

NORTHEAST OHIO REGIONAL SEWER DISTRICT

2010 Dugway Brook Biological, Habitat, Water Chemistry Baseline Assessment Study



**Prepared by
Water Quality and Industrial Surveillance Division**

Introduction

In 2010, the Northeast Ohio Regional Sewer District (NEORSD) continued to proceed with a baseline assessment study at sites on Dugway Brook, a tributary to Lake Erie (Figure 1). The purpose of the study was to collect data at select locations on Dugway Brook prior to completion of the Dugway East Interceptor Relief Sewer (DEIRS) construction project. Construction on the DEIRS project began in the spring of 2009 and is expected to be completed by early 2012. This project entails providing wet weather relief in the existing Dugway East Interceptor Sewer in the cities of Cleveland and East Cleveland. In 2009, baseline data was gathered on the East and West Branches of Dugway Brook under a variety of flow conditions. The 2009 sampling included fish and benthic macroinvertebrate sampling, water chemistry and bacteriological sampling, and habitat assessments.

The same sampling was completed again in 2010 with an additional site on the west branch of Dugway Brook at the Lakeview Cemetery Dam site at River Mile (RM) 2.40. Data collected at this site also is expected to be used for future reference prior to the start of construction of the Dugway West Interceptor Relief Sewer (DWIRS).

As of March 2010, the *Ohio Administrative Code* 3745-1-07 (Ohio EPA, 2009a) indicated that, the “Outside Mixing Zone Maximum” (OMZM) and “Outside Mixing Zone Average” (OMZA) water quality criteria identified for warmwater habitat use designation apply to water bodies not assigned an aquatic life use designation. In 2010, chemical water quality criteria identified for the warmwater habitat (WWH) use designation were applied for Dugway Brook at all the sampling locations.

Although Dugway Brook has no Aquatic Life or Recreational Use Designation for biological and bacteriological criteria, the biological criteria and Primary Contact Class B Recreational Use Criteria for *Escherichia coli* (*E. coli*) were applied to all the sites for comparative purposes only. The biological integrity of Dugway Brook was assessed at RM 0.37 (downstream from Lakeshore Boulevard) and RM 2.40 (Lakeview Dam). Dugway Brook was evaluated at these sites using Ohio EPA’s Qualitative Habitat Evaluation Index (QHEI), Index of Biotic Integrity (IBI), Qualitative Community Tolerance Value (QCTV), and Invertebrate Community Index Score (ICI).

To evaluate the macroinvertebrate community, a Hester-Dendy artificial substrate sampler (HD) was installed in Dugway Brook at Lakeshore Boulevard at RM 0.37. However, during the course of inspections, it was found that the artificial sampler was not completely submersed for the full six-week installation period due to fluctuations of the water level caused by Lake Erie. The artificial sampler was incidentally removed two weeks earlier than the six-week required installation period. Since the HD was removed on September 10, 2010, it was too late in the season for reinstallation. The sampler was processed and an ICI score was calculated. A QCTV score was also calculated from the

qualitative sample that was collected. Sampling will again be performed after construction completion of the DEIRS to determine any biotic improvement from elimination of sanitary sewer overflows. Sampling was conducted by NEORSD Level 3 Qualified Data Collectors certified by Ohio EPA in Fish Community and Benthic Macroinvertebrate Biology, Chemical Water Quality and Stream Habitat Assessments as explained in the NEORSD study plan approved by Ohio EPA on May 12, 2010.

Figure 1 is a map of the sampling locations on Dugway Brook. Table 1 indicates the sampling locations and includes river mile (RM) where applicable, latitude/longitude, description, and the types of surveys conducted.

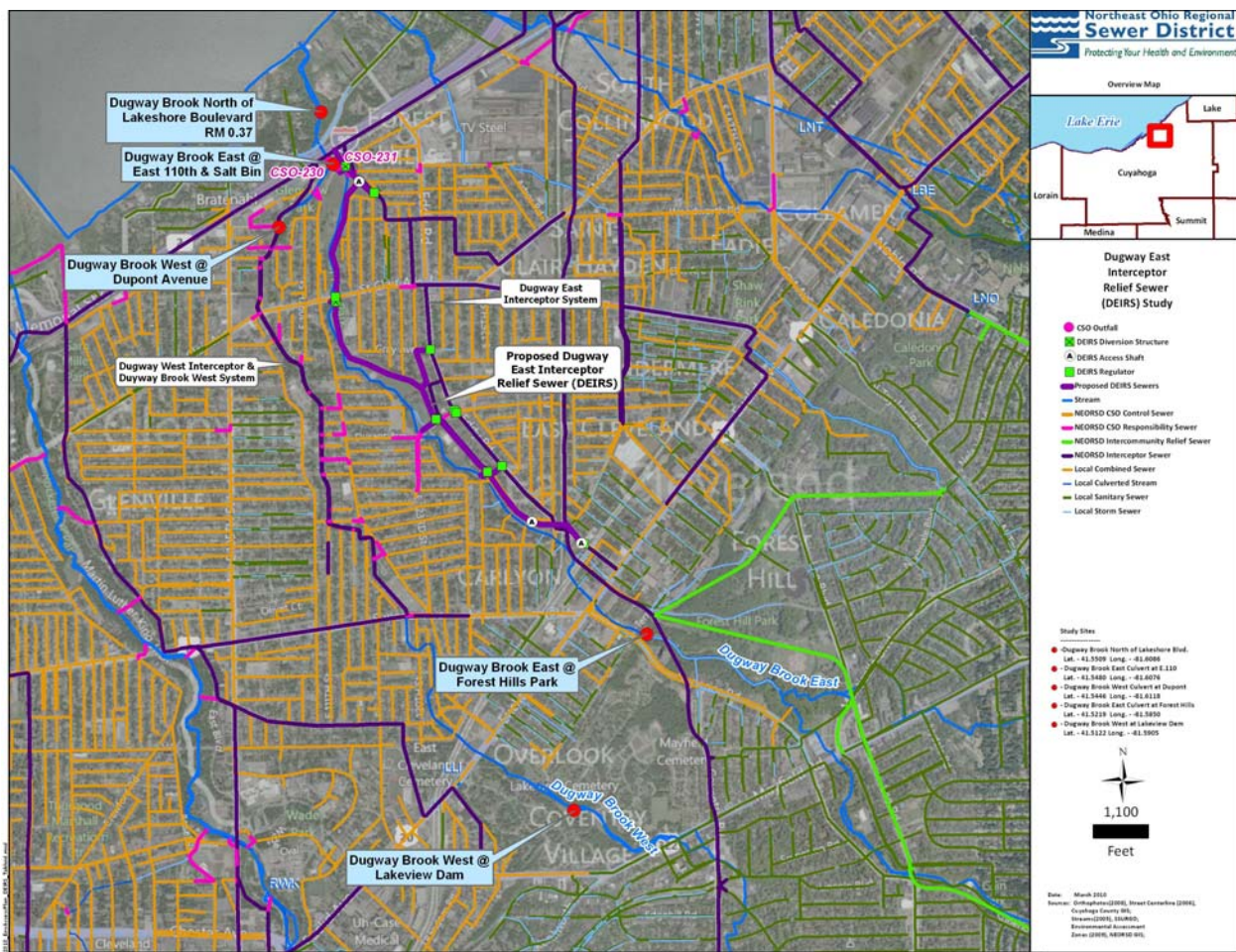


Figure 1

Table 1.

Location	Latitude	Longitude	River Mile	Description	Quadrangle	Purpose
Forest Hills Park Forest Hills Blvd. and Forest Hills Ave.	N41.5218°	W81.5850°	N/A	Dugway Brook, East Branch Upstream of DEIRS Alignment	East Cleveland	Evaluate water chemistry prior to DEIRS completion
East 110 th Street Salt Dome Road	N41.5479°	W81.6076°	N/A	Dugway Brook, East Branch Downstream of DEIRS Alignment	East Cleveland	Evaluate water chemistry prior to DEIRS completion
North of Lakeshore Blvd. North of NEORS D Netting facility	N41.5509°	W81.6086°	0.37	Dugway Brook Main Branch North of Lakeshore Blvd.	East Cleveland	Evaluate water chemistry, fish, habitat and macroinvertebrates
Lakeview Cemetery downstream of NEORS D flood control dam.	N41.5122°	W81.5905°	2.40	Dugway Brook, West Branch Upstream section	East Cleveland	Evaluate water chemistry, fish, habitat and macroinvertebrates prior to DWIRS completion
10658 Dupont Avenue	N41.5446°	W81.6118°	N/A	*Dugway Brook, West Branch	East Cleveland	Evaluate water chemistry prior to DWIRS completion
*This is the furthest downstream access location of all regulators tributary to the West Branch of Dugway Brook. It should be noted that there are two regulators (D-61 & D-03A) downstream of this location that will not be captured during sample collection as there is no access to the culvert downstream of this location.						

Water Chemistry and Bacteriological Sampling

In 2010, water quality samples were collected from Dugway Brook at the five locations listed in Table 1. Twenty-five samples were collected from July 29, 2010, to August 26, 2010. All of the water chemistry sampling followed the procedures listed in the *Manual of Ohio Environmental Protection Agency's (Ohio EPA) Surveillance Methods and Quality Assurance Practices (2009a)*.

Water quality monitoring of Dugway Brook prior to the DEIRS completion will provide baseline data which, when compared to data to be collected after work completion, will demonstrate any improvements in water chemistry and the aquatic life community present in the brook.

For each water quality sampling event, a sample was collected in two 4-liter disposable polyethylene Cubitainers with disposable polypropylene lids, two 473-mL

plastic bottles, and one 500-mL treated bacteriological bottle. One of the plastic bottles was field preserved with trace nitric acid and the other was field preserved with trace sulfuric acid. All samples were placed in a cooler with ice and stored on the locked vehicle until the samples were transferred to the NEORSD's Analytical Services sample receiving. All samples were released to an authorized Analytical Services employee with a Chain of Custody.

Field parameters were measured in stream, when flow conditions permitted. Field analyses included the use of a YSI-556 MPS Multi-Parameter Water Quality Meter or a YSI 600 XL sonde to measure dissolved oxygen, water temperature, conductivity and pH at the time of sampling. A Surface Water Condition Sampling Field Data Form was filled out for each site during each sampling event.

During the five sampling events, three sample duplicates and three field blanks were obtained for QA/QC purposes. The sample duplicates were collected at RMs 0.37, 2.40, and Dupont Avenue. The sample field blanks were collected during the month of August. The field blank results appeared to be normal and did not show any signs of contamination through handling or transportation. The results from the sample duplicates were compared to the primary sample using relative percent difference (RPD) see Formula 1:

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

X= is the concentration of an analyte in the primary sample

Y= is the concentration of the same analyte in the duplicate sample

An RPD was calculated for each of the 43 individual chemical parameters reported on the Certificates of Analysis. The acceptable RPD between duplicate and primary samples is less than or equal to 30 percent. Any difference greater than 30 percent was investigated as to the cause of the disparity. After evaluating the RPD values, nineteen potential disparities were found (Table 2). All the reported concentrations of the below chemical parameters were less than 10 times their practical quantitation limit (PQL), except for, iron, manganese, total metals and turbidity, which were greater than 10 times the PQL. The RPD may be inflated because of site limitations as samples were collected from a manhole and not an open stream. The higher RPD values may be likely because of the low concentrations measured for those parameters.

Table 2.

2010 Dugway Brook Relative Percent Difference (RPD)			
Site	Date	Parameter	Percent (%)
River Mile 0.37	August 5, 2010	COD	80
River Mile 2.40	August 12, 2010	Co	40
10658 Dupont Ave.	August 19, 2010	Al	95.3
		As	78.5
		Be	133.3
		Cd	72
		Cr	137.2
		Cu	94.5
		Fe	53
		Pb	141.4
		Sb	59.5
		V	135.8
		Tl	48
		Zn	102.5
		Mn	49.8
		Co	89.1
		Total metals	102
Turbidity	119.3		
Ti	142.8		

Results and Discussion

Dugway Brook is not assigned an aquatic life use designation; however, the OMZM and OMZA water quality criteria identified for warmwater habitat use designation apply to water bodies not assigned an aquatic life use designation (Ohio Administrative Code 3745-1-07). Therefore the warmwater habitat designated use was applied. The Lake Erie Drainage Basin (LEDB) human health non-drinking water criteria and the wildlife criteria also apply to each site. The water chemistry samples collected at each site were compared to the applicable Ohio Water Quality Standards for the designated uses to determine attainment (Ohio EPA, 2009a).

All sites may have exceeded the Protection of Wildlife OMZA criterion for mercury for all thirty-day periods. The Protection of Human Health Nondrinking water OMZA criterion for mercury was also exceeded for four thirty-day periods at the East 110th Street location, three periods at Dupont Avenue, four periods at Lakeshore Boulevard, four periods at the Lakeview Dam site, and four periods at the Forrest Hills Boulevard site. These are considered potential exceedances because all mercury concentrations were either below the minimum detection limit (MDL) or estimated to be

between the MDL and PQL. Since the criteria are below the MDL, attainment cannot be determined.

Since the MDL is greater than the mercury criteria, it cannot be said for certain whether there was an actual exceedance of the mercury criteria in these cases. However, use of the low-level EPA Method 1631E for the water chemistry samples collected on the Cuyahoga River on June 22, 2011 resulted in mercury concentrations just below the detection limit for EPA Method 245.1. Based on this data, it is expected that the use of EPA Method 1631E for all of the samples may have resulted in actual exceedances of the criteria.

Lead exceeded the Protection of Aquatic Life OMZA criterion for one 30-day period (8/19 – 9/17) for the Dupont Avenue site. This exceedance coincided with dry weather and could not be explained.

The Ohio water quality criteria for the protection of recreational uses apply outside the mixing zone to all water bodies assigned a recreational use designation (Ohio Administrative Code 3745-1-07), however, there is no recreational use designation on Dugway Brook. Bacteriological criteria do not apply on Dugway Brook, however, the *E. coli* criterion was applied for informational purposes only. With the exception of the Forrest Hills site, every site would have been in non-attainment of the *E. coli* criterion for Class B primary contact recreation use by exceeding the single sample maximum of 523 colony counts per 100 milliliters (CFU/100 ml) in more than ten percent of the samples taken in a 30-day period for all four thirty-day periods. Also, all sites, including the Forrest Hills site, would have been in non-attainment of the seasonal geometric mean of 161 CFU/100 mL. The Forrest Hills site met the *E. coli* criterion for Class B primary contact recreation use for one 30-day period from August 19, 2010 thru September 17, 2010. Table 3 lists the *E. coli* sample results for each site.

Sample Date	Lakeview Cemetery RM 2.40	Forrest Hills Park	East 110th Street	Dupont Avenue	Lakeshore Boulevard RM 0.37	Precipitation within 3 days of Sampling *Rain Gauge RCL & RWK
	<i>E. coli</i> (colony counts per 100mL)					(Total Inches)
7/29/2010	1,560	1,460	20,000	3,060	2,922	0.78
8/05/2010	4,255	4,059	67,000	2,686	64,000	1.23
8/12/2010	12,700	9,200	19,400	8,200	27,200	0.34
8/19/2010	760	175	2,549	39,000	2,150	0
8/26/2010	315	275	2,000	6,600	1,660	0

*Rain Gauges at Cleveland Hts. High School (RCL) & Wade Park Maintenance Bldg (RWK)

The elevated levels of *E. coli* from sampling during dry weather on August 19 and 26, 2010, at East 110th Street, Dupont Avenue and RM 0.37 sites may have been caused by NEORSD dry weather overflows. NEORSD documented two dry weather overflows to Dugway Brook in 2010 (Table 4). These dry weather overflows may have been overflowing to the brook before their discovery which resulted in elevated *E.coli* levels on sampling dates. Other sources of sanitary contamination may include unknown sanitary sewage overflows within the local collection system.

Date found	Location and stream branch	Overflow (gal./event)
8/23/2010	D-38, East 111 th Street & Primrose Avenue	565
8/24/2010	CD-16, 10662 Helena Drive	9,263

The NEORSD Community Discharge Program Status Report lists eight Sanitary Sewer Overflows (SSOs) that are tributary to Dugway Brook (Table 5).

Community	SSO #	Location
Cleveland Heights	CH-11	Hampshire Lane at Mayfield Rd.
Cleveland Heights	CH-24	3003 Euclid Heights Blvd.
Cleveland Heights	CH-28	Euclid Heights Blvd. and Lee Rd.
Cleveland Heights	CH-10	Hampshire Lane at Mayfield Rd.
Cleveland Heights	CH-25	Cumberland Rd. and Somerton Rd.
Cleveland Heights	CH-30	South Compton and Blanche Rd.
Cleveland Heights	CH-14	Derbyshire at Euclid Hts. Blvd.
University Heights	32	Meadowbrook Blvd. and Canterbury Rd

SSOs, CSOs and other unknown sources of sanitary contamination to the Dugway Brook watershed may be contributing to the elevated bacteria levels during wet¹ and/or dry weather conditions.

Habitat Assessment

Methods

The Qualitative Habitat Evaluation Index (QHEI) score was determined for the open-water sites on Dugway Brook at RM 0.37 and RM 2.40 (Figure 2). The QHEI,

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 are considered wet weather samples; greater than 0.25 inches, the samples collected that day and the following two days are considered wet weather samples.

developed by Ohio EPA, is used to assess the aquatic habitat conditions at each sample location by providing an evaluation of the physical components 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. These metrics describe the physical attributes of a stream and may be important in explaining why fish species are present or absent. A more detailed description of the QHEI can be found in Ohio EPA's (2006), *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)*. The Ohio Environmental Protection agency has set a QHEI target goal of 60 for WWH with a score of ≥ 60 indicating adequate habitat diversity to support a warmwater habitat fish community. The QHEI field sheets for these sites are available upon request.

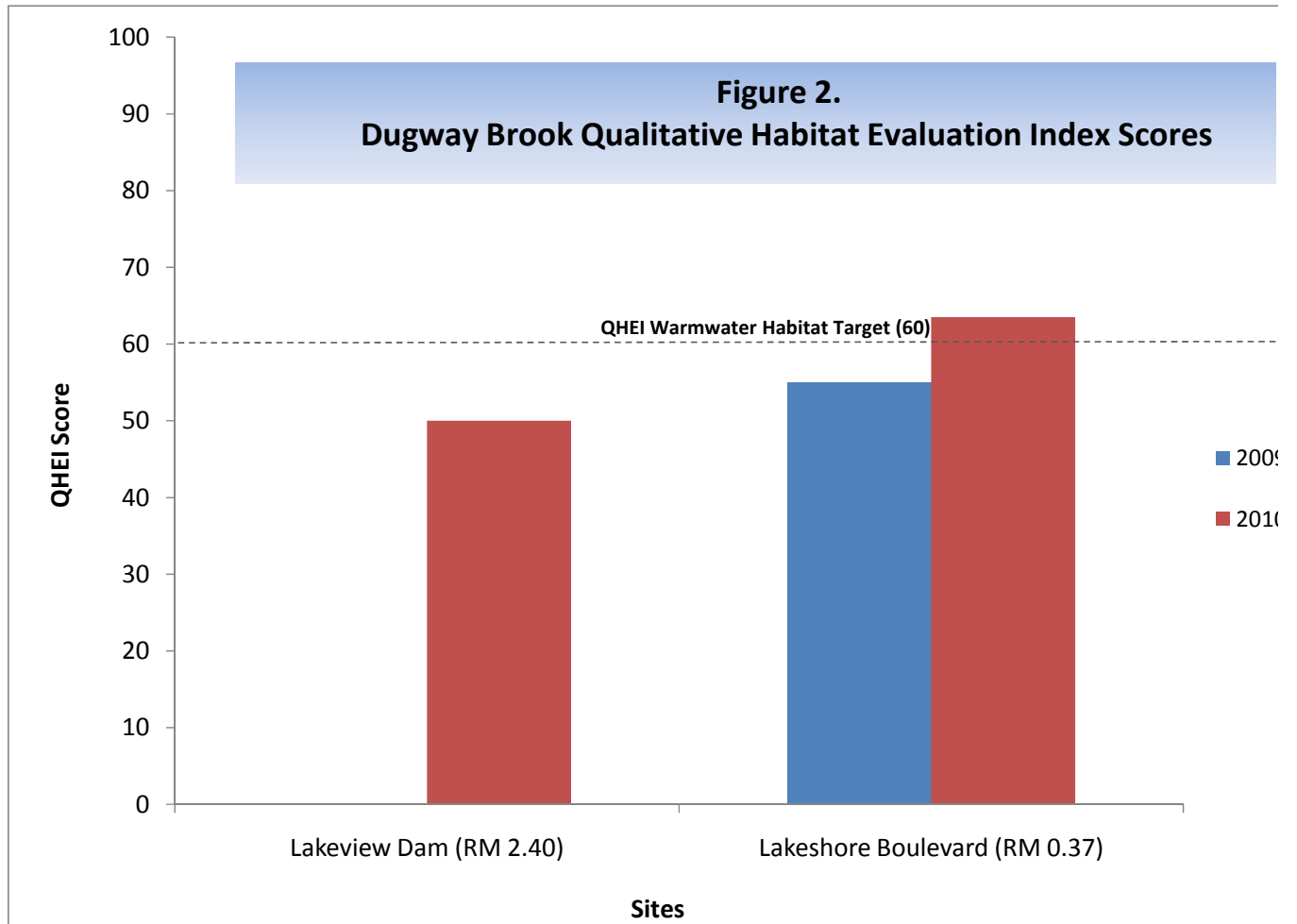
Results and Discussion

On August 12, 2010, a QHEI score of 63.5 was measured on Dugway Brook at RM 0.37 (Table 5). Sand and muck were the two predominant substrate types within the assessment area. The stream had moderate instream cover with high quality undercut banks, woody debris and deep pools present in the greatest amounts. A functional stable riffle with a cobble/boulder substrate was scored in 2010, increasing the riffle metric score to 5 points. No functional riffle was present in 2009 due to the Lake Erie seiche effect on the brook. The lack of a riffle in 2009 decreased the stream habitat quality for that year.

The west branch of Duway Brook at RM 2.40 received a QHEI score of 50 on August 12, 2010. Cobble and gravel were the predominant substrate types. This relatively straight, poorly developed channel scored low in the instream cover metric, showing sparse amounts of cover present. Instream cover consisted of some boulders, rootmats and shallows. Very shallow pools and no functional riffle present all contributed to the low score measured at RM 2.40. The stream habitat was not assessed in 2009 at this site.

Table 6 lists the QHEI results from each site in 2009 and 2010. Figure 2 shows how these results compare to the QHEI target score of 60, at or above which a site should be able to support a warmwater habitat fish community.

Site	Location	2009 Score	2010 Score
RM 2.40	Lakeview Dam	-	50 (<i>Fair</i>)
RM 0.37	Lakeshore Boulevard	55 (<i>Good</i>)	63.5 (<i>Good</i>)



Electrofishing

Methods

Two electrofishing passes were conducted on Dugway Brook at RM 0.37 and RM 2.40. Sampling was conducted using longline electrofishing techniques and consisted of shocking all habitat types within a sampling zone, which was 0.15 kilometers in length, while moving from downstream to upstream. Electrofishing methods followed Ohio EPA protocols described in *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). The results from this sampling were used to calculate an Index of

Biotic Integrity (IBI) score for the site. A Modified Index of Well Being (MIwb) was not calculated because these sites had a drainage area less than twenty square miles.

A list of the species, numbers, pollution tolerances and incidence of DELT anomalies for fish collected during the fish assessments is available upon request.

Results and Discussion

Dugway Brook is not assigned an aquatic life use designation; however, the warmwater habitat biocriteria was applied for comparison purposes.

IBI scores of 38 and 36 (*Marginally Good*) were obtained on Dugway Brook at RM 0.37 in 2009 and 2010, respectively (Figure 2) (Table 7). The site fell within non-significant departure (≤ 4 IBI units) of the WWH IBI biocriterion of 40 both times.

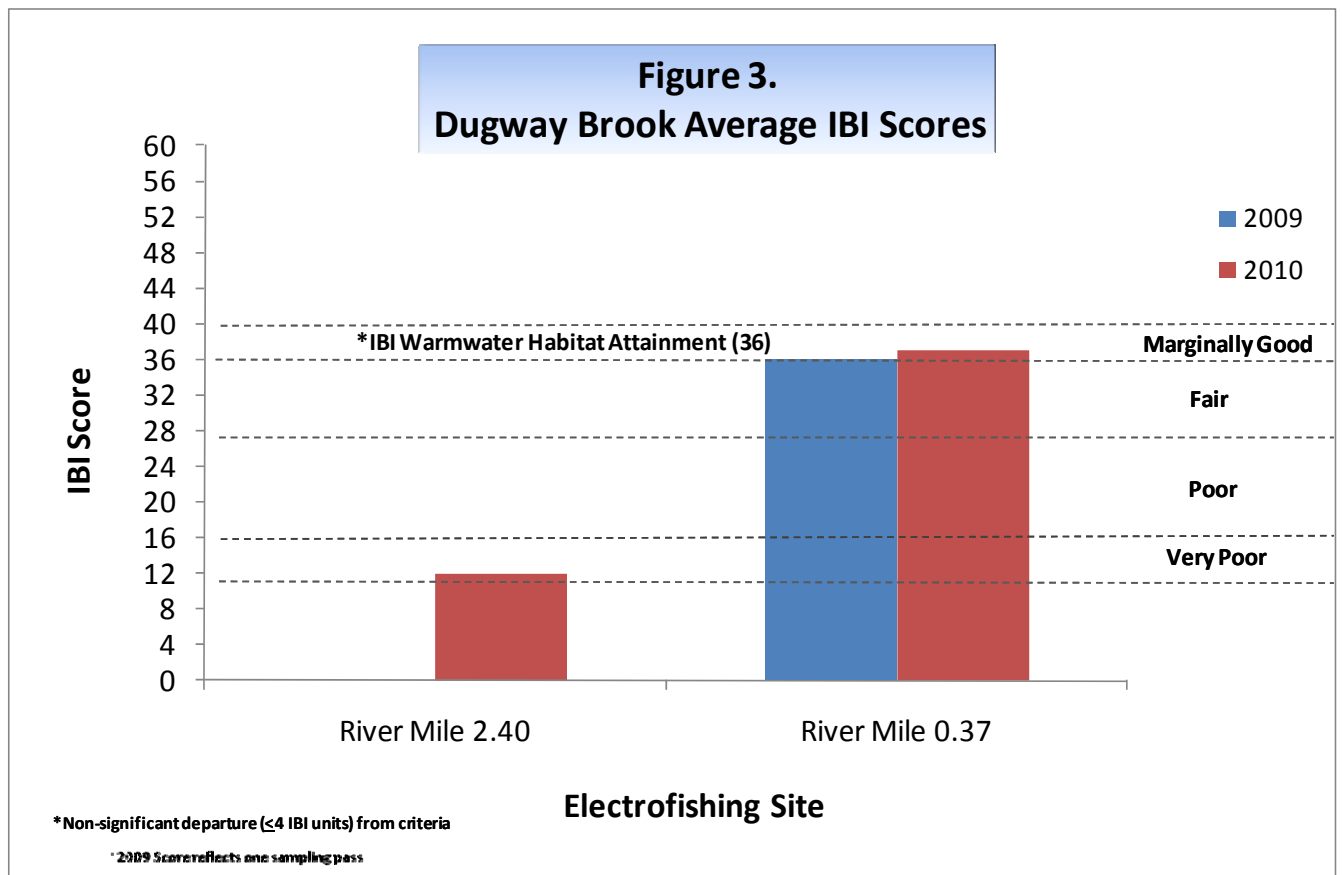
A total of ten species were collected at this site, the dominant fish being the pumpkinseed sunfish, comprising seventy-seven percent of the total fish collected. The remaining catch was comprised of common emerald shiners, common white sucker, common carp, largemouth bass, fathead minnows, golden shiners, bluegill sunfish, round gobies and sand shiners. At this site, which is the most downstream site and closest to Lake Erie; the high number of sunfish species and emerald shiners may have entered the Brook from Lake Erie. The highest metric scores (5) were obtained for the relative abundance of native fish collected (1,970) and a high proportion of insectivores present (95%). The low proportion of tolerant fish (2.7%), omnivore fish (2.6%) and pioneering species of fish (1.5%) also scored a (5) which resulted in the increased IBI scores.

In 2010, one of the principal sources of impairment in Dugway Brook is organic enrichment, which was evident in this stretch of stream when sampling for fish. The organic enrichment may deter other pollution sensitive fish from Lake Erie from seeking desirable habitats in the brook. At RM 0.37, evidence of nuisance odors from the disturbance of the substrate of organic material along the creek bottom was documented when completing both electrofishing passes. Although this did not appear to have an impact on the IBI score at the time, continuous organic enrichment may exacerbate biological impacts in following years.

An IBI score of 12 (*Very Poor*) was calculated for RM 2.40 for each electrofishing pass (Figure 2). No fish were collected on the first electrofishing pass, and a total of one fathead minnow was collected on the second pass. The fathead minnow is a highly pollution tolerant species. The sampling zone for this site is situated between Lakeview Dam, which is approximately $\frac{1}{4}$ mile upstream of the site and two Lakeview Cemetery ponds, which the west branch of Dugway Brook drain into before entering the culverted

section near Euclid Avenue. Upstream of the sampling zone, the brook consists of a concrete bottom up to the dam. This type of habitat is not suitable to sustain a fish population. The population of fish in the sampling zone may be impacted by the unsuitable habitat upstream and downstream of the sampling zone. The ponds downstream of the sampling zone may not be suitable for fish propagation due to limited upstream fish migration. Even though the biological criterion is not applicable to Dugway Brook, this site obtained the lowest possible score for the calculation of an IBI for headwater sites.

Site	Location	1st Pass	2nd Pass	Average	Narrative Rating
RM 0.37	Lakeshore Boulevard	38	36	37	<i>Marginally Good</i>
RM 2.40	Lakeview Dam	12	12	12	<i>Very Poor</i>



Macroinvertebrate Sampling

Methods

Benthic macroinvertebrates were sampled quantitatively for one six-week period in 2010 using a modified HD substrate sampler in conjunction with a qualitative assessment performed during HD retrieval. The modified HD is a type of sampling that has been utilized by the Ohio EPA since 1973. Methods for sampling followed the Ohio EPA's Biological Criteria for the Protection of Aquatic Life, Volume III (1987b).

The Invertebrate Community Index (ICI) was used as the principal measure of overall macroinvertebrate community condition. Developed by the Ohio EPA, the ICI is a modification of the Index of Biotic Integrity for fish (OEPA,1987a).

The ICI consists of ten individually scored structural community metrics:

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 and non-insects
9. Percent tolerant organisms
10. Total number of qualitative EPT taxa

Macroinvertebrate qualitative samples were sent to Aquatic Macroinvertebrate Taxonomy for identification and enumeration. Specimens were identified to the lowest practical taxonomic level as recommended in Ohio EPA's *Biological Criteria for the Protection of Aquatic Life, Volume III* (1987, updated September 30, 1989; November 8, 2006; and August 26, 2008). The taxa lists and enumerations are available upon request.

Results and Discussion

HDs were installed and retrieved from RMs 0.37 and 2.40 on Dugway Brook in 2010. The ICI scores for each site are listed in Table 6.

River Mile	2009	2010	2010 Narrative Rating
0.37	*24	10	<i>Poor</i>
2.40	-	22	<i>Fair</i>

*Qualitative Community Tolerance Value (QCTV Score)

In 2009, a HD artificial substrate sampler was set in Dugway Brook at Lakeshore Boulevard River Mile 0.37; however, during the course of inspections, the artificial sampler was found to be not completely submersed for the full six-week installation period due to fluctuations of the water level from Lake Erie. The sampler was therefore not processed. A qualitative sample was collected in its place and a QCTV score of 24 was obtained. The QCTV score of 24 had an associated rating of *Fair/Poor* which suggests that the site would not achieve the WWH criterion if it were applicable to Dugway Brook.

In 2010, a HD was set, removed and processed and an ICI score of 10 (*Poor*) was calculated on Dugway Brook at RM 0.37. The majority of individual ICI metrics scored either zero or two, which indicates strong deviation from the range of good values. There were no metric values characteristic of good macroinvertebrate communities collected at this site. Twenty-three different taxa were collected at this site with the taxa *Polypedilum illinoense* group (non-biting fly) being the most abundant (51%). These taxa group are listed as very pollution tolerant.

Data was not collected at RM 2.4 in 2009. In 2010, an ICI score of 22 (*Fair*) was obtained at RM 2.40. The highest number of individuals were from the taxa Turbellaria (flatworms) and Oligochaeta (segmented worms). The metric for number of caddisfly taxa at RM 2.40 received a score of six, which is comparable to an exceptional healthy stream community. The percent Tanytarsini midges and percent caddisflies metrics each received a score of four, which is indicative of good macroinvertebrate communities.

Conclusions

Chemical and bacteriological sampling showed poor results at the Dugway Brook sample sites. Bacteriological criteria do not apply on Dugway Brook, however, the *E. coli* criterion was applied for informational purposes only and if bacteriological sampling data applied every site would have been in non-attainment of the *E. coli* criteria for the seasonal geometric mean of 161 CFU/100 mL. Elevated bacterial contamination during wet and dry weather may have resulted, at least in part, from two documented sources of dry weather overflows (Table 4), and unknown sanitary sewage overflows within the local collection system.

The *Marginally Good* fish community scores at RM 0.37 were attributable to the migration of pumpkinseed sunfish and emerald shiners from Lake Erie. These high numbers of non-resident fish increased the fish metric scores. It is unknown why the macroinvertebrate community is poor at RM 0.37, given the *Marginally Good* fish community present. The presence of organic enrichment on the stream bottom may be a limiting factor for a better macroinvertebrate community.

One fathead minnow was collected in two electrofishing passes at RM 2.40 indicating a *Very Poor* fish community. Poor IBI scores at this site reflected habitat that was not suitable to sustain a fish population. The population of fish in the sampling zone may be impacted by the unsuitable habitat upstream, downstream and in the sampling zone. This is further supported by the fact that the QHEI score at this location did not attain the Ohio EPA target score of 60. The *Very Poor* biological scores are attributable to documented CSOs, SSOs, urban and stormwater runoff into the stream and organic enrichment present at this site.

Although the biological criteria do not apply, both Dugway Brook sites would be in non-attainment of the WWH ICI biocriterion for macroinvertebrates. The potential exists for the macroinvertebrate community to improve over time at RM 2.40, considering the good scores that were achieved in the percent Tanytarsini midge metric and percent Caddisfly metric. The Tanytarsini midge group is relatively intolerant to environmental disturbances, which leaves room for stream improvement.

RM 0.37 demonstrated poor results and none of the ICI metric values were characteristic of good macroinvertebrate communities. Contributing to the low ICI score are organic enrichment present in the stream, documented CSOs, SSOs, urban and stormwater runoff, and a predominate substrate of muck on the stream bottom..

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Analytical Services Division – Completed analysis for all water chemistry sampling

Reference List

- Ohio EPA. 1987a. *Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters* (Updated January 1988; September 1989; November 2006; August 2008). Division of Water Quality Monitoring and Assessment. Columbus, Ohio.
- Ohio EPA. 1987b. *Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities* (Updated September 1989; March 2001; November 2006; and August 2008). Division of Water Quality Monitoring and Assessment. Columbus, Ohio.
- Ohio EPA. 2006. *Manual for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)*. Ohio Environmental Protection Agency, Division of Surface Water. Columbus, Ohio.
- Ohio EPA. 2009a. State of Ohio Water Quality Standards *Ohio Administrative Code* Chapter 3745-1. Revision: Adopted December 15, 2009; Effective March 15, 2010. Ohio Environmental Protection Agency, Division of Surface Water, Standards and Technical Support Section. Columbus, Ohio.
- Ohio Environmental Protection Agency. (2009). *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practice*. Columbus, OH: Division of Surface Water; Division of Environmental Services.