of South Miles Road, upstream of Kerruish Park stormwater basin, first site upstream of NEORSD CSOs	Shaker Heights	Upstream of NEORSD CSOs, evaluate overall watershed health, monitor in support of capital improvement projects	34.6
6.80	41.4233	-81.5659	Rex Avenue, upstream of Wolf Creek, downstream of Kerruish Park stormwater basin	Shaker Heights	Evaluate overall watershed health, monitor in support of capital improvement projects	34.0
3.15	41.4422	-81.6216	Broadway Avenue, upstream of Mill Creek Falls and downstream of Wolf Creek	Shaker Heights	Evaluate overall watershed health, monitor in support of capital improvement projects	32.6
2.75	41.4451	-81.6271	Downstream of the Mill Creek Falls	Cleveland South	Evaluate overall watershed health, monitor in support of capital improvement projects	32.4
0.70	41.4240	-81.6376	Upstream of the Warner Road Tributary, adjacent to 5000 Warner Road	Cleveland South	Evaluate overall watershed health, monitor in support of capital improvement projects	32.2
0.12	41.4178	-81.6387	Upstream of Canal Road	Cleveland South	Evaluate overall watershed health. Site required by Ohio EPA NPDES Permit No. 3PA00002*FD	31.0
* Water chemistry, habitat, fish, and macroinvertebrates were evaluated at each site						

Water Chemistry Sampling

Methods

Water chemistry samples were collected from all ten sites during five weekly sampling events, beginning July 12, 2011 and ending August 9, 2011. To fulfill permit requirements under Ohio EPA NPDES Permit No. 3PA00002*FD, a sixth sample was collected at RM 0.12 on August 16, 2011. Samples collected on July 12, July 19, August 2, August 9, and August 16 were associated with wet weather events[1]. Techniques for water chemistry sampling and subsequent chemical analysis followed the *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices* (Ohio EPA, 2009b).

Samples were collected in two 4-liter disposable polyethylene cubitainers with disposable polypropylene lids and two 473-milliliter plastic bottles. One of the plastic bottles was field preserved with trace nitric acid and the other was field preserved with trace sulfuric acid. The bacteriological samples were collected in sterile 250 mL plastic bottles. Due to weather and time constraints, chlorophyll *a* sampling was not conducted in 2011. All samples were stored on ice in a cooler in the locked vehicle until they were relinquished to NEORSD's Analytical Services with a Chain of Custody (COC). A NEORSD Surface Water Condition Sampling Field Data Form detailing site observations was also completed for each sample. All Certificates of Analysis, COCs, and Surface Water Condition Sampling Field Data Forms are available upon request from the NEORSD Water Quality and Industrial Surveillance (WQIS) Division.

The instruments used for field analysis included YSI 600XL Sondes for measuring dissolved oxygen, conductivity, pH, and water temperature. The meters were calibrated weekly for dissolved oxygen and specific conductance; pH was calibrated each sampling day. Field turbidity was measured at NEORSD's Environmental and Maintenance Services Center (EMSC) using either a Hach 2100P IS Portable Turbidimeter, a LaMotte 2020 Portable Turbidity Meter, or an Orion AQUAfast AQ4500 Turbidimeter.

One field blank was obtained on each sampling date, for a total of six, for Quality Assurance/Quality Control (QA/QC) of the water samples. Field blanks were collected to determine if contamination not associated with the sample, such as airborne dust, had been introduced. Sample duplicates were also collected from one site on each sample date, for a total of six. The sample duplicate results were compared to the sample results using relative percent difference (RPD), given below in Formula 1.

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[1] Wet weather sampling events: greater than 0.10 inches of rain but less than 0.25 inches, samples collected that day and the following day were considered wet weather samples; greater than 0.25 inches of rain, samples collected that day and the following two days were considered wet weather samples. Rainfall data taken from the following NEORSD rain gages: RBH_A0030 in Beachwood, RMA_A0030 in Maple Heights, RSG_A0030 in Shaker Heights, and RSY_A0030 in Cuyahoga Heights.

Formula 1. $$RPD = \left(\frac{|X-Y|}{((X+Y)/2)} \right) * 100$$

X= is the concentration of the analyte in the primary sample[2]
Y= is the concentration of the analyte in the duplicate sample[2]

Each sample site was analyzed for 45 chemical parameters, plus 4 field measurements. The sample and the sample duplicate were compared for 42 individual laboratory parameters reported on the Certificate of Analysis. Total metals, hardness, and nitrate parameters were not compared, since they are calculated from other parameters.

Along with field blanks and duplicates, a third tier of data review involved paired parameters, such as nitrate+nitrite and nitrate, in which the second parameter is a subset of the first. Guidelines for these three tiers of data review are outlined in the draft *QC Sample Results Guidelines* developed by Ohio EPA (2011). This third tier involves examining the data for occasions in which the subset parameter is greater than the total parameter, within an allowable limit of 40% RPD. Otherwise, depending on the RPD, the data must be qualified, or if it does not fulfill the Ohio EPA requirements of level 3 credible data, downgraded to level 2 or rejected,. Results of these three tiers of data review are summarized below. The fourth tier, which examines whether samples were analyzed within their appropriate holding times, is conducted by Analytical Services. No issues with this item were reported.

Results and Discussion

There were several occasions where concentrations of certain substances in the field blank were high enough to result in either qualification or rejection of corresponding data in the samples and duplicates collected on the same day. The analysis below follows the draft guidelines set forth by Ohio EPA (2011). Further guidance on handling field blank values that were less than their respective practical quantitation limits (PQL) was provided by Jeff Reynolds of the Ohio EPA via email on January 10, 2012. Field blank values that when multiplied by 10 were still below the PQL were considered non-detects and the river sample data was left alone. However, if the field blank result was greater than the PQL when multiplied by 3, 5, or 10, river sample values above the PQL were given the appropriate qualifiers based upon their concentration relative to the field blank. Table 2 lists for each date the number of parameters in the blank that were above the minimum detection limit (MDL), how many of those affected the corresponding data in the samples and duplicates, and the number of corresponding data points that were qualified, downgraded to Level 2, or rejected. Metals and nutrients comprised many of

[2] For *E. coli,* the log of the result was used instead.

the parameters detected above the MDL, with ammonia, copper, and zinc being the most problematic. It is unclear at this time what is causing the blank contamination, and the issue will be investigated further.

Table 2. Summary of Field Blank Results

Sample Date	Total Parameters in Field Blank above MDL	Parameters Above MDL Affecting Corresponding Data	Correspondin g Data Points Qualified	Corresponding Data Points Downgraded to Level 2	Corresponding Data Points Rejected
July 12, 2011	13	5	21	2	9
July 19, 2011	13	3	12	10	9
July 26, 2011	19	7	13	5	18
August 2, 2011	16	7	31	12	2
August 9, 2011	17	6	11	5	18
August 16, 2011	15	4	5	3	0

Overall, there were 21 instances across the six duplicates in which the RPD was greater than 40%. According to the draft guidelines in Ohio EPA (2011), RPDs between 40-60% result in the data being considered estimated and downgraded to Level 2, and RPDs greater than 60% result in rejection of the data. However, parameter values that were less than ten times their respective PQL indicated that the concentrations were very small and the slightest differences resulted in an increase in the RPD. Therefore, only the aluminum values obtained on August 9, 2011, from RM 11.85 were given the appropriate qualifiers, as these values were the only ones greater than ten times the PQL. Table 3 lists the results of the duplicate comparison.

Table 3. Summary of Duplicate RPD Comparisons

Sample Date	River Mile	Parameter(s)	RPD Range	Qualifier	>10x PQL?
July 12, 2011	6.80	Hg	40-60%	None	No
		Sb, Tl	>60%	None	No
July 19, 2011	3.15	Hg, Tl	>60%	None	No
July 26, 2011	0.70	Cd, Cr, Se, Ti, Tl, Total-P	40-60%	None	No
August 2, 2011	3.15	Pb	40-60%	None	No
		BOD	>60%	None	no PQL
August 9, 2011	11.85	COD, Cd, Pb, Zn*	40-60%	None	No
		Co, Hg	>60%	None	No
		Al	>60%	Rejected (R)	Yes
August 16, 2011	0.12	Hg	>60%	None	No

*Zinc values previously qualified otherwise due to field blank contamination – one downgraded to Level 2, other rejected

As shown in Table 3, the zinc data points on August 9 were previously downgraded or rejected due to blank contamination. However, the aluminum discrepancy on August 9, 2011, could not be explained by either blank contamination or very small values. A possible reason for this unexplained discrepancy could be that the samples were collected after a morning rain shower from an elevated stream whose chemistry could have been changing continuously.

The Nitrate/Nitrite – Nitrate and Total Chromium – Hexavalent Chromium paired parameters were also examined for the 2011 Mill Creek dataset. No issues were noted for the Nitrate/Nitrite – Nitrate pair. However, there were some instances in which the hexavalent chrome value was greater than the total chromium value, but in each case, either both values were estimated, or the total chromium value was above its respective PQL while the hexavalent chromium value was not. Since the PQL for the hexavalent chromium method was greater than that of the total chromium method, it is uncertain whether the hexavalent chromium values were actually higher or not, and thus no qualifiers were added.

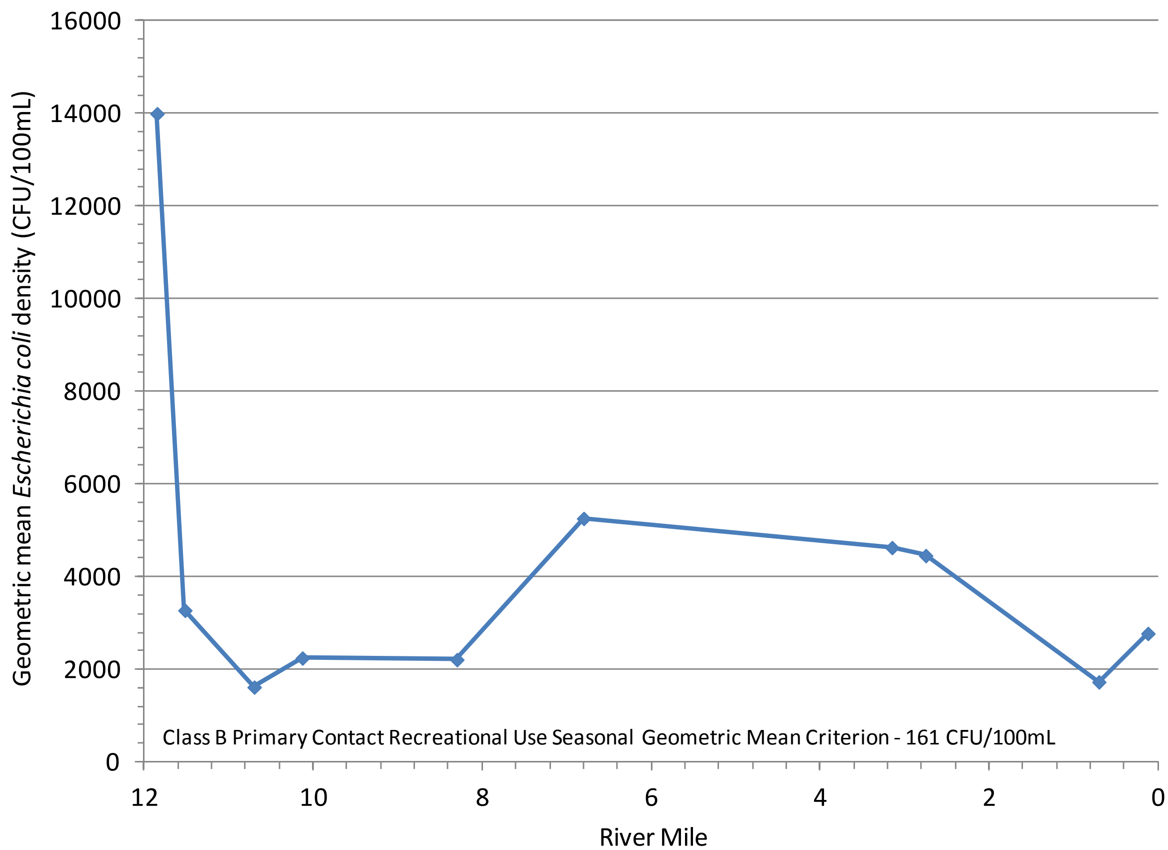
A study will be conducted in 2012 to investigate the reasons for failure of data points to meet QA/QC requirements, and evaluate steps that can be taken to mitigate those issues.

Each of the ten sites on Mill Creek is designated as warmwater habitat (WWH), agricultural water supply, industrial water supply, and Class B primary contact recreation waters. The Lake Erie Drainage Basin (LEDB) and Tier I criteria and Tier II values for aquatic life, wildlife, and human health nondrinking water criteria developed pursuant to OAC 3745-1 and 3745-2 also apply at each site. Once the downgraded (Level 2) and rejected data points as described above were culled from the data set, the remaining Level 3 data was compared to the applicable Ohio EPA Water Quality Standards (OAC 3745-1) for each site. Exceedances of these criteria are detailed below.

For the primary contact recreation criteria, the seasonal geometric mean criterion of 161 colony-forming units per 100 milliliters (CFU/100 ml) was exceeded at all ten sites (see Figure 2). The single sample maximum criterion of 523 CFU/100 ml was also exceeded at all ten sites in more than ten percent of samples taken in each 30-day period with two or more samples. *E. coli* values ranged widely, from 115 CFU/100 ml at RM 8.30 to 86,000 CFU/100 ml (estimated count) at RM 11.85. Both of these values were collected on a dry-weather day (July 26) from sites upstream of NEORSD CSOs. It should be noted that *E. coli* densities at RM 11.85 decreased after July 26 to densities similar to the other sites, but still remained above the recreational criteria.

The warmwater habitat – aquatic life use outside mixing zone maximum (OMZM) and outside mixing zone average (OMZA) hardness-based criteria for copper were exceeded at RM 11.85. This was the result of a copper value of 40.22 µg/L obtained on July 26, 2011, a dry-weather day. Due to variation in the hardness values, only the hardness values obtained on July 12, July 26, and August 2 were used to calculate the OMZA criteria, as the copper values for these dates were the ones that remained Level 3. Possible sources of copper at this site could include urban and stormwater runoff or chemicals used by the Canterbury Golf Course.

Figure 2. 2011 Season Geometric Mean *Escherichia coli* Densities on Mill Creek



The human health nondrinking water and wildlife outside mixing zone average (OMZA) criteria for mercury were exceeded at all ten sites in 2011. It should be noted that the MDL for USEPA Method 245.1 for mercury is above both criteria, and each site had mercury values below the MDL; i.e. exceedances would be indeterminate from these values alone. However, all ten sites also had mercury values either above the method PQL and/or estimated between the MDL and PQL, and these values were the ones that contributed to the exceedances. The two values above the PQL were obtained at RMs 10.70 and 6.80 on July 19, 2011, a wet weather day. Overall, mercury concentrations generally tended to be higher earlier in the season, and dropped as the season went on. Atmospheric deposition may be a source of mercury in the Mill Creek watershed.

Wet weather may have played an important role in contributing to the *E. coli* and mercury exceedances. 2011 was the wettest year on record for Cleveland, with over 60 inches of precipitation (NOAA, 2012). All water chemistry sampling events except July 26 were associated with wet weather. From July 12 to August 16 alone, the heavy rainfall resulted in 11 recorded wet weather overflows to Mill Creek. CSO 072 at East 78th Street and Harvard Avenue released 4.4 million gallons [MG] in seven events, CSO 025 at East 131st Street and Cranwood Park Boulevard released 0.063 MG in two events, and the Mill Creek Tunnel Overflow Silo in Harvard Landfill overflowed twice (8.615 MG) to prevent flooding at Southerly Wastewater Treatment Center. These overflows contained a mixture of rainwater, urban and stormwater runoff, and raw sewage and, based on their locations, could have impacted the four most downstream sites.

The Cuyahoga County Board of Health has conducted dry-weather sampling (at least 72 hours after rainfall) of storm sewer outfalls throughout the Mill Creek watershed, and the available 2005-2010 results have shown them to frequently have elevated densities of fecal coliform and/or *E. coli* bacteria (CCBH, 2012). There is also a Sanitary Sewer Overflow (SSO) in Maple Heights (OF1) whose status is listed as unknown in the NEORSD 2011 Community Discharge Program Status Report, but is due to be eliminated in the near future. Other potential sources of bacteria include urban and stormwater runoff and other unidentified sources throughout the Mill Creek watershed. Continued illicit discharge detection and elimination (IDDE) efforts and completion of the Miles Avenue and Lee Road Relief Sewers and the Mill Creek Tunnel may result in the reduction of overflows to Mill Creek and improvement of water quality.

Habitat Assessment

Methods

Qualitative Habitat Evaluation Index (QHEI) scores were determined for all ten headwater sites on Mill Creek between June 17 and October 13, 2011. The QHEI was developed by the Ohio EPA to assess aquatic habitat conditions that may influence the presence or absence of fish species by evaluating the physical attributes of a stream. The index is based on six metrics: stream substrate, instream cover, stream channel morphology, riparian and bank condition, pool and riffle quality, and stream gradient. A more detailed description of the QHEI can be found in Ohio EPA's *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)* (2006). QHEI field sheets for each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

The QHEI scores for all ten sites are shown in Table 4, below, and Figure 3. A QHEI score of 60 or more suggests that sufficient habitat exists to support a fish community that attains the warmwater habitat criterion (Ohio EPA, 2003). The seven sites downstream of the golf courses (RM 10.13 to the mouth) met this target. Scores at RMs 10.13, 8.30, and 2.75 also exceeded a score of 70, which indicates that they have the potential to support exceptional warmwater fish communities.

Table 4. 2011 Mill Creek QHEI Results and Stream Flows

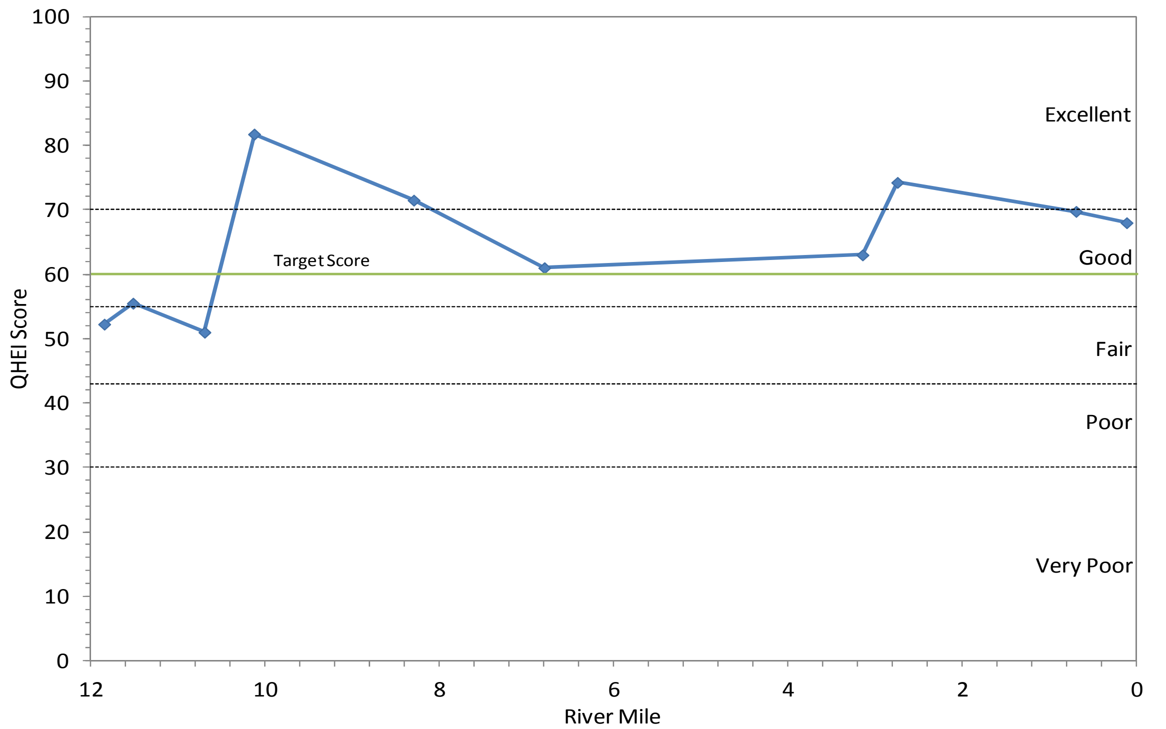
River Mile	Date	QHEI Score	Narrative	Stream Flow (ft^3/s)*
11.85	June 29, 2011	52.25	*Fair*	7.0
11.52	October 13, 2011	55.50	*Good*	26
10.70	June 29, 2011	51.00	*Fair*	7.0
10.13	September 21, 2011	81.75	*Excellent*	41
8.30	October 13, 2011	71.50	*Excellent*	26
6.80	October 11, 2011	61.00	*Good*	9.6
3.15	October 11, 2011	63.00	*Good*	9.6
2.75	October 6, 2011	74.25	*Excellent*	20
0.70	August 31, 2011	69.75	*Good*	4.2
0.12	June 17, 2011	68.00	*Good*	15

*Provisional flow data obtained from USGS 04208460 Mill Creek flow gauge in Garfield Heights, Ohio

Overall, the three lowest-scoring sites were located within Highland Park Golf Course (HPGC) and Canterbury Golf Course. Being surrounded by maintained grassy acreage on both sides, these high-gradient sites, especially those at HPGC, largely lacked any protective riparian zones and often had grass clippings floating on the water surface. The open mile section of Mill Creek at HPGC, which ranges from a stone channel at the downstream end to eroding false banks at the upstream end, is due to undergo habitat restoration under the Highland Park Stream Restoration project mentioned earlier. The restoration work may improve the QHEI scores to the target score of 60 indicated to support a healthy warmwater habitat fish community.

In addition to examining overall QHEI scores, individual components of the index can also be used to evaluate whether a site is capable of attaining the warmwater habitat designated use (Table 5). This is done by categorizing specific attributes as indicative of either a warmwater habitat or modified warmwater habitat (Rankin, 1995). Attributes that are considered characteristic of modified warmwater habitats are further classified as being of moderate or high influence to fish communities. The presence of one high or four moderate influence characteristics has been found to result in lower IBI scores, with a greater prevalence of these characteristics usually preventing a site from meeting warmwater habitat attainment (Ohio EPA, 1999).

Figure 3. 2011 Mill Creek Qualitative Habitat Evaluation Index Scores



Only two sites, RM 10.13 and RM 8.30, had less than one high and four moderate-influence attributes. Both of these sites scored in the *Excellent* range, as did RM 2.75. Located immediately downstream of Mill Creek Falls, RM 2.75 had one high-influence attribute – sparse instream cover – and only two moderate-influence attributes. As for the rest of the sites, most lacked adequate instream cover, a high influence attribute, and had three or more moderate attributes, mostly related to fair to poor development, low sinuosity, and moderate to high embeddedness of riffles and the overall stream reach. While these limitations may help define whether the sites can physically support warmwater habitat fish communities in and of themselves, it is important to note that Mill Creek Falls, located at RM 2.80, acts as a migration barrier to fish from the Cuyahoga River and lower reaches of Mill Creek that may otherwise colonize these sites in accordance with their habitat and water quality characteristics.

Table 5. Qualitative Habitat Evaluation Index scores and physical attributes

				WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence												
River Mile	Average IBI Score	QHEI Score	Habitat Rating	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinousity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max. Depth >40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or no Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max. Depth <40 cm (WD, HW sites)	**Total High Influence Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total Moderate Influence Attribute**
11.85	12	52.25	Fair	x						x				2				x	x	2					x	x		x	x	x	x		6
11.52	15	55.50	Good		x							x		2			x	x		2	x				x				x	x	x		5
10.70	20	51.00	Fair		x				x	x				3	x		x		x	3					x			x	x	x	x		5
10.13	20	81.75	Excellent	x	x		x	x	x	x	x	x	x	9						0				x									1
8.30	22	71.50	Excellent	x			x	x	x	x		x		6						0				x						x	x		3
6.80	22	61.00	Good	x						x		x		3				x		1					x	x				x			3
3.15	23	63.00	Good									x		1			x	x		2	x				x				x	x	x		5
2.75	31	74.25	Excellent	x	x					x	x	x	x	6				x		1					x	x							2
0.70	36	69.75	Good	x								x		2				x		1		x			x	x				x	x		5
0.12	36	68.00	Good	x			x			x		x		4				x		1						x				x	x		3

Electrofishing

Methods

Longline electrofishing was conducted twice at RMs 11.52, 10.70, 10.13, 8.30, 6.80, 3.15, 2.75, 0.70, and 0.12 on Mill Creek. RM 11.85 was only sampled once. The first sampling passes were conducted in mid to late June 2011, and the second passes were conducted in mid August 2011. Sampling consisted of shocking all habitat types within the sampling zone while moving from downstream to upstream. The sampling zone was 0.15 kilometers for all ten headwater sites. The methods followed those described in Ohio EPA's *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). Fish were identified to species level, counted, and examined for the presence of external anomalies including deformities, erosions, lesions, and tumors (DELTs). Fish were then returned to the waters from which they were collected with the exception of those collected as voucher specimens. Lists of the species, numbers, pollution tolerances and incidence of DELT anomalies are available upon request from the NEORSD WQIS Division.

The electrofishing results for each pass were utilized to calculate the Index of Biotic Integrity (IBI) for all ten sites. The IBI was developed by the Ohio EPA to evaluate fish community health by incorporating 12 metrics based upon structural attributes, such as fish numbers and diversity, and functional attributes, such as environmental tolerances, feeding strategies, reproductive requirements, and incidence of disease (Ohio EPA, 1987a). The metrics applicable to headwater sites are listed below.

1. Number of native species
2. Number of darter species
3. Number of headwater species
4. Number of minnow species
5. Number of sensitive species
6. Proportion of tolerant species
7. Proportion of omnivores
8. Proportion of insectivores
9. Proportion of pioneering species
10. Number of individuals
11. Number of simple lithophils
12. Proportion with DELT anomalies

Individual metric scores in each respective index are determined by comparing the fish data collected at each site with values expected at reference sites in a similar geographical region. The individual metric scores were added together to produce an overall IBI score for each site. The maximum possible score is 60 and the minimum is 12. The IBI score corresponds to a narrative rating of *Exceptional, Very Good, Good, Marginally Good, Fair, Poor,* or *Very Poor*.

Results and Discussion

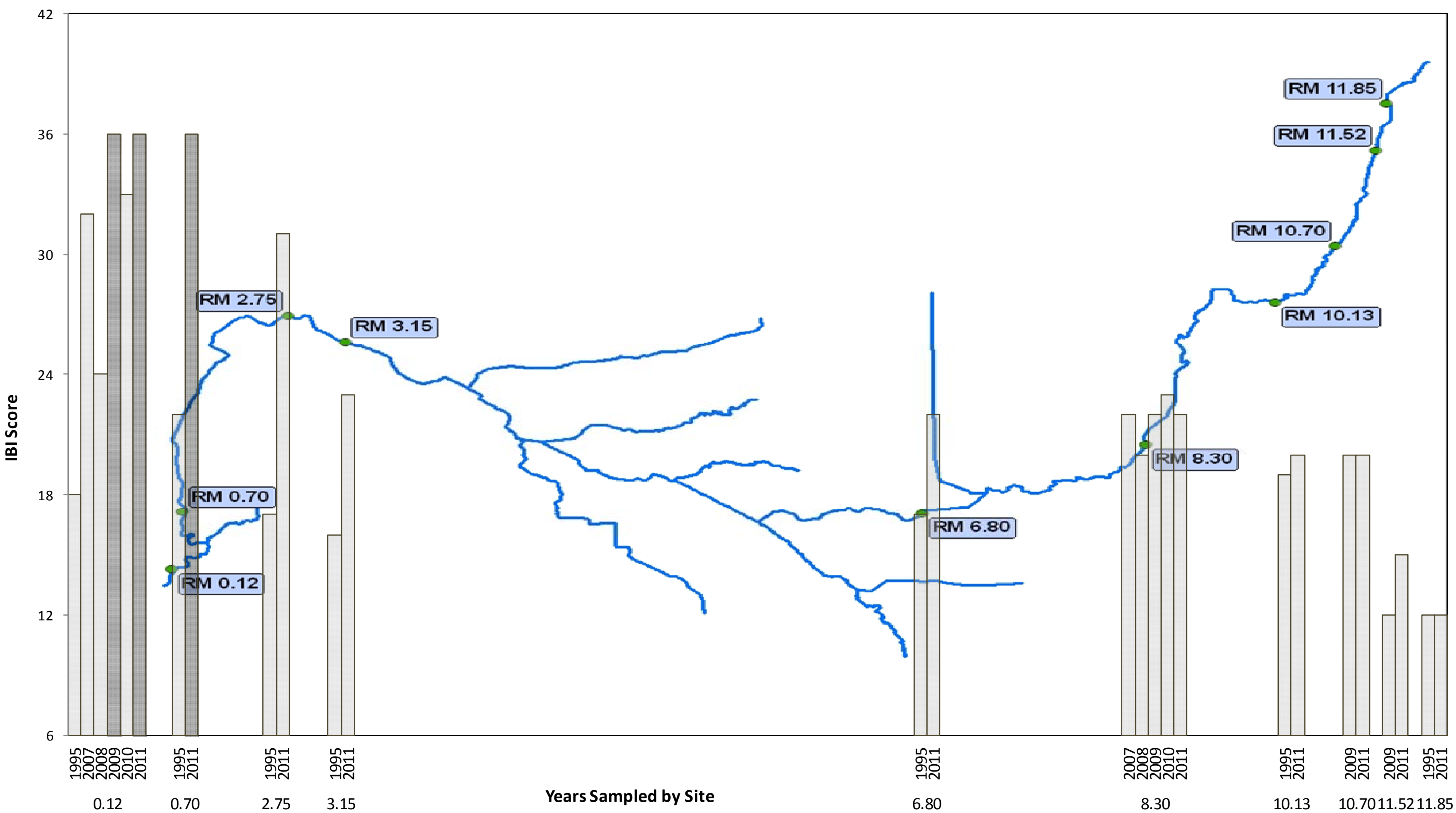
The WWH IBI criterion in the Erie-Ontario Lake Plain (EOLP) ecoregion is 40 for headwater sites. A site is considered in non-significant departure if it is within 4 IBI units of its applicable criterion. Therefore, an IBI score of 36 is considered to be in attainment. Table 6 shows the individual scores for each pass conducted in 2011. Scores from the comprehensive survey of Mill Creek that was conducted in 1995 as a part of the Mill Creek Watershed Management Project are included for reference purposes only, as these surveys were conducted prior to the implementation of Ohio EPA's Credible Data Program in 2006. These scores are shown along with the 2007-2011 scores in Figure 4 on the following page.

Table 6. 2011 Mill Creek IBI Results

River Mile	Average IBI Score	Narrative	Stream Flow (ft^3/s)*	Individual IBI Scores	Total No. of Species	No. of Native Species	No. of fish collected
11.85	12	*Very Poor*	7	12	1	0	2
11.52	15	*Very Poor*	7	12	2	1	5
			14	18	2	1	29
10.70	20	*Poor*	7	20	2	2	79
			14	20	3	2	567
10.13	20	*Poor*	7	20	2	2	140
			12	20	4	3	183
8.30	22	*Poor*	8.2	24	4	4	182
			12	20	3	3	427
6.80	22	*Poor*	11	22	2	2	662
			12	22	2	2	498
3.15	23	*Poor*	11	24	4	4	307
			15	22	3	3	289
Mill Creek Falls							
2.75	31	*Fair*	11	32	8	8	495
			15	30	8	8	404
0.70	*36*	*Marginally Good*	59	34	13	13	333
			15	38	17	16	804
0.12	*36*	*Marginally Good*	15	34	19	18	579
			35	38	16	15	335

*Provisional flow data obtained from USGS 04208460 Mill Creek flow gauge in Garfield Heights, Ohio
Non-significant departure from WWH criterion (≥36 IBI units)

Figure 4. 1995-2011 Mill Creek Index of Biotic Integrity (IBI) Scores



1995, 2010 and 2011 scores reflect the average of two passes. One pass was conducted at RM 11.85 in 2011.
Dark gray shading indicates attainment of the WWH biocriterion (≥ 36 IBI units).

As seen in Table 6 and Figure 4, IBI scores have generally improved over the years from the mouth of Mill Creek to RM 6.80, and have stayed relatively steady in the *Poor* to *Very Poor* range further upstream. The highest scores, including the two sites in non-significant departure of the WWH criterion, were all found downstream of Mill Creek Falls, which acts as a fish migration barrier. In 2011, 24 species and one hybrid sunfish were found downstream of the falls, and all of these species have been found in the Cuyahoga River. Upstream of Mill Creek Falls, fish diversity has been limited to just six highly tolerant species – the golden shiner, western blacknose dace, creek chub, northern fathead minnow, green sunfish, and exotic goldfish. Two other species, the black crappie and the pumpkinseed sunfish, were only found in 1995 and 2007, respectively. Based on these results, it appears that fish are migrating into Mill Creek from the Cuyahoga River, but are unable to move upstream of the waterfall.

In examining the individual IBI metrics both temporally and spatially, some interesting trends were noted. The metrics for the number of darter species and the number of headwater species never scored higher than a "1" for all sites during all years sampled, and the metrics for the number of sensitive species and the proportion of insectivores only scored higher than a "1" one time apiece. The sensitive species found on Mill Creek include the northern hogsucker, smallmouth bass, sand shiner, shorthead redhorse, and greenside darter, all found downstream of Mill Creek Falls. Since 1995, several other metrics have never scored above a "1" upstream of the falls, but are generally improving downstream of it. This includes the number of native species, proportion of tolerant species, relative number of individuals, and the number of simple lithophils. Simple lithophilic fish need clean gravel and cobble substrates to spawn successfully; one or both of these were predominant substrates at all sites on Mill Creek.

Given the current and historical IBI results, it appears that more fish from the Cuyahoga River are moving in and establishing communities in Mill Creek, but there are factors remaining that may hinder further improvement. As stated before, most sites on Mill Creek lacked adequate instream cover and had fair to poor development, low sinuosity, and moderate to high embeddedness of riffles and the overall stream reach. Other environmental inputs such as CSOs, SSOs, and urban and stormwater runoff, which may increase the pollutant and sediment load during very wet years like 2011, may also negatively impact the fish community. The habitat restoration project at Highland Park Golf Course, the Miles Avenue and Lee Road Relief Sewers, and the Mill Creek Tunnel may result in a reduction of stormwater runoff and combined sewage entering Mill Creek and improve water quality conditions. Post-construction monitoring will be used in conjunction with baseline data to evaluate this point. However, despite any improvements in habitat or water quality that may occur, significant improvement of the upstream fish community will be precluded by Mill Creek Falls unless fish are purposefully stocked or otherwise introduced.

Macroinvertebrate Sampling

Methods

Quantitative macroinvertebrate sampling was attempted at RMs 11.52, 10.70, 10.13, 8.30, 6.80, 3.15, 2.75, 0.70, and 0.12 on Mill Creek using a modified multi-plate Hester-Dendy (HD) artificial substrate sampler. Five identical HD sampler replicates were tied to a cinderblock and installed at these sites on July 14, 2011, for a six-week period. An HD was not installed at RM 11.85 due to site limitations. HDs were retrieved from RM 10.13 on August 22, 2011, RMs 0.70 and 2.75 on August 23, 2011, and RMs 10.70 and 11.52 on August 24, 2011. The HDs at RMs 0.12, 3.15, 6.80, and 8.30 were either not found or were unrecoverable. Embedded HDs are not a new problem in Mill Creek – four of the eight HDs set in 1995 were embedded at the time of retrieval as well.

Qualitative sampling was conducted at all ten sites, and at the five sites where HDs were retrievable, sampling was conducted during HD retrieval. A D-frame dip net was utilized to collect taxa inhabiting all habitats in the sampling area. Methods for sampling followed the Ohio EPA manual *Biological Criteria for the Protection of Aquatic Life, Volume III* (1987b). Stream flow was measured using a Marsh-McBirney FloMate Model 2000 Portable Flow Meter or an Aquaflow Probe Model 6900 during HD installation and retrieval, and an NEORSD Macroinvertebrate Field Sheet was completed during sample collection at each site. Since stream flow over the HD is second only to water quality in determining the macroinvertebrate community represented during sampling, stream flow should be 0.3 feet per second (fps) or greater for comparability (DeShon, 1995). All flows during HD installation and retrieval met this requirement. The macroinvertebrate samples were sent to Midwest Biodiversity Institute (MBI) for identification and enumeration. Specimens were identified to the lowest practical taxonomic level as described in the Ohio EPA *Biological Criteria for the Protection of Aquatic Life*, *Volume III* (1987b). Field sheets, taxa lists, and enumerations are available upon request from the NEORSD WQIS Division.

At the five sites where HDs were retrievable, the macroinvertebrate communities were assessed using Ohio EPA's Invertebrate Community Index (ICI), which consists of ten metrics (Ohio EPA, 1987a). Metrics 1-9 are based upon the quantitative sample, while Metric 10 is based upon the taxa richness of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), or EPT taxa, in the qualitative sample.

1. Total number of taxa
2. Total number of mayfly taxa
3. Total number of caddisfly taxa
4. Total number of dipteran taxa
5. Percent mayflies
6. Percent caddisflies
7. Percent Tanytarsini midges
8. Percent other dipterans & non-insects
9. Percent tolerant organisms
10. Total number of qualitative EPT taxa

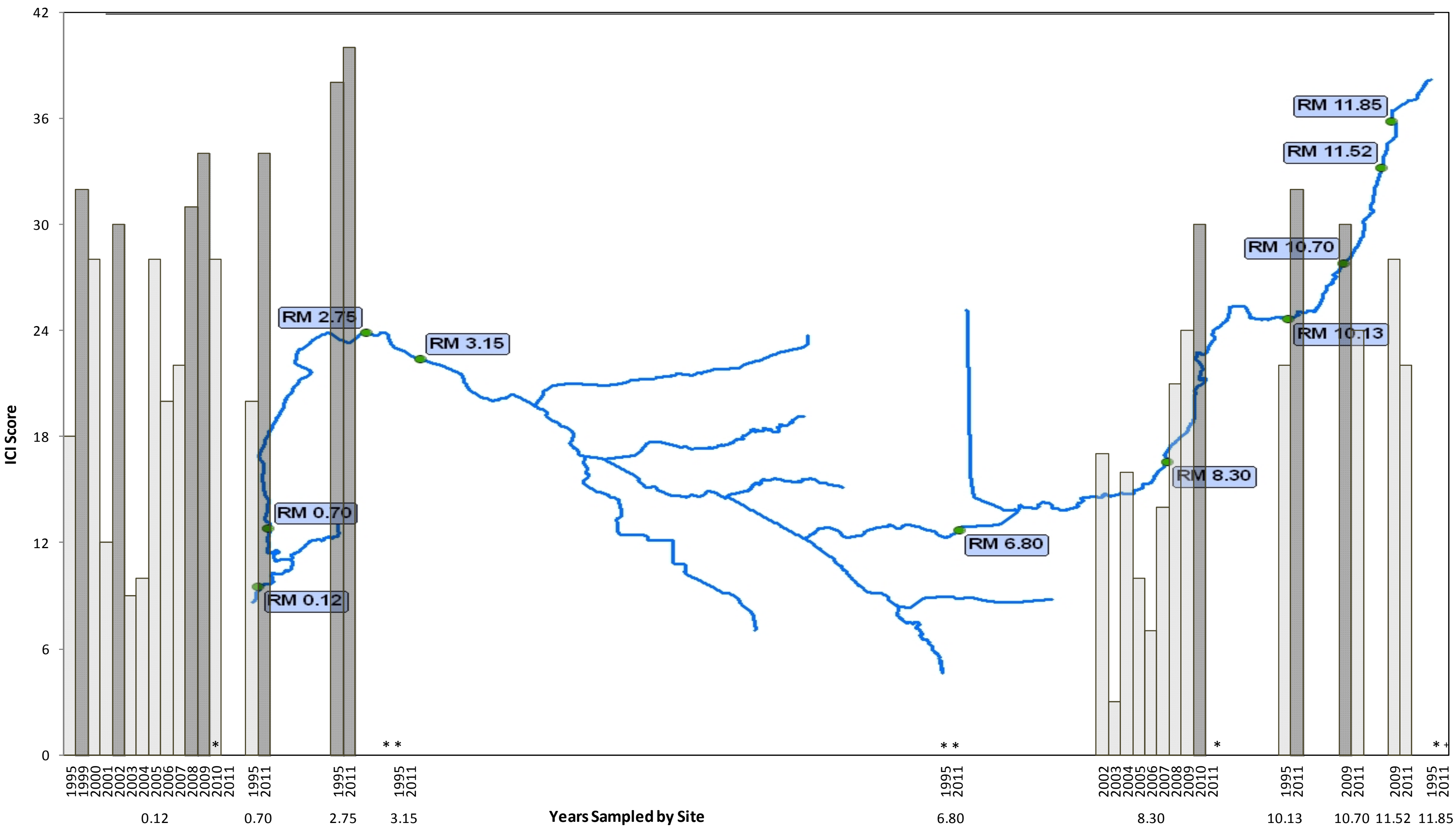
Scoring criteria for all ten metrics is dependent upon drainage area. The scoring of an individual sample is based on the relevant attributes of that sample compared to equivalent data from reference sites in the Erie-Ontario Lake Plain (EOLP) ecoregion. Metric scores range from six points for values comparable to exceptional community structure to zero points for values that deviate strongly from the expected range of values based on scoring criteria established by Ohio EPA (1989). The sum of the individual metric scores resulted in the ICI score for that particular location. The total metric score corresponds to a narrative rating of *Exceptional, Very Good, Good*, *Marginally Good, Fair, Poor,* or *Very Poor.*

When the quantitative sample was not collected, the macroinvertebrate community was evaluated and given a narrative rating based upon the qualitative sample, EPT taxa, field sampling notes, best professional judgment, and other relevant information. This information was also used at RM 11.52 and 10.13 to further evaluate the narrative ratings given by the ICI scores, as the HDs collected at these sites were partially buried at the time of retrieval.

Results and Discussion

The WWH ICI criterion in the EOLP ecoregion is 34. A site is considered in non-significant departure if it is within 4 ICI units of the criterion. Therefore, an ICI score of 30 is considered to be in attainment. Table 7 shows the 2011 ICI scores for sites where HDs were collected and narrative ratings for each site. On the following page, Figure 5 shows the historical ICI scores for each site. ICI scores from surveys conducted prior to the implementation of Ohio EPA's Credible Data Program in 2006 are included for reference purposes only.

Figure 5. 1995-2011 Mill Creek Invertebrate Community Index (ICI) Scores



* HDs not found or unrecoverable.
⁺ HD not installed due to site limitations.
Dark gray shading indicates attainment of the WWH biocriterion (≥ 30 ICI units).

At RM 0.12 and 8.30, scores from 2002, 2003, 2004, 2006, and 2008 represent the average of two ICI scores.

Table 7. 2011 Mill Creek ICI Results							
River Mile	ICI Score	Narrative Rating	Density (organisms per ft^2)	Total No. of Taxa	Total No. of Qualitative Taxa	No. of Qualitative EPT Taxa	% Tolerant***
11.85	---	*Very Poor**	---	---	20	2	---
11.52	22	*Fair*	664.0	32	21	3	53.4
10.70	24	*Fair*	332.0	35	26	6	21.7
10.13	*32*	*Marginally Good*	375.6	39	32	4	15.9
8.30	---	*Fair***	---	---	23	5	---
6.80	---	*Poor***	---	---	15	3	---
3.15	---	*Poor***	---	---	21	4	---
2.75	**40**	*Good*	390.2	39	26	5	5.9
0.70	**34**	*Good*	766.6	42	35	6	7.6
0.12	---	*Fair***	---	---	19	6	---

* HD not installed; narrative rating based upon best professional judgment
** HD not recovered; narrative rating based upon best professional judgment
***Based upon taxa listed as Moderately Tolerant, Tolerant, or Very Tolerant
Non-significant departure from WWH criterion (≥30 ICI units)
Attainment of WWH criterion (≥34 ICI units)

As seen in Table 7 and Figure 5, ICI scores at RM 0.12, 0.70, 2.75, 8.30, and 10.13 have been improving overall, with several sites currently in attainment of the WWH biocriteria. However, this improvement has not been steady, as the macroinvertebrate community in this highly urbanized stream has historically been subjected to environmental stress. NEORSD's Mill Creek Interceptor broke in February 2000, requiring three months of emergency repairs and releasing millions of gallons of raw sewage into Mill Creek downstream of RM 2.00. This may have been the cause of the decline in the ICI score at RM 0.12 from 2000 to 2001, which had previously been in attainment. The community at RM 0.12 recovered briefly in 2002 only to decline again from 2003 through 2007, possibly due to the construction of the first two phases of the Mill Creek Tunnel. However, the low scores seen in 2003, 2006, and 2007 at RM 8.30, which is upstream of NEORSD CSOs and the Mill Creek Tunnel, indicate that there may have been other watershed factors that affected the macroinvertebrate communities in Mill Creek as well. Benthic macroinvertebrate communities generally respond to and recover from environmental change more rapidly than fish communities, which may account for the greater variation seen in the historical macroinvertebrate data. Reduction or elimination of environmental stressors may result in further improvement to the health of the macroinvertebrate communities in Mill Creek.

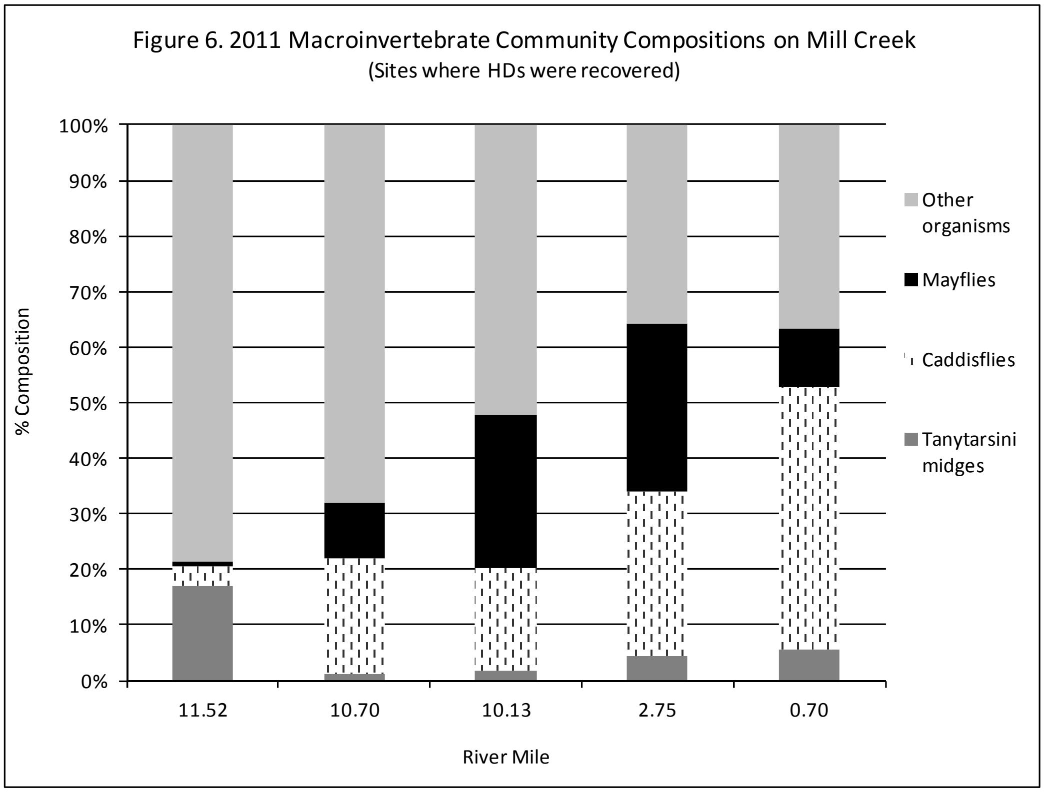
In examining the 2011 data, there did not appear to be a clear trend in the health of the macroinvertebrate community moving from upstream to downstream, so results will be explained in order of increasing performance. The lowest-performing site was RM

11.85 in Canterbury Golf Course with a narrative rating of *Very Poor*. As explained earlier, this site has a very low drainage area, failed to meet the WWH QHEI target score, and also experienced water quality issues with copper and bacteria. Freshwater invertebrates are sensitive to copper, even more so than fish, which may help explain the low number of taxa collected at this site (USEPA 2007).

The two sites performing in the *Poor* range were RMs 6.80 and 3.15, consisting mostly of organisms ranging in pollution tolerance from facultative to tolerant. These sites were among the most contaminated with *E. coli* (Figure 2). While *E. coli* contamination in and of itself may not necessarily be problematic, it may indicate the presence of other substances such as raw sewage, pathogenic organisms and viruses, runoff, and other associated pollutants that may be harmful to biological communities. In 2011, RM 3.15 had the same number of total taxa and EPT taxa seen in 1995, while RM 6.80 had the same number of EPT taxa, but nine fewer total taxa. Given that the HDs were deeply embedded in 1995 and missing in 2011, these sites may have also had rapidly changing (“flashy”) flow regimes and sedimentation issues that affected the organisms’ ability to colonize the substrate.

Flow regimes were also problematic at RM 0.12 in 2011, which flooded out several times due to high water influences from the Cuyahoga River. The substrate of the riffle-run complex shifted, and evidence of new depositional material was noted. The soft material covered the existing substrate and embedded the riffle, displacing many of the macroinvertebrates. RM 0.12 received a narrative rating of *Fair*, as there were six pollution-sensitive EPT taxa collected, but it had a low number of taxa collected overall. Historical data has shown that this site has the capability to achieve WWH attainment, so wet weather may have played an important role in the site’s performance in 2011. RM 8.30, which has also historically been improving and was in non-significant departure of the criteria in 2010, received a score of *Fair* in 2011. Based upon qualitative observations, EPT taxa were common in the community, but the total number of taxa was relatively low. Although this site is upstream of NEORSD CSOs, it still had bacteriological contamination and may have had flashy flow conditions due to the record wet weather. The site’s proximity to a landfill and its runoff may have also had a negative impact on the macroinvertebrate community.

Given the habitat limitations and potential for runoff due to the surrounding land use, wet weather may have also influenced the communities at RM 11.52 and 10.70 in Highland Park Golf Course, whose scores declined 6 ICI units from 2009 to 2011. The percentage of pollution-sensitive Tribe Tanytarsini midges declined considerably, and dipterans and other organisms increased by about 50%. However, the abundance of mayflies and caddisflies did improve from 2009 to 2011, particularly at RM 10.70 where six EPT taxa were collected. Figure 6 shows the community composition at the five sites where HDs were recovered in 2011.



There was a water main break discovered on July 12, 2011, about 100 yards upstream of RM 10.70 that discharged to the creek and was subsequently repaired. It is unclear how long this discharge occurred and whether it negatively affected the macroinvertebrate community. However, there is a large pond located halfway between RM 11.52 and 10.70 that may have influenced the macroinvertebrate communities by altering water chemistry conditions. Temperature was an average of three degrees Celsius higher downstream at RM 10.70, but conductivity, total solids, and total dissolved solids were over 50% lower downstream of the pond and total suspended solids were 22% lower. This reduction in solids may have contributed to the higher prevalence of pollution-sensitive EPT taxa and lower percentage of tolerant organisms at RM 10.70 compared with RM 11.52. Post-construction monitoring after the completion of the habitat restoration project in the area may give a better indication of these two sites' potential to maintain healthy macroinvertebrate communities.

Faring better in 2011 was RM 10.13, which received a narrative rating of *Marginally Good* and was within non-significant departure of the WWH biocriterion, effectively attaining it. This was a large improvement over the *Fair* narrative rating it received in 1995. This site has a defined riffle-run complex, margin habitats and diverse cover, and deep pools. As seen in Figure 6, this site had a relatively similar community composition to RM 2.75, although dipterans and other organisms were more predominant. Its percentage of tolerant organisms (15.9%) consisted mainly of oligochaetes and midges (Table 7). Given the site's excellent habitat and other relevant field observations, it is possible that the site may have scored higher if the HD had not been partially buried.

The macroinvertebrate communities at RM 2.75 and RM 0.70 were the highest-performing of the ten sites in 2011, receiving narrative ratings of *Good* and achieving attainment of the WWH biocriterion. Both sites had a low percentage of tolerant organisms (Table 7), and unlike the other sites, dipterans and other organisms comprised less than half of the communities (Figure 6). Although the diversity of mayfly and caddisfly taxa was similar between the two sites, RM 2.75 had a fairly balanced population of mayflies and caddisflies, whereas RM 0.70 had a higher predominance of caddisflies.

Conclusions

Overall, the results of field sampling activities in Mill Creek in 2011 seemed to reflect the record wet weather experienced in 2011. *E. coli* densities were elevated throughout the creek, and some sites, particularly RM 0.12, showed evidence of wet weather flow regimes and the resultant undesirable habitat changes. The sites varied somewhat in habitat quality, with the best habitat found at RM 10.13 by Northfield Road and the most limited habitat found shortly upstream within the golf courses. Mill Creek Falls, located at RM 2.80, appeared to significantly influence the distribution of the fish community and effectively halt further upstream migration of species from the Cuyahoga River. The macroinvertebrate communities did not appear to be affected by the presence of Mill Creek Falls like the fish were. They may have been more affected by water quality problems and elevated flows caused by the wet weather conditions.

Based upon the fish and benthic macroinvertebrate sampling results, RM 0.70 achieved full attainment of the WWH biocriteria, and RM 0.12 and RM 2.75 achieved partial attainment. All of the sites upstream of Mill Creek Falls were in non-attainment, largely due to the poorly performing fish communities. Efforts to improve the health of the watershed, such as CSO control and IDDE efforts and the habitat restoration project in Highland Park Golf Course, as well as a return to normal amounts of precipitation, may result in an improvement of the health of the biological communities in Mill Creek.

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References

Cuyahoga County Board of Health. (2012). Comprehensive Outfall Database, Phase II Sampling Summary Report, 2005-2010.

DeShon, JE. (1995). Development and application of the Invertebrate Community Index (ICI). In Davis and Simon (Eds.), *Biological assessment and criteria, tools for water resource planning and decision making* (pp. 217-243). Boca Raton, FL: Lewis Publishers.

National Oceanic and Atmospheric Administration (NOAA). (2012). Ohio Climate Division 3 Precipitation, January-December 1895-2011. NOAA's National Climatic Data Center. Information accessed on January 20, 2012 from http://www.ncdc.noaa.gov/temp-and-precip/time-series/index.php

Ohio Administrative Code. OAC 3745-1 (October 15, 2009).

Ohio Environmental Protection Agency. (1987a, updated January 1988, September 1989, November 2006, and August 2008). *Biological criteria for the protection of aquatic life: Volume II: Users manual for biological field assessment of Ohio surface waters.* Columbus, OH: Division of Water Quality Planning and Assessment, Ecological Assessment Section.

Ohio Environmental Protection Agency. (1987b, updated September 1989, March 2001, November 2006, and August 2008). *Biological criteria for the protection of aquatic life: Volume III: Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities.* Columbus, OH: Division of Water

Quality Planning and Assessment, Ecological Assessment Section.

Ohio Environmental Protection Agency. (1999). *Biological and Water Quality Study of the Cuyahoga River and Selected Tributaries, Volume 1*. (Ohio EPA Technical Report MAS/1997-12-4). Columbus, OH: Division of Surface Water.

Ohio Environmental Protection Agency. (2003). *Total Maximum Daily Loads for the Lower Cuyahoga River*. Columbus, Ohio: Division of Surface Water, Water Standards and Technical Support Section.

Ohio Environmental Protection Agency. (2006). *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)* (Ohio EPA Technical Bulletin EAS/2006-06-1). Columbus, OH: Division of Surface Water, Ecological Assessment Section.

Ohio Environmental Protection Agency. (2009a). Highland Park Stream Restoration, Project number 392938-01, Awarded to the Northeast Ohio Regional Sewer District in December 2008. Project title listed in a chart located at http://epa.ohio.gov/LinkClick.aspx?fileticket=bhdBT9HTlCs%3d&tabid=2200

Ohio Environmental Protection Agency. (2009b). *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices.* Columbus, OH: Division of Surface Water.

United States Environmental Protection Agency. (2007). *Aquatic life ambient freshwater quality criteria – copper* (EPA-822-R-07-0001). Washington, DC: Office of Water, Office of Science and Technology.