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Natural Resource Stewardship and Science

Cuyahoga Valley National Park Headwater Stream Inventory

Final Report

Natural Resource Report NPS/CUVA/NRR—2024/2628



ON THE COVER
A stream sampled at Cuyahoga Valley National Park.
Photo EnviroScience, Inc.

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Natural Resource Report NPS/CUVA/NRR—2024/2628

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Executive Summary

EnviroScience, Inc. (EnviroScience) was contracted by the National Park Service (NPS) to design and implement a study plan to inventory the headwater stream resources within the Cuyahoga Valley National Park (CUVA). The parameters and expectations of the study are described in a Statement of Work (SOW) developed by NPS staff (NPS, 2021) to collect and analyze data to guide decision-making in the development of management plans to protect these resources within CUVA.

The headwater stream inventory was comprised of three components to evaluate the resources as follows:

1. habitat and biological assessments to classify the streams in the context of the Ohio EPA Primary Headwater (PHW) stream classification system (Ohio EPA, 2020) and the beneficial aquatic life uses promulgated in Chapter 3745-1 of the *Ohio Administrative Code* (OAC), where applicable;

2. fluvial geomorphological assessments to determine stream channel types and to evaluate the potential and degree of streambank erosion associated with the assessment sites; and

3. development and testing of a visitor use impact assessment (VUIA) protocol for potential park-wide application to manage and protect stream resources in the context of public access.

A total of 125 headwater stream sites were assessed to complete the inventory. The SOW identified eighty-three (83) of the sites designated as Primary sites by NPS. These sites were selected to document the condition of headwater streams with watershed areas of approximately 1.0 mi^2. These sites were assessed using desktop methods and field reconnaissance. The final list of sites was modified as appropriate for approval by NPS.

Forty-two (42) additional sites were proposed for assessment as Secondary sites following the assessment of Primary sites according to the SOW and study plan. These sites were selected to either provide additional data within Primary site watersheds or to expand coverage of the inventory within the park to target specific tributaries of interest. All inventoried sites were selected to meet the definition of Primary Headwater (PHW) streams as that term is defined in Ohio EPA headwater stream protocols. The identified locations were used to characterize the biological communities within the streams and to identify factors affecting the ecological integrity and water quality of the headwater streams within CUVA.

A project study plan describing the site assessment activities necessary to meet the objectives of the SOW was developed by EnviroScience and approved by NPS. The assessment methods selected used tools developed by Ohio EPA to classify PHW streams. The PHW classification system identifies three types of PHW streams:

- “Class I” identifies ephemeral streams where water flow is confined to periods of precipitation runoff such as storm events or snowmelt;

- "Class II" PHW streams include intermittent or warm water perennial streams where surface flows dominate the hydrology and fauna inhabiting the streams are adapted to intermittent lack of flow or warm temperature conditions (temperatures > 22 °C for extended periods); and

- "Class III" streams where continual groundwater discharge provides perennial flows at summertime temperatures typically less than 22 °C. Class III PHW streams can support vertebrate and macroinvertebrate taxa with complex life histories requiring cool or cold water stream flows over a multi-year period. The Class III PHW classification is further divided into sub-classes denoted as Class IIIA and Class IIIB based upon the number cold water adapted taxa present using listings developed by Ohio EPA. Both vertebrate (salamanders and/or fish) and macroinvertebrate cold water taxa lists are used for these determinations.

Evaluation of the physical stream habitat potential to support aquatic life was conducted using the Headwater Habitat Evaluation Index (HHEI). The HHEI is designated as a Level 1 assessment method developed by Ohio EPA to predict the potential of small headwater streams to support biological communities indicative of perennial flow conditions. The HHEI is designed to provide a conservative prediction of the PHW stream class with inherent bias towards over-classifying PHW stream classes since it is often used in a regulatory context without supporting biological data.

The PHW evaluation protocols also include simplified biological assessment methods (Level 2 assessments) and definitive biological assessment procedures (Level 3 assessments) for classification of PHW streams. For the CUVA headwater stream inventory, the assessment protocols for Level 3 PHW analysis were used to provide definitive data for assignment of stream classes.

Stream channel geomorphology and stream types were classified according to the Rosgen Classification of Natural Rivers system (Rosgen, 1985, 1994, 1996). Measurements of stream channel gradient, widths at bankfull and flood prone elevations, sinuosity, and bed material were combined to assign classifications for valley and stream types. In addition, streambank condition and erosion hazard potential were assessed using measurements to derive Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) values for study banks at 123 of the 125 headwater stream inventory sites using protocols developed by Dave Rosgen (Rosgen, 2001a, 2001b, 2009). Results of these evaluations are used to determine whether patterns of biological community outcomes can be discerned with respect to stream and streambank conditions.

Habitat assessment using the HHEI resulted in values ranging from 56 to 93, with a mean HHEI score of 75.6. Of the 125 habitat assessments made within the study area, over 80% (100 sites) yielded HHEI scores equal to or greater than 70, a score predictive of Class III PHW biological communities. An additional 22 sites with HHEI scores less than 70 were also classified as Class III PHW streams based upon the complete Level 1 PHW screening process. Only three of the sites assessed during the inventory were classified as Class II PHW streams based upon the HHEI Level 1 classification analysis, and none of the sites were classified as Class I PHW using the HHEI.

Comparison of the HHEI classification results to definitive biological community outcomes (Level 3 analyses) reveals the limitations and strengths of the use of habitat assessments alone for PHW classification. Sixteen percent of the sites were overclassified when the Level 1 and Level 3 results were compared (i.e., Class II or Class I streams classified as Class III) and 4.8% of the sites were under classified (i.e., Class III streams classified as Class II) using the HHEI scores alone. These outcomes are consistent with the conservative interpretive approach built into the HHEI methodology which is intentionally overprotective of stream resources.

Biological site assessments using the Ohio EPA Level 3 PHW protocols found that 103 (82.4%) of the inventoried streams meet the definition of perennial Class III PHW with cool or cold thermal regimes governed by groundwater fed flow characteristics. The streams were further classified into Class IIIA (diverse native fauna) and Class IIIB (superb native fauna) stream types based upon the composition of the biological communities of aquatic species adapted to these conditions. Roughly half of the Class III streams met the characteristics for Class IIIB PHW streams, indicating support of cold water adapted fauna. Twenty inventoried streams (16%) were found to have either intermittent flow conditions or were marginal warm water perennial PHW systems (Class II) and two sites were determined to be ephemeral channels (Class I) based upon the biological assessment results.

Preserved macroinvertebrate voucher samples were collected from all 125 CUVA headwater stream inventory sites using Ohio EPA qualitative sampling methods. Taxonomic evaluation of the samples identified a total of 256 macroinvertebrate taxa of which 35 are listed as cold-water indicators by Ohio EPA. The number of macroinvertebrate taxa collected per site ranged from 1 to 57, with a median number of 22 taxa collected in each sample. Statistical analyses found that Class IIIB streams had higher numbers of total taxa than both the Class II and Class IIIA streams inventoried during the study. The median number of taxa in Class IIIB streams ranged from 16 to 57, with a median number of 29 taxa per site as compared to a median of 15 and 17 taxa per site for the Class II and Class IIIA sites in the inventory.

Salamanders were observed at 107 (85.6%) of the 125 inventoried sites. Three species, each with obligate aquatic life stages, were encountered at the inventoried locations: *Desmognathus ochrophaeus* (Allegheny Mountain Dusky Salamander), *Desmognathus fuscus* (Northern Dusky Salamander), and *Eurycea bislineata* (Northern Two-lined Salamander). The Redback Salamander (*Plethodon cinereus)*, a terrestrial species that has no aquatic life stages, was also collected during the inventory.

The predominant salamander species collected during the inventory was *E. bislineata*, which was found at 104 (83.2%) of the CUVA Headwater Inventory sites. The two species of Dusky Salamanders were encountered far less frequently, with *D. ochrophaeus* being found at only three sites and *D. fuscus* present at 25 sites (20% of the total sites). *E. bislineata* was also more abundant numerically, with a median density, where present, of 16.4 Individuals per 100 m^2 vs. 10.5 and 3.9 Individuals per 100 m^2 for *D. ochrophaeus* and *D. fuscus*, respectively. The difference in relative abundances of the salamander species is explained by species distributions and differences in life histories. The developmental life history of *E. bislineata* consists of a multi-year time frame during which gilled larvae are confined to flowing waters. In contrast, both Dusky Salamander species have

a very short egg incubation and larval developmental periods which limits the amount of time that these species must remain in the stream prior to gill resorption and transformation to the adult stage. At this point in their life history, they begin foraging in the adjacent stream margins and forests. CUVA also lies within the periphery of the range for *D. ochrophaeus*, therefore limiting its distribution within the park.

Fish were found to be present at 98 sites (78.4% of the total). A total of twenty-one species were collected and identified during the inventory. Three fish species collected from the CUVA headwater streams are identified as cold-water adapted fish species by Ohio EPA: *Chrosomus erythrogaster* (Southern Redbelly Dace), *Clinostomus elongatus* (Redside Dace) and *Culaea inconstans* (Brook Stickleback). The fish communities at the CUVA Headwater Inventory sites generally exhibited low diversity with respect to the number of species present.

The macroinvertebrate community was the primary driver for distinguishing between Class IIIA and Class IIIB stream types within the inventory data set based upon Level 3 PHW assessments. Forty-seven of the Class IIIB sites supported Class IIIB macroinvertebrate communities (90.3% of this class), while thirteen Class IIIB streams (25% of the class) were found to support cold water fish species. In contrast, the presence of reproducing populations of *E. bislineata* was the sole indicator determining stream class at 47 of the 51 streams found to meet the definition for the Class IIIA PHW stream type. Reproducing populations of *E. bislineata* were also found at 69% of the Class IIIB sites, but this species of salamander is not considered to be a Class IIIB indicator taxon because of its tolerance for higher water temperatures.

Eighteen sites (14.4% of the inventoried sites) assessed during the CUVA headwater stream inventory were determined to meet criteria for higher aquatic life beneficial uses as defined in the Ohio Water Quality Standards [Chapter 3745-1 of the *Ohio Administrative Code* (OAC)] based upon the biological assessment results. The Cold Water Habitat (CWH) use is fully attained at eight of these locations, with one site also meeting the criteria for Exceptional Warmwater Habitat (EWH) for both fish and macroinvertebrates. The other ten sites in this group fully meet the Warmwater Habitat (WWH) aquatic life use. Five of these sites were found to have macroinvertebrate communities meeting the CWH use, and two of the WWH-attaining sites also supported a population of at least one species of cold-water indicator fish. Notable among the sites supporting higher tier uses were ten sites located within HUC 041100020505, where all sites attaining the CHW use and the site attaining both the CWH and EWH uses were located. Of particular note is the stream network within the "CMA Tributary" (River Mile 21.70 Tributary to the Cuyahoga River) watershed, where all five assessment sites fully meet the CWH use. This watershed represents the highest quality headwater stream network within CUVA based upon the results of the inventory and merits special consideration with respect to resource protection.

In terms of stream channel geomorphology, many Cuyahoga Valley PHW streams have reached an equilibrium with respect to vertical and lateral stability. Control of the condition of these ravine stream channels is generally derived from contact with the underlying bedrock resulting in stability vertically and from steep valley sides that prevent lateral movement of the channel because of the presence of overlying bedrock layers. Although the potential for bank erosion in these streams is high based upon BEHI scores, the high width to depth ratios observed at these sites produce low NBS values, producing a net result of channel stability, as indicated by examination of the biological communities, particularly the macroinvertebrates and salamander components.

The VUIA procedure developed for the CUVA headwater stream inventory was successfully completed at all 125 assessment sites. The methodology proved to be efficient and provided consistent results among the teams collecting the data. Although the assessments did not detect significant problems with respect to overall impacts to habitat quality or aquatic life at the stream inventory sites within CUVA, the method did detect significant impacts to a small number of sites that were attributable to visitor use relating mainly to litter, bank erosion, and impacts to the stream channel.

It was concluded that the VUIA procedure is sufficient to capture important aspects of anthropogenic disturbance to headwater streams within CUVA. This was especially true for sites where the assessment zones were placed near trail crossings or other points of easy stream access. There was an absence of visitor use impacts noted for many remotely located sites apart from issues related to legacy trash disposal or transport of litter via stream flows or from aerial deposition. It is recommended that further study of the use of the VUIA within CUVA be considered through comparison of remote sites used as controls to sites associated with trail crossings and other points of public access to determine whether the use of VUIA-derived data developed on a wider scale can become a useful tool for future resource management planning and implementation of protective strategies.

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List of Terms

ALU:	Aquatic Life Use
ANOVA:	Analysis of Variance
AOC:	Area of Concern
Avg:	Average
BANCS:	Bank Assessment for Non-point source Consequences of Sediment
BEHI:	Bank Erosion Hazard Index
Dbkfl:	Bankfull Depth
°C:	Degrees Celsius
CMP:	Cleveland Metroparks
COR:	Contract Officer Representative
CO:	Contract Officer
CUVA:	Cuyahoga Valley National Park
CWH:	Cold Water Habitat
Dmax:	Maximum Depth
Dnb:	Near-Bank Maximum Depth
DFA:	Discriminant Function Analysis
DO:	Dissolved Oxygen
DQO:	Data Quality Objective
DST:	Downstream terminus of an assessment zone
EWH:	Exceptional Warmwater Habitat
EPT:	Ephemeroptera, Plecoptera, and Trichoptera
°F:	Degrees Fahrenheit
ft:	feet (U.S.)
GIS:	Geographic Information System
GNSS:	Global Navigation Satellite System
HHEI:	Headwater Habitat Evaluation Index
HMFEI:	Headwater Macroinvertebrate Field Evaluation Index
HUC:	Hydrologic Unit Code
HUC12:	12-Digit Hydrologic Unit Code
HVE:	High Value Experience Zone
IACUC:	Institutional Animal Care and Use Committee
IBI:	Index of Biotic Integrity
ICI:	Invertebrate Community Index
K:	Stream Channel Sinuosity (unitless)
kg:	Kilogram
m^2:	Square Meters
mg:	Milligram
mi^2:	Square Miles
MID:	Mid-point of an assessment zone
MWH:	Modified Warmwater Habitat

n:	Number of observations or data points
NABS:	North American Benthological Society
NBS:	Near Bank Stress
NPS:	National Park Service
NRR:	Natural Resources Report
NZ:	Natural Zones
OAC:	Ohio Administrative Code
ODNR:	State of Ohio Department of Natural Resources
ODNR DOW:	ODNR Division of Wildlife
Ohio EPA:	State of Ohio Environmental Protection Agency
p:	Probability with respect to statistical tests
PDOP:	Position Dilution of Precision
PHW:	Primary Headwater Stream
PI:	Principal Investigator
PSP:	Project Study Plan and Quality Assurance Project Plan
QAPP:	Quality Assurance Project Plan
QDC:	Qualified Data Collector
QHEI:	Qualitative Habitat Evaluation Index
QR Code:	Quick Response Code
RPRS:	Research Permit and Reporting System
SMP:	Summit Metro Parks
SOW:	Statement of Work
SRZ:	Sensitive Resource Zone
SU:	Standard Units (pH)
UAA:	Use Attainability Analysis
USGS:	United States Geological Survey
UST:	Upstream terminus of an assessment zone
VES:	Visual Encounter Survey
VUIA:	Visitor Use Impact Assessment
WL:	Channel Width at the Bankfull Elevation
WInt:	Channel Width at 1.5 times the Bankfull Elevation
Wfp:	Floodprone Width of the Stream (2.0 times the Bankfull Elevation)
W/D:	Width to Depth Ratio
WQS:	Water Quality Standard
WWH:	Warmwater Habitat

Introduction

As part of the inventory and monitoring program of the National Park Service (NPS), an assessment of headwater stream resources within the Cuyahoga Valley National Park (CUVA) was conducted in 2022. The parameters and expectations for the inventory are described in a Statement of Work (SOW) developed by NPS staff (NPS, 2021). The purpose of the inventory is to develop a data compendium regarding the characteristics of headwater streams throughout CUVA to guide decision-making in the development of future management plans to protect these resources. EnviroScience, Inc. designed and implemented a project study plan (PSP) to inventory the headwater stream resources within CUVA (EnviroScience, 2022a) which was approved by NPS.

A total of 125 sites were assessed to complete the inventory. Of those, 83 of the sites were designated as Primary sites, which were selected to document the condition of headwater streams with watershed areas of approximately 1.0 mi^2. The remaining 42 sites, categorized as Secondary sites, were added to the inventory to further characterize primary watersheds. Sites were placed at points that appeared to be probable locations of cold spring-fed streams or other unique water sources, or to target specific tributaries or conditions of interest. Inventoried sites were selected to meet the definition of Primary Headwater (PHW) streams as that term is defined in Ohio EPA headwater stream protocols described in Revision 4.0 of the *Field Manual for the Evaluation of Primary Headwater Streams, Rev. 4.0* (Ohio EPA, 2000). The identified locations were assessed to characterize the biological communities within the streams and to identify factors affecting the ecological integrity and water quality of the headwater streams within CUVA.

The Ohio EPA PHW classification system is based upon three distinct types of biological communities that are indicative of headwater stream hydrology and ecological condition:

- "Class I" identifies ephemeral PHW streams where water flow is confined to periods of precipitation runoff such as storm events or snowmelt;
- "Class II" PHW streams include intermittent or warm-water perennial streams where surface flows dominate the hydrology and fauna inhabiting the streams are adapted to intermittent lack of flow or warm temperature conditions (temperatures > 22 °C for extended periods); and
- "Class III" streams where continual groundwater discharge provides perennial flows at summertime temperatures typically less than 22 °C. Class III PHW streams can support vertebrate and macroinvertebrate taxa with complex life histories requiring cool or cold-water stream flows over a multi-year period. The Class III PHW classification is further divided into sub-classes denoted as Class IIIA (perennial warm water) and Class IIIB (spring water perennial) based upon the number cold-water adapted and pollution sensitive taxa present based upon listings by Ohio EPA. Both vertebrate (salamanders and/or fish) and macroinvertebrate cold water and sensitive taxa lists are used for these determinations.

Assessments were conducted at all 125 sites using Ohio EPA PHW Level 3 Assessment survey methods (Ohio EPA, 2020). These methods include water quality measurements for field parameters, qualitative evaluation of the habitat for aquatic life, and definitive biological assessments of the vertebrate and macroinvertebrate communities present within each PHW stream sampling reach including the following elements:

- **Water Quality Measurements** - documented for the following parameters: water clarity, temperature, pH, dissolved oxygen, and specific conductance.

- **Salamander Assemblage Assessment** - taxonomic evaluation of salamanders present including classification by life stage (egg, larvae, juveniles, and adults). Assessment of salamanders included both quantitative and qualitative surveys.

- **Macroinvertebrate Assessment** - the macroinvertebrate community was assessed at each sampling site according to Ohio EPA qualitative sampling methods (Ohio EPA, 2015). Field identifications were conducted to the level necessary (generally family-level) to calculate the Ohio EPA Headwater Macroinvertebrate Field Evaluation Index (HMFEI). Representative specimens of all macroinvertebrate taxa collected were vouchered for evaluation in the laboratory to identify organisms to the lowest practicable taxonomic level to complete the Level 3 assessment of the macroinvertebrate communities.

- **Fish Community Assessment** – fish communities found in the stream at each sampling location were assessed using electrofishing techniques where possible. Fish were enumerated and identified to species.

- **Habitat Characteristic Assessment** – stream habitat characteristics were documented using the Headwater Habitat Evaluation Index (HHEI), a multi-metric, qualitative rapid assessment method used by Ohio EPA to classify PHW streams (Ohio EPA, 2020).

- **Fluvial Geomorphic Measurements** - longitudinal measurements were taken of the stream to measure channel gradient and sinuosity. Channel cross-sectional area measurements were taken based upon average width measurements at 1.0, 1.5, and 2.0 times the bankfull elevation within each evaluated reach.

- **Streambank Assessments** - evaluations of the streambanks were completed to calculate the Bank Erosion Hazard Index (BEHI) and near-bank stress (NBS) (Rosgen, 2001) as assessment tools to determine the degree of streambank erosion and the potential impacts upon stream ecology.

- **Visitor Use Impact Assessment** – qualitative surveys were conducted to rank the levels of various human induced stream disturbances within three zones associated with the assessment site: the riparian zone, the stream bank, and the stream channel including the channel margin (associated gravel bars and stream bed normally above the waterline).

For each headwater stream, all metrics and submatrices in the Ohio EPA PHW protocols were computed to provide a definitive (Level 3) classification of the site by PHW stream type (Class III, Class II, and Class I). Data from Class III PHW streams were evaluated to determine whether they met the characteristics of Class III PHW Type A or Type B or if the data support classification of the stream under defined Ohio EPA beneficial use categories for the support of aquatic life found in OAC Chapter 3745-1.

Analysis is focused on the abundance and distribution of cold-water indicator taxa and their interrelationship with other biological indicators. Relationships to habitat and biological indices, and patterns in HHEI and HMFEI scores among the sites, are described and analyzed through appropriate statistical comparisons, including potential responses to covariates. The biotic composition/integrity for each site is compared against expected outcomes based upon habitat assessment. Some streams were recognized for having exceptional ecological value and therefore recommendations are made for prioritization and protection.

The SOW required the development of a system to score or assess visitor use impacts at sampled sites. A Visitor Use Impact Analysis (VUIA) procedure was developed specifically for the CUVA headwater stream inventory and was implemented at all the inventoried sites. Analysis of VUIA results includes an evaluation of the types of impacts observed comparing frequencies for each stream assessment zone and comparative severity rankings for these impacts upon stream habitat for the support of aquatic life. The usefulness and accuracy of the VUIA procedure is evaluated and recommendations for applicability and future use of the VUIA procedure within CUVA are provided.

Broad recommendations are also made regarding headwater streams that have the highest priority (or would benefit most from) for restoration based on the data collected and best professional judgement. The potential effects of various options for remedial activities upon water quality are also discussed based upon the data obtained.

Study Area Description

The Cuyahoga Valley National Park encompasses a total area of 32,950 acres within Summit and Cuyahoga Counties in northeast Ohio (Figure 1). Federally owned land (19,113 acres) comprises approximately 58% of the authorized area of CUVA (NPS, 2022). An additional 8,962 acres, comprising approximately 27% of the authorized CUVA park area, are publicly owned lands. The majority of the non-federal public lands within the CUVA boundaries are owned and managed by Cleveland Metroparks (within Cuyahoga County) or by Summit County Metro Parks, both of which are park districts created under Ohio law (*Ohio Revised Code* Chapter 1545). Privately held lands make up the remainder (approximately 15%) of the jurisdictional area within CUVA.

Setting of Study Area

Cuyahoga Valley National Park lies entirely within the Cuyahoga River watershed. The Cuyahoga River is a tributary to Lake Erie, with a watershed area of 812 mi^2. The National Park lies within the lower portion of the Cuyahoga River basin which is demarcated upstream by the former dam site in Munroe Falls, Ohio and downstream by the mouth of the river where it flows into Lake Erie in Cleveland, Ohio. Land use within the lower Cuyahoga River watershed is dominated by urban and suburban land uses, interspersed with forest and some extant areas of agricultural activity. Major urban areas within the watershed include Cuyahoga Falls and the City of Akron to the south and the City of Cleveland to the north. Multiple other local jurisdictions including incorporated municipalities as well as unincorporated townships are located partially, totally within, or adjacent to CUVA.

The lower 46.5 miles of the Cuyahoga River, including the associated watersheds and tributaries within CUVA, are included in the Cuyahoga River Area of Concern (AOC). The Cuyahoga River AOC was designated under the Great Lakes Water Quality Agreement in 1987, and the AOC boundaries were most recently revised in 2010. Almost half of the Cuyahoga River mainstem included in the AOC designated area flows through CUVA. Information regarding the efforts to address beneficial use impairments within the Cuyahoga River AOC can be found on the USEPA website: https://www.epa.gov/great-lakes-aocs/cuyahoga-river-aoc.

The Cuyahoga River was designated as an American Heritage River in 1998, and a National Heritage Corridor in 1996. Information regarding the importance of the river to regional and national cultural and historical resources can be found at the following links:
https://www.nps.gov/articles/000/cuyahoga-national-heritage-river.htm and
https://www.nps.gov/places/ohio-and-erie-canalway-national-heritage-area.htm.

The CUVA headwater stream inventory study area falls within the Erie/Ontario Drift and Lake Plain Ecoregion (Ecoregion 61) based upon the Level 3 ecoregional classifications (Omerick, 1987). Some Level 3 ecoregions were subsequently divided into Level 4 ecoregions based upon physiographic, geological, climatological, and ecological patterns (Woods, et al., 1998; Omerick and Griffith, 2014). This proved to be helpful for discerning local ecological conditions that may not be captured by analysis at the Level 3 ecoregional level.

Surrounding the Lake Erie Gorges Ecoregion within the upstream portions of the Cuyahoga River Watershed to the east, south, and west are more heavily developed areas that fall within the Low Lime Drift Plain Ecoregion (Ecoregion 61c). This ecoregion is the predominant Level 4 ecoregion within the Erie/Ontario Drift and Lake Plain Ecoregion. This ecoregion has less topographical relief than Ecoregion 61d has a higher percentage of fertile, loamy soils, and has a scarcity of exposed bedrock when compared to Ecoregion 61 c. Land use is more developed within these upland areas surrounding CUVA, and includes small acreage agricultural uses, high to moderate density urban/suburban residential developments, and commercial and industrial areas. Recreational areas, in particular golf courses and ski areas, are also found within the transition areas between Ecoregions 61c and 61d along the periphery of CUVA. Potential impacts to streams flowing into (or within) CUVA from these areas is therefore variable depending on the upstream land uses of each individual PHW watershed.

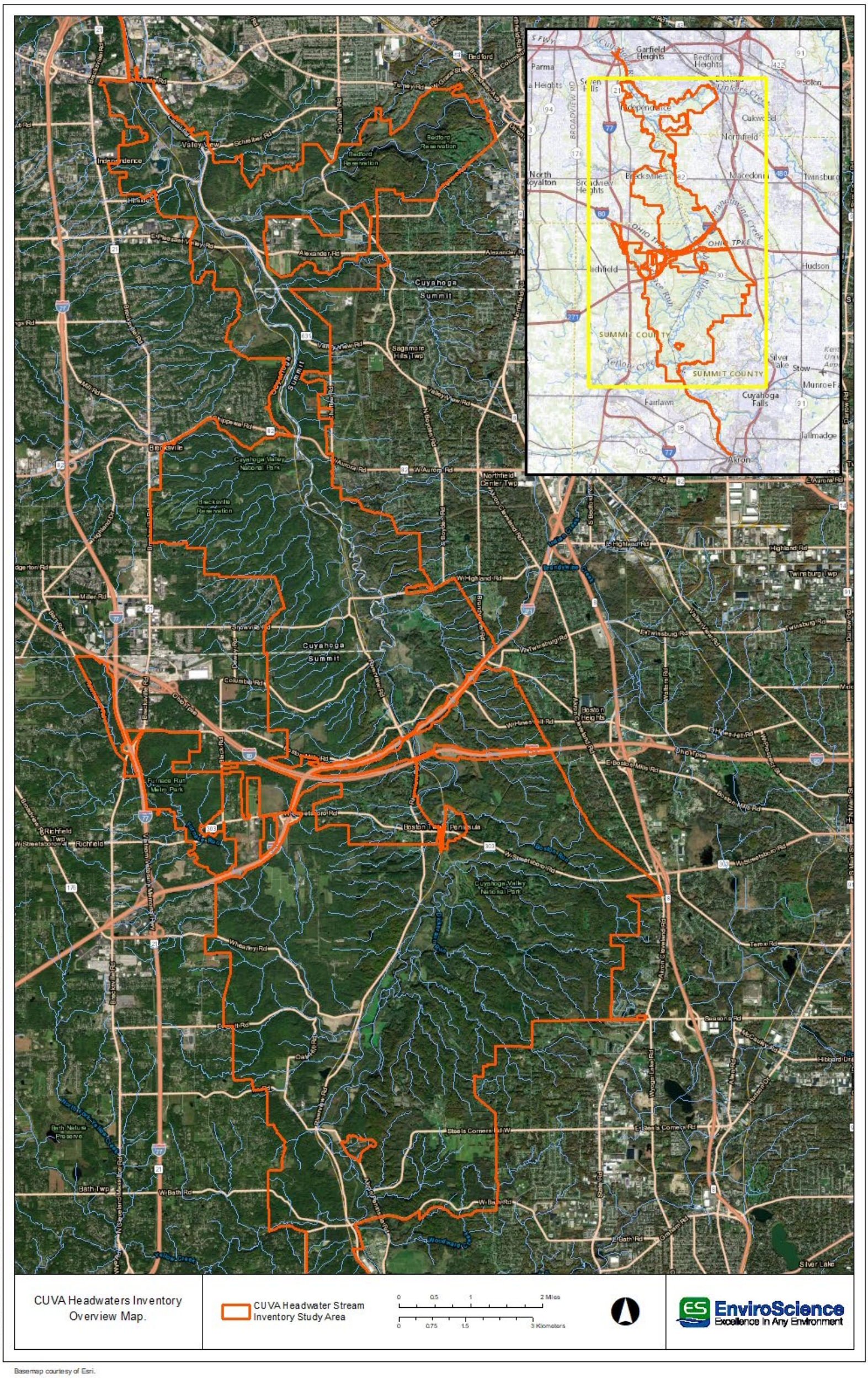


Figure 1. Cuyahoga Valley National Park headwater stream inventory study area.

With respect to Ohio EPA biological water quality criteria (OAC Rule 3745-1-07), all CUVA PHW inventory sites are located within the Erie Ontario Lake Plain Ecoregion (EOLP). The identified ecoregions used by Ohio EPA are mapped according to the original Level 3 ecoregions of the United States identified by Omerick (1987) and have not been subsequently modified by Ohio EPA based upon revisions to ecoregion delineations spanning national and continental scales.

The Cuyahoga River watershed comprises a single 8-digit hydrologic unit code (HUC) watershed, designated 04110002, under the U.S. Geological Survey (USGS) Watershed Boundary Dataset. The 8-digit HUC watershed for the Cuyahoga River watershed is further subdivided into a total of six 10-digit HUC watersheds, three of which cover portions of CUVA: 0411000204, Yellow Creek - Cuyahoga River; 0411000205, Tinkers Creek - Cuyahoga River; and 0411000206, Big Creek - Cuyahoga River. The smallest watershed unit supported by USGS is the 12-digit HUC watershed (HUC12). The HUC12 watershed delineation scale is the unit used by Ohio EPA as the assessment unit for conducting integrated watershed assessments for water quality planning and reporting purposes. The seven HUC12 watersheds in which CUVA and the headwater streams inventoried by the present study lie are listed in Table 1. This watershed delineation unit is used throughout this report as the primary means to group the sites for data analysis.

Table 1. Listing of 12-digit HUC watersheds for the study area.

HUC12 Code	HUC12 Name	HUC12 Area (mi^2)	Area in CUVA (mi^2)	Percent of HUC12 in CUVA
041100020403	Furnace Run	20.261	5.932	29.3%
041100020404	Brandywine Creek	27.016	1.627	6.0%
041100020405	Boston Run - Cuyahoga River	46.365	26.334	56.8%
041100020503	Headwaters Chippewa Creek	17.793	1.987	11.2%
041100020504	Town of Twinsburg - Tinkers Creek	55.429	3.721	6.7%
041100020505	Willow Lake - Cuyahoga River	24.185	8.299	34.3%
041100020602	Village of Independence - Cuyahoga River	16.938	2.410	14.2%
Other	NA – Other CUVA Areas	–	1.174	–
Totals	**–**	**207.987**	**51.484**	–

Headwater Stream Inventory Site Selection

An initial listing of 83 Primary inventory locations was selected by NPS staff for evaluation and inclusion within the CUVA Headwater Inventory. The Primary sites provided were selected to capture all catchments within CUVA meeting the PHW stream definition at or near the 1.0 mi^2 drainage scale. Therefore, watershed areas for the initial Primary sites were at or near the upper limit of calibration of the PHW stream assessment protocols. The NPS SOW also called for the selection of 42 secondary sites to be used to resolve primary watersheds that appear to be mixtures of cold spring-fed and other water sources, or to target specific tributaries or conditions of interest.

Resource management planning and implementation within CUVA by NPS is conducted in the context of 18 management zones classified as Natural Zones (NZ), Sensitive Resource Zones (SRZ), or High Value Experience Zones (HVE; Figure 2). Sites selected for the inventory were located within each of these zones. In addition, sites were also selected within Brecksville Reservation and Bedford Reservation, metro parks managed by Cleveland Metroparks (CMP) and within Furnace Run Metro Park, managed by Summit Metro Parks (SMP) for the CUVA headwater stream inventory. The site lists that follow indicate the management zone within which each assessment site was located. A cumulative tally of sites within each HUC12 cross referenced to management zone is provided in Table 2.

Primary Site Locations and Drainage Areas

Primary sites proposed by NPS were screened prior to final site selection and field work through an iterative process consisting of delineation of watershed boundaries for each stream site followed by examination of aerial photographs. Site locations were examined in comparison to local topography, land use, accuracy of stream connectivity and drainage pattern, and accessibility to determine suitability for sampling. Site locations were also examined for confirmation of land ownership to determine what steps might be required for access to the sites without trespassing on private lands. In addition, a field reconnaissance visit was conducted on December 10, 2021 with NPS staff to discuss the site selection process and to inspect some of the prospective sampling sites.

During the screening process, sites initially located within the Cuyahoga River floodplain were moved upstream to provide more representative data regarding upstream watershed condition with respect to annual flow condition (perennial, intermittent, or ephemeral) and to ensure that biological conditions were not affected by backwater conditions or alluvial deposits from the Cuyahoga River. Additional sites were relocated if the selected site was placed in areas where the stream channel was obviously degraded as the result of road crossings, culverts, or channel alterations. In these cases, the assessment points were relocated upstream to points appearing to be more representative of the stream condition on a watershed scale. Sites falling within lentic water bodies (ponds or wetlands) were also relocated upstream or downstream to points where free-flowing stream conditions are apparent.

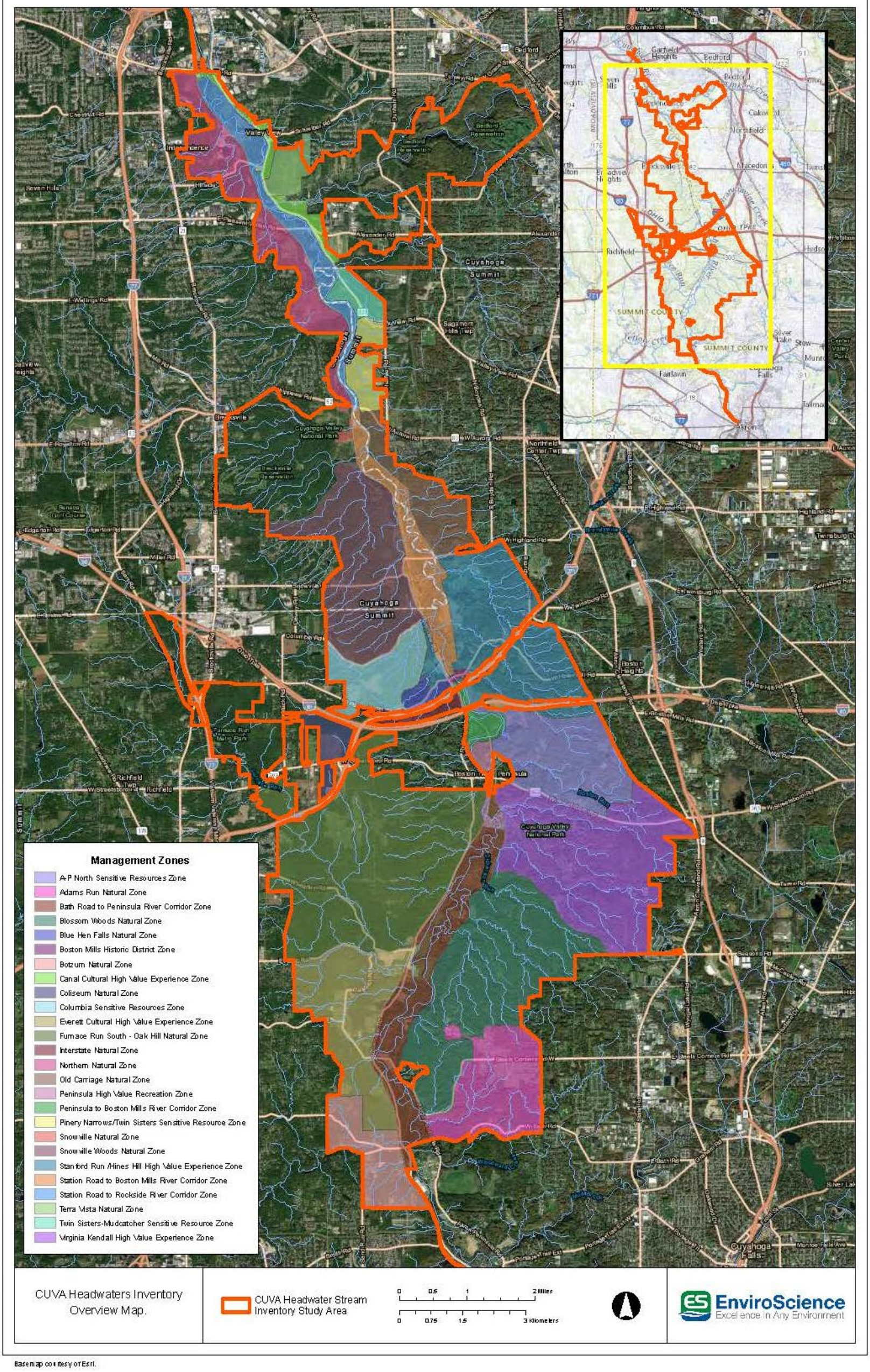


Figure 2. Management Zones within the CUVA headwater stream inventory study area.

Table 2. Distribution of headwater stream inventory sites by HUC12 watersheds and NPS management zones. Key: HVE = High Value Experience Zone, NZ = Natural Zone, SRZ = Sensitive Resource Zone

Management Zone	0403	0404	0405	0503	0504	0505	0602	Totals
Adams Run NZ	–	–	1	–	–	–	–	**1**
A-P North SRZ	–	–	2	–	–	–	–	**2**
Blossom Woods NZ	–	–	8	–	–	–	–	**8**
Blue Hen Falls NZ	–	–	4	–	–	–	–	**4**
Boston-Brandywine HVE	–	2	–	–	–	–	–	**2**
Botzum NZ	–	–	3	–	–	–	–	**3**
Columbia SRZ	–	–	6	–	–	–	–	**6**
Everett Cultural HVE	2	–	5	–	–	–	–	**7**
Furnace Run S-Oak Hill NZ	8	–	7	–	–	–	–	**15**
Interstate NZ	–	–	2	–	–	–	–	**2**
Northern NZ	–	–	–	–	–	2	10	**12**
Old Carriage NZ	–	–	–	–	–	11	–	**11**
Pinery Narrows/Twin Sisters SRZ	–	–	–	–	–	4	–	**4**
Snowville Woods NZ	–	–	1	–	–	13	–	**14**
Stanford Run-Hines Hill HVE	–	3	3	–	–	–	–	**6**
Terra Vista	–	–	–	–	–	–	1	**1**
Twin Sisters-Mudcatcher SRZ	–	–	–	–	–	7	–	**7**
Virginia Kendall HVE	–	–	7	–	–	–	–	**7**
CMP Bedford	–	–	–	–	4	–	–	**4**
CMP Brecksville	–	–	–	4	–	2	–	**6**
SMP Furnace Run	3	–	–	–	–	–	–	**3**
Totals	**13**	**5**	**49**	**4**	**4**	**39**	**11**	**125**

In addition to the screening described above, county tax maps were consulted to positively identify property ownership of the locations for the selected and relocated sites. Where necessary, site locations were adjusted further to place the sampling locations within either federal property, other publicly owned land (e.g., local park district properties), or other locations where NPS has site access rights or permission.

In situations where the screening described above determined that a site could not be relocated to provide useful information regarding stream resource quality using the PHW assessment protocols, the site was dropped from the inventory and alternative sites were selected.

The final Primary site locations are depicted in Figure 3, and additional maps are included in Appendix C. Changes to the locations for Primary inventory sites relative to the original NPS site list prior to PSP approval included the replacement of two proposed sites and the relocation of 20 additional sites. The final approved list of 83 Primary sites was published in the final PSP (EnviroScience, 2022a).

Location and drainage area information based for the completed field assessments of the Primary stream inventory sites are provided in Appendix A. Watershed areas for Primary sites all met the data quality objectives for the inventory, ranging from 0.10 to 1.03 mi^2. The median watershed area for Primary sites is 0.46 mi^2, and the average watershed area is 0.51 mi^2 with a standard deviation of 0.35 mi^2.

Adjustments of the site locations by a channel distance greater than 200 linear feet, the standard length of an assessment zone for PHW streams, from the point listed in the PSP occurred at 25 of the Primary sites during the assessment visit. These adjustments in assessment locations were based upon best technical judgment of the Field Crew Leader for the following reasons:

1. Access to the target location was deemed unsafe or impractical for the field crew (6 sites);
2. Adjustment of locations necessary to meet data quality objectives (DQOs) based upon localized stream characteristics such as extensive log jams, waterfalls, etc. (14 sites);
3. Adjustments made to sync assessment reaches with historical Ohio EPA sampling efforts (two sites: Sites CUVA-64 and CUVA-126);
4. An instance where the base map used for desktop analysis was in error with respect to the flow path of the stream (Site CUVA-52A);
5. An instance where the target location and other alternative sampling locations were found to not be on NPS property and permission for access could not be obtained (Site CUVA-62A);
6. A site moved upstream under instructions of NPS staff to facilitate priority data needs (Site CUVA-18).

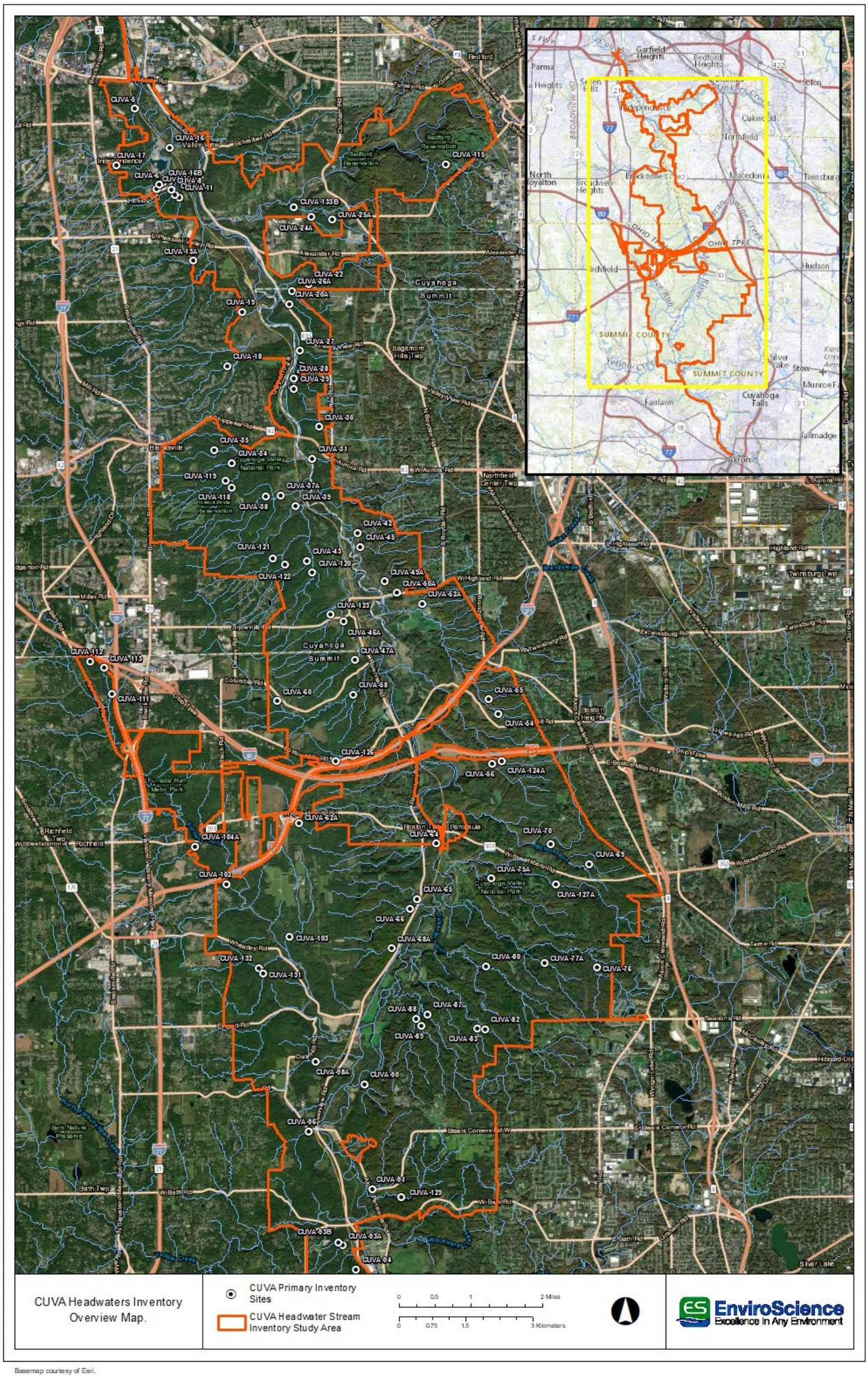


Figure 3. Primary site locations for the CUVA headwater stream inventory.

All sites that were moved and the reason for the adjustment are listed in Appendix A site table.

The median distance for the adjustment of Primary sites was 378 feet of channel, and the maximum distance was 6,600 feet (Site CUVA-62A, noted above). Listings for all Primary sites that were moved as well as the reasons for adjustment of locations are also included in Appendix A.

Secondary Site Locations and Drainage Areas

Potential secondary site locations were proposed to NPS to meet the SOW data quality objectives to inventory 42 secondary sites based upon preliminary data collected from the primary site evaluations. The screening process used to allocate secondary sites was based upon the following objectives:

1. Identification of locations within smaller drainage area PWH streams within CUVA where the potential to support spring water or cold water biological communities was identified based upon local topography, land use, geology, and the preliminary results from the evaluation of linked primary sites.

2. Locations chosen to provide reference data useful for guiding future management decisions based upon existing upstream land uses that may affect water quality, stream channel integrity, and/or ecological condition.

3. Sites with the potential to serve as upstream reference sites to document impacts of in-stream impoundments upon stream condition.

4. An alternative replacement site (Site 98B) identified for use as a substitute for replacement Site 98A should field reconnaissance determine it necessary based upon site conditions.

5. Tributary streams upstream of primary inventory sites identified as having the potential to provide useful data regarding connectivity of the stream networks within the watershed with respect to spring water conditions or seasonal dryness.

Field reconnaissance was conducted by NPS staff to verify secondary site locations prior to assignment for sampling. The final secondary site list was approved by NPS and was incorporated within the PSP as an amendment (EnviroScience, 2022b).

The locations of Secondary sites within the study area are depicted in Figure 4. Secondary site location and drainage area information is presented in Appendix B. The Secondary sites listings include a cross-reference to associated Primary or Secondary sites located upstream or downstream from the site in question. These associations are provided for ease in data comparison of sites within the same stream flow path.

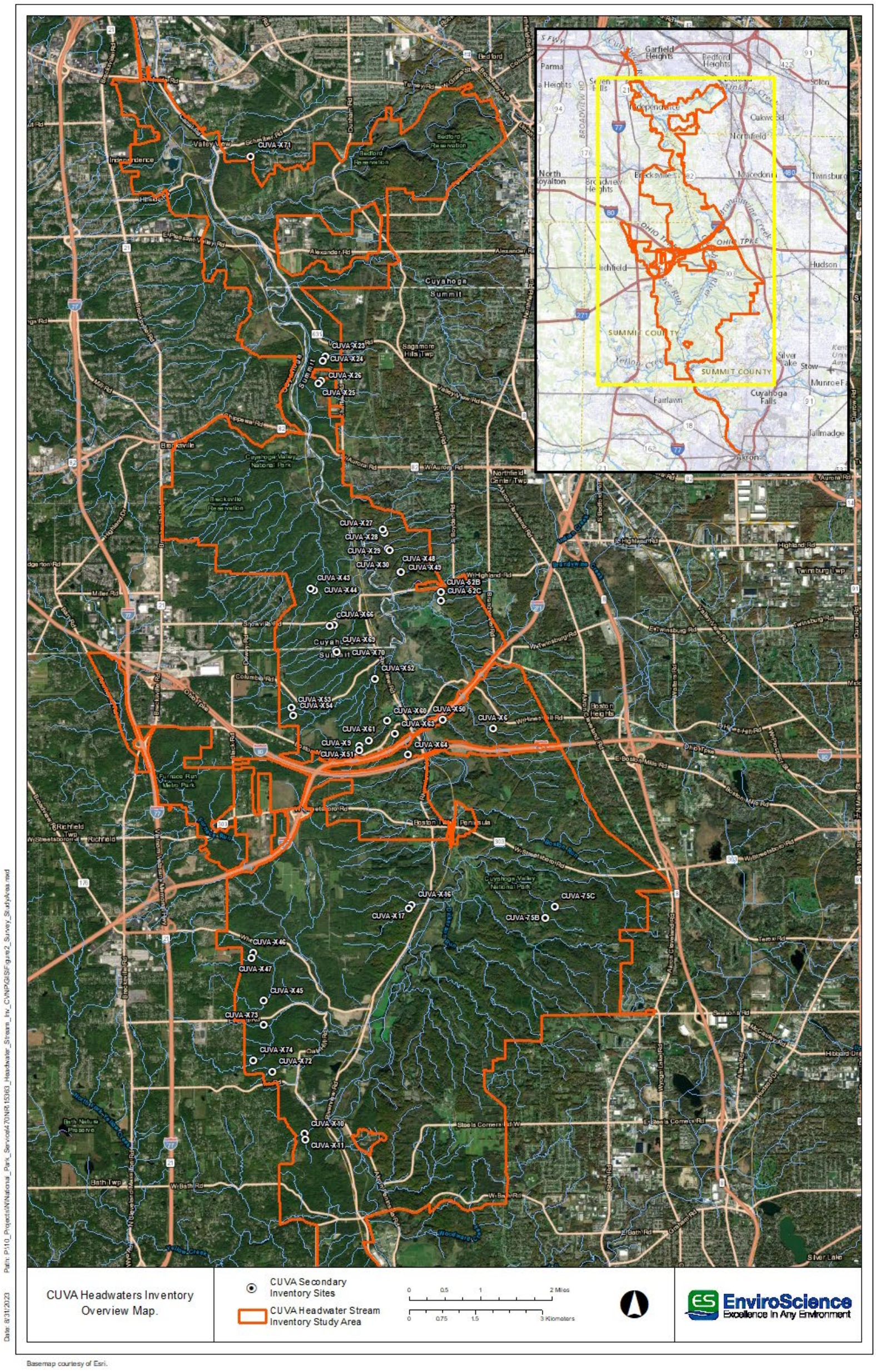


Figure 4. Secondary site locations for the CUVA headwater stream inventory.

Watershed areas for Secondary sites are more variable than those for Primary sites, ranging from 0.11 mi^2 to 1.43 mi^2, with both the mean and standard deviation of the watershed areas equaling 0.35 mi^2. Five Secondary sites have drainage areas greater than the 1.0 mi^2 guideline for the upper limit of the definition for PHW streams. Three of these sites were selected by NPS for a special survey of Spring Creek and tributaries within the Blue Hen Falls NZ (Sites CUVA-X9, CUVA-X60, and CUVA-X61). Drainage areas for these sites ranged from 1.28 to 1.43 mi^2. The other two sites with drainage areas greater than 1.0 mi^2, Sites CUVA-X74 and CUVA-X71, had drainage areas of 1.14 and 1.01 mi^2, respectively, and are considered to be within the data quality objectives for the inventory.

Assessment reach locations were adjusted at 13 Secondary sites by the Field Crew Leaders. Reasons for these adjustments included access and safety considerations at three sites and ten instances where adjustment was deemed necessary to meet project DQOs. The median distance for the adjustments for Secondary sites was 280 channel feet with the maximum adjustment of 1,075 channel feet (Site CUVA-X45). The adjustment of location at Site CUVA-X45 was based upon site access and safety considerations. Detailed listings and causalities for site adjustments for Secondary sites are also provided in Appendix B.

Park Resource Management Issues

For each headwater stream, all metrics and submatrices in the Ohio EPA PHW protocols were computed to provide a definitive (Level 3) classification of the site by PHW stream type (Class III, Class II, and Class I). Data from Class III PHW streams were evaluated to determine whether they met the characteristics of Class III PHW Type A or Type B or if the data support classification of the stream under defined Ohio EPA beneficial use categories for the support of aquatic life found in OAC Chapter 3745-1.

Appendix C provides supplemental maps depicting features that affect headwater stream channel integrity and stream flow conditions including land use, surficial geology, and bedrock geology in relation to the inventory sites. The Appendix also includes higher resolution maps for each HUC12 watershed overlain with inventory site locations coded for site category (Primary or Secondary) and PHW classification results.

Analysis is focused on the abundance and distribution of cold-water and pollution-sensitive indicator taxa and their interrelationship with other biological indicators. Relationships to habitat and biological indices, and patterns in HHEI and HMFEI scores among the sites, are described and analyzed through appropriate statistical comparisons, including potential responses to covariates. The biotic composition/integrity for each site is compared against expected outcomes based upon habitat assessment. Some streams were recognized for having exceptional ecological value and therefore recommendations are made for prioritization and protection.

The SOW required the development of a system to score or assess visitor use impacts at sampled sites. A Visitor Use Impact Analysis (VUIA) procedure was developed specifically for the CUVA headwater stream inventory and was implemented at all the inventoried sites. Analysis of VUIA results includes an evaluation of the types of impacts observed comparing frequencies for each stream assessment zone and comparative severity rankings for these impacts upon stream habitat for

the support of aquatic life. The usefulness and accuracy of the VUIA procedure is evaluated and recommendations for applicability and future use of the VUIA procedure within CUVA are provided.

Broad recommendations are also made regarding headwater streams that have the highest priority (or would benefit most from) for restoration based on the data collected and best professional judgement. The potential effects of various options for remedial activities upon water quality are also discussed based upon the data obtained.

Permits

The following permits and authorizations were obtained to complete the work reported herein:

1. National Park Service Scientific Research and Collecting Permit (Permit# CUVA-2021-SCI-0021);

2. U.S. Department of Interior, National Park Service Institutional Animal Care and Use Committee Animal Research Protocol Approval (OH_CUVA_Anderson_Herps.Fish_2022.A3);

3. Ohio Department of Natural Resources, Division of Wildlife Scientific Collection License SC220035;

4. Summit Metro Parks Special Use Permits for access to Furnace Run and Hampton Hills Metro Parks;

5. Cleveland Metroparks research permit dated April 25, 2022; and

6. Ohio Turnpike Commission property access authorization dated September 13, 2022.

Copies of each permit and authorization document are provided in a supplemental appendix to this report (EnviroScience, 2023).

Methods

Assessment of the CUVA headwater stream inventory sites followed the study plan approved by NPS (EnviroScience, 2022a; 2022b). All data collection activities adhered to the EnviroScience Quality Assurance Plan for Aquatic Survey (EnviroScience, 2020) and followed standard Ohio EPA protocols as specified herein. Specific methods, references, sampling locations, personnel, and schedules are detailed below.

Site Location and Characterization Summary

Assessment zones for the stream inventory locations were established by the Field Crew Leader to provide representative sampling reaches to meet the data quality objectives of the project. The selected stream reaches were positioned to avoid locations where stream channel condition was obviously affected by man-made structures (bridges, culverts, check dams, impoundments, bank armoring, etc.). Assessment zones were set to not span the confluences of tributary streams wherever possible. If, at the time scheduled for the stream assessment, the field crew leader deemed that the sampling location was inappropriate for inclusion in the inventory, assessment activities were postponed until a decision was made about elimination or relocation of the inventory site through consultations between the Field Crew Leader, the PI, and with NPS staff.

The assessment zones were surveyed using the following methods:

1. Prior to any upstream disturbance, the sampling zone was approached from the downstream direction whenever possible to assure that the site was not initially disturbed prior to setting up the sampling reach.

2. The Field Crew Leader confirmed the location of the stream reach to conduct the assessment. Where necessary, the evaluation zone was adjusted to meet the data quality objectives for the inventory and/or considerations listed in the Ohio EPA procedures.

3. Conditions at the inventory site were assessed to determine whether conditions were suitable for the collection of valid data. If, in the opinion of the Field Crew Leader, the DQOs for the study could not be met given temporary conditions such as high-water or elevated turbidity, assessment activities were postponed and rescheduled. Where site conditions indicated a permanent or long-lasting condition such as site safety hazards, stream channel modifications, or barriers to access that made it impractical or impossible to conduct the site assessment, conditions were documented, and the site was considered for relocation or removal from the inventory. These changes were made based upon consultations with the PI and NPS staff and were subject to approval by the NPS Contract Officer Representative (COR).

4. Sampling zones were photographed for future reference, and Global Navigation Satellite System (GNSS) coordinates were recorded for channel locations as described below.

5. Field water quality measurement data were collected at the downstream end of the assessment zone.

6. Assessment of the biological communities was conducted using the Level 3 protocols described in Section 7.0 of the Ohio EPA *Field Manual for Ohio's Primary Headwater Habitat Streams* (Ohio EPA, 2020) for fish, amphibians, and macroinvertebrates (Section 3.1.3).

7. Habitat assessments were conducted using the HHEI (Ohio EPA, 2020) for all locations in the study.

8. Stream geomorphological measurements were taken for stream channel gradient and flood prone area widths.

9. Streambank assessments were conducted to complete scoring for BEHI and NBS measurements.

10. The visitor use impact survey was completed for the site.

Data collection using paper forms was limited to a single sheet used to map the assessment site as part of the HHEI procedure. Each site mapping form was labeled with a unique two-letter field trip identification code (Field Trip ID) with a matching QR code for linkage to the unique site identification number (See Appendices A and B). The Field Trip ID was then used to synchronize electronic data forms used to collect all subsequent field data. Tablet computers or cell phones were used for data entry using ArcGIS Survey 1-2-3®, an application for data entry and management programmed to collect data input in a manner consistent with direct transfer to a project-specific database. Sets of all applicable field forms printed on waterproof paper were available during the site evaluation if the tablet computer malfunctioned or became otherwise unavailable, but this proved to be unnecessary during the survey.

Survey Methods

Study Reach Delineation and Documentation

Following verification of the site location, the Field Crew Leader determined the correct positioning of the sampling reach to meet project DQOs. Flagging was then placed at the upstream, midpoint, and downstream points to set up a 61m (200ft) length of channel to be used for the inventory evaluation. Additional flags were then placed demarcating a 10m zone for the Level 3 salamander survey zone. A schematic for setting up the sampling reach is provided in Figure 5.

Geolocations

Each of the five flag locations was geo-referenced using a GNSS unit with sub-meter accuracy. Field crews primarily used a Geode™ GNSS receiver (Juniper Systems, Inc.) connected to either a tablet computer or smart phone to collect GNSS data to delineate the assessment zones. Points within the assessment were identified using the following notation:

- UST-<*Site_#*> (e.g., UST-Site_16B), this point marks the upstream terminus of the 61m assessment zone.

- MID-<*Site_#*> (e.g., MID-Site_16B), this point marks the mid-point of the 61m assessment zone.
- DST-<*Site_#.*> (e.g., DST-Site_16B), this point marks the downstream terminus of the 61m assessment zone.
- SAL-UP-<*Site_#*> (e.g., SAL-UP-Site_16B), this point marks the upstream terminus of the 10m salamander sampling zone.
- SAL-DN-<*Site_#*> (e.g., SAL-DN-Site_16B), this point marks the downstream terminus of the 10m salamander sampling zone.

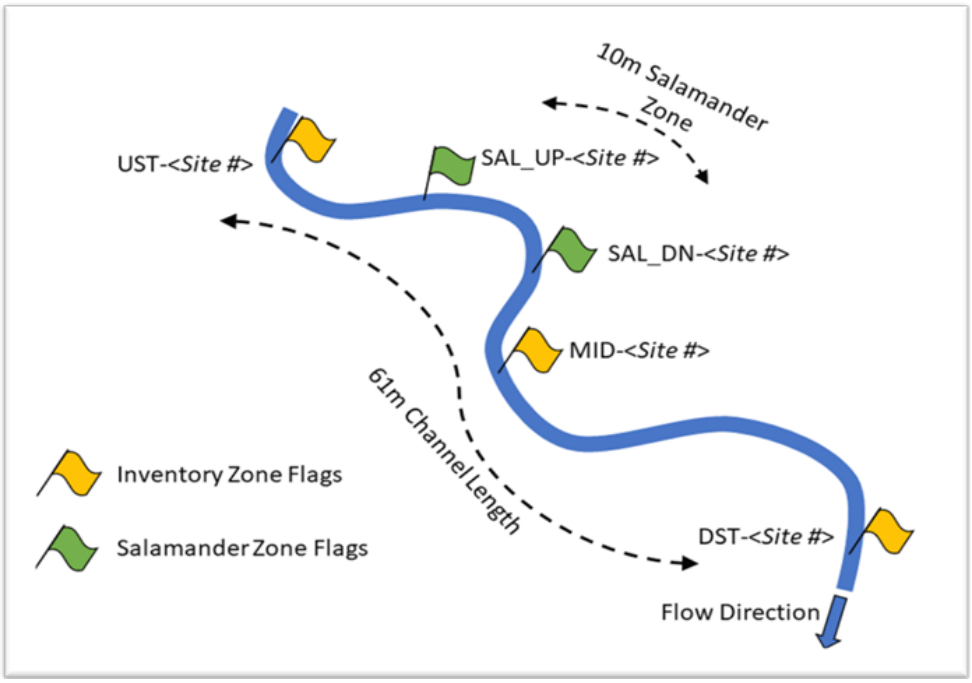


Figure 5. Stream assessment zone layout and georeferencing points.

Note that in some instances the upstream terminus of the assessment zone was the same point as the upstream terminus of the salamander assessment zone. In general, crews did not place the 10m salamander sampling zone at the lower end of the stream assessment zone as that would have prevented other members of the crew from conducting assessment activities until the salamander sampling was completed so that the water flowing into the salamander zone did not become turbid.

Site Photographs

Representative georeferenced digital site photographs were taken of the stream channel in both the upstream and downstream aspect at each location flagged in the assessment zone. Additional site photos were also collected at the discretion of the sampling crew of the riparian area, at surface water inflow locations or seeps noted draining to the stream, and of other points of interest at each assessment site.

Water Quality Measurements

Field water chemistry measurements were taken at all sampling sites following EnviroScience and Ohio EPA methodologies (EnviroScience, 2020a; Ohio EPA, 2019). Field data collection was conducted or supervised by personnel who are trained for water chemistry evaluation. Measurements were taken for water temperature, pH, specific conductance, and dissolved oxygen (DO) using a portable YSI ProDSS® multi-parameter water quality meter, or equivalent. All field measurements were recorded using an electronic form using ArcGIS Survey 1-2-3® to a tablet computer or cell phone for water sample collection and field measurements.

Field meters were calibrated daily in accordance with the manufacturer's specifications prior to each sampling event. Corrective measures were taken in instances where either the field calibration or erratic readings indicated that the field meter was malfunctioning.

Water clarity was measured prior to any site disturbance. Water clarity was measured using a transparency tube to provide an estimate of water turbidity at the time of the assessment. The use of these devices is described in Anderson and Davic (2004).

Headwater Habitat Evaluation Index (HHEI) Assessment

The habitat for aquatic life was evaluated within each zone using the Headwater Habitat Evaluation Index (HHEI) (Ohio EPA, 2020) as described in the PSP. Data was recorded using a tablet computer or cell phone in the field using an electronic form that emulated the Ohio EPA HHEI form, included in a supplemental appendix to this report (EnviroScience, 2023). In all cases a stream drawing was sketched for the assessment site using a revised HHEI Substrate Form that included the unique Field Trip ID and matching QR code. This form is also included in a supplemental appendix to this report (EnviroScience, 2023).

The field drawings are used to depict the channel pattern, flow direction, cardinal directions, relevant habitat characteristics, depth and width measurements and locations, and any other features helpful for evaluating the site or locating the assessment zone in the future.

All habitat assessments were conducted by personnel who have successfully completed training in the Ohio EPA HHEI and Qualitative Habitat Evaluation Index (QHEI) protocols.

Stream Geomorphology Measurements

Stream geomorphic assessments were conducted at each sampling site to document the physical stream channel conditions with respect to channel type, based upon the Rosgen Classification System for Natural Rivers (Rosgen, 1985,1994, 2009). The stream geomorphology measurements necessary for the channel classification are summarized in Figure 6. Geomorphology measurements included stream channel gradient, stream channel and flood prone area widths, channel pattern, and bed material characterizations. Data were collected at multiple locations within each assessment zone to generate the data necessary to complete the classification.

The Rosgen stream channel classification system is widely used to standardize the nomenclature for the characterization of channel types. Classification results provide a basis to predict near and long-term behavior with respect vertical channel stability, sediment transport, hydrology, streambank

stability, and potentially ecological conditions. The stream channel classifications are also useful to augment aquatic habitat assessments using the HHEI and biological characterizations for the sites.

Classification using the Rosgen method relies upon measurements to define the stream valley type, categorized into types using a letter system from A through G, the predominant channel material using a numeric system, and stream channel gradient, using lower case letters from a through c dependent upon valley type (see Figure 6). An example for the complete classification result appears in the format "F2b", indicating an F valley type, dominated by boulders as the channel material with a channel slope in the range of 0.02 – 0.039.

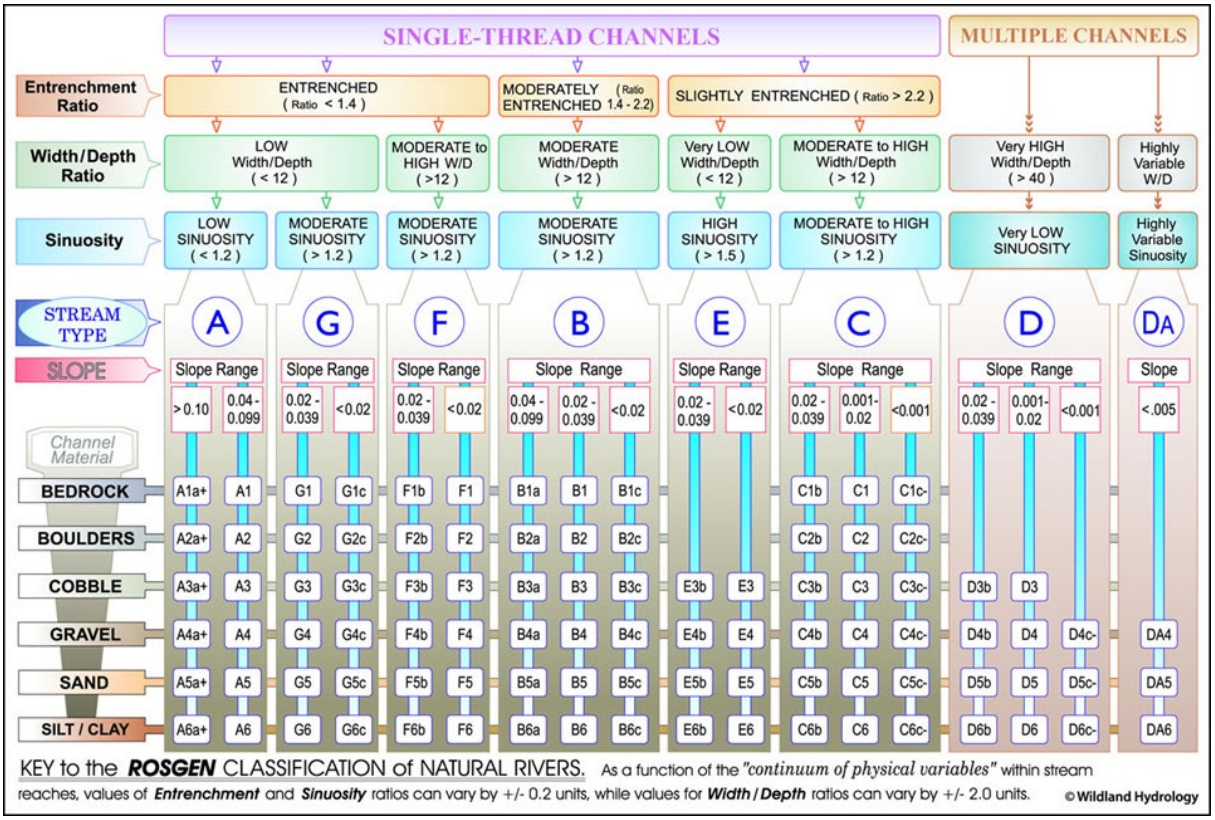


Figure 6. Decision chart for the geomorphological classification of stream channels. (© 2009 WILDLAND HYDROLOGY; Rosgen)

Bankfull and Flood Prone Width Measurements and Calculations

Stream channel and flood prone area widths were collected at the stream at inventory sites to provide data for the calculation of stream geomorphology indicators used to both classify the channel using the Rosgen classification system and to assess streambank condition erosion potential. Measurements were taken at two to four stations set up in straight sections (riffle, run, or glide) of the stream assessment zone for averaging. Measurements were input to a tablet computer or cell phone using the ArcGIS Survey 1-2-3® software programmed to emulate the EnviroScience Stream Geomorphology Data form developed for the project. This form is included in a supplemental appendix to this report (EnviroScience, 2023). Channel width measurements were collected to provide data for the

determination of channel cross-sectional area based upon measurements at 1.0, 1.5, and 2.0 times the maximum depth at the bankfull elevation (D_{max}) as described in the PSP and depicted in Figure 7.

In addition to the measurements used to document the channel and flood prone widths, depth measurements were also taken from the bankfull level line elevation to the channel bottom at three additional locations: 1) a single measurement at the water's edge to determine the depth to water under base flow conditions and 2) measurements at the points of maximum depth one-third of the bankfull channel width from the bankfull marker for each bank (denoted as the near bank maximum depth or D_{nb}). These measurements are used along with D_{Max} to calculate the average bankfull depth (D_{bkfl}). Both measurements are also used to calculate the Near Bank Stress (NBS) used to evaluate streambank erosion characteristics as described below.

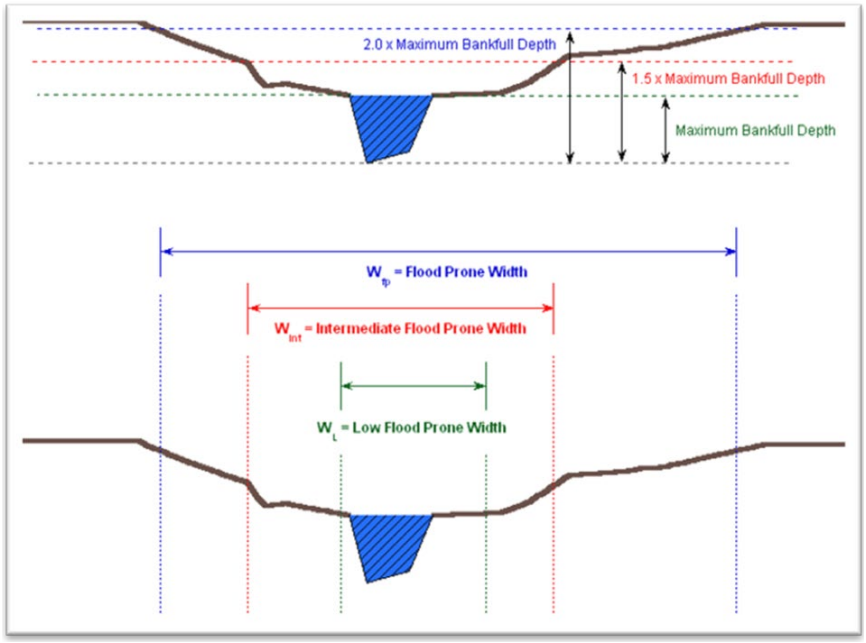


Figure 7. Stream floodprone area measurement diagram.

Other variables that are calculated using the geomorphology measurements collected during the headwater stream inventory are used in the Rosgen stream channel classification chart (Figure 6) to derive the stream channel type. These include the Width to Depth Ratio (W:D), calculated as the bankfull width (W_L) divided by the mean bankfull depth (D_{bkfl}), and Entrenchment, calculated as the Flood prone Width (W_{fp}) divided by the bankfull width (W_L).

The entrenchment ratio (entrenchment) is defined as the ratio of the floodprone width to the width of the stream channel at the bankfull elevation (bankfull width) (Rosgen, 1994). The minimum value for entrenchment is 1.0 (fully entrenched), and high values indicate a wide floodprone area. The width to depth ratio (W/D) is by dividing the bankfull width by the average depth of the bankfull channel. Low values for W/D are indicative of deep channels while high values indicate very wide shallow channels. Sinuosity (K) is calculated as the ratio of the stream channel length to the straight-line valley length. The minimum value of K is 1.0, which indicates a perfectly straight channel.

Channel Gradient Measurements

Longitudinal measurements of the stream sufficient to measure channel gradient and sinuosity were collected as follows:

1. Channel gradient was measured by taking sequential sight level measurements against grade rods from riffle crests in an upstream to downstream direction along the thalweg (Figure 8).

2. The values obtained by subtracting elevations on the two grade rods from each measurement were summed and then divided by the length of channel measured within the assessment zone (typically 200ft) to provide gradient in units of feet (gradient) per foot of channel. Sequential measurements were made from riffle crest to riffle crest as necessary to determine the stream channel to account for instances where the line of sight within the zone was obscured.

3. The values for all measurements were entered into the tablet computer using ArcGIS Survey 1-2-3® software that emulated the CUVA Headwater Inventory Geomorphology Form. This form is included in a supplemental appendix to this report (EnviroScience, 2023). Data from this program was then downloaded for subsequent analysis.

Channel Sinuosity Estimations

Sinuosity (K, unitless) is calculated as the ratio of the stream channel length measured along the thalweg, defined as the line of flow connecting the deepest points along the channel bed, to the valley length, defined as the straight-line distance between the upstream and downstream termini of the assessment reach. The PSP for the inventory (EnviroScience, 2022) contemplated calculation of K using desktop procedures combining GNSS data to determine valley length for the sites and the measured thalweg length (standardized to 200 ft). However, because of the variable x, y error associated with geolocation of the points associated with the assessment zone (up to 30 m, or half of the length of the zone), the geolocation data set could not be used for this purpose. Therefore, the qualitative stream sinuosity category recorded in the field during the site characterization performed to complete the HHEI was used in conjunction with the geolocation data and interpolation from aerial photos to set the valley length for each site. These values are used to calculate K for the purpose of stream channel classification.

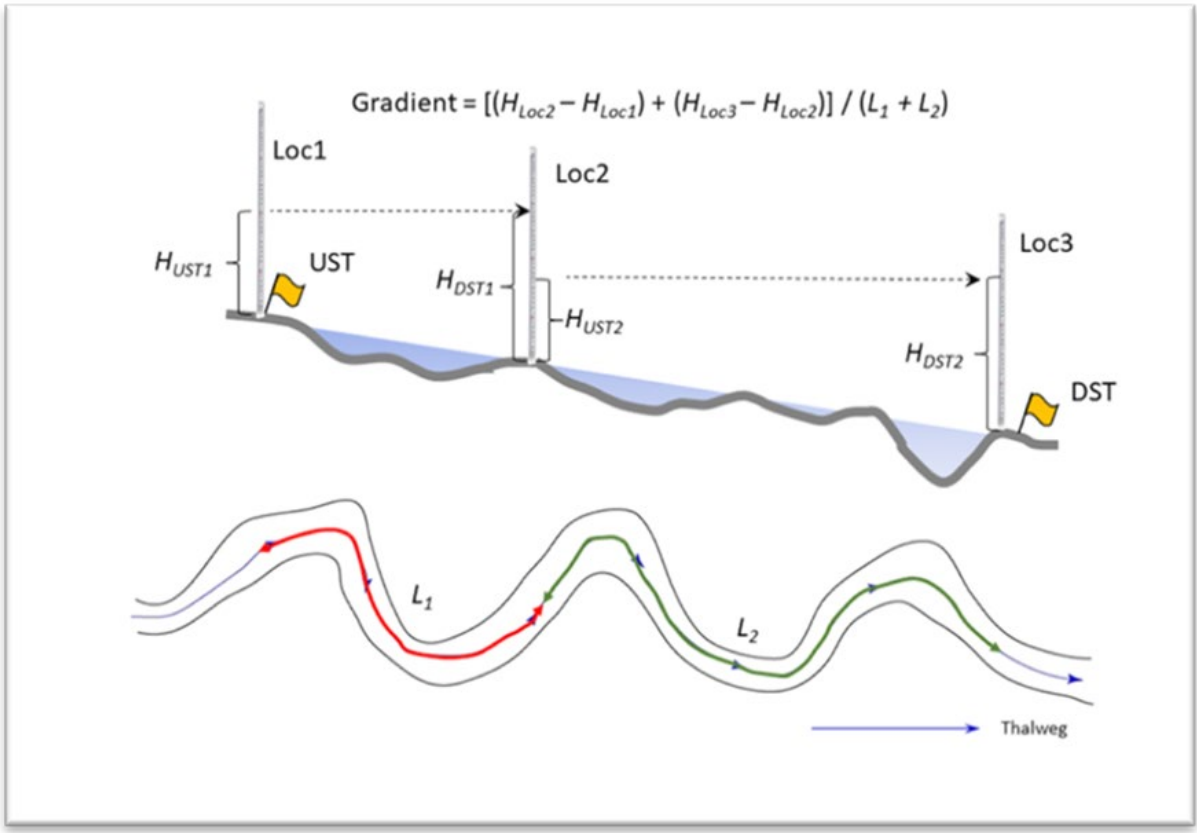


Figure 8. Schematic representation of the method for measurement of stream channel gradient.

Streambank Condition and Erosion Potential Evaluation

The prediction of stream bank erosion rates uses the "Bank Assessment for Non-point source Consequences of Sediment" (BANCS) method. This method as published by Rosgen (2001a, 2001b, 2009) utilizes two bank erodibility estimation tools: the Bank Erosion Hazard Index (BEHI), and Near Bank Stress (NBS). Calculation of BEHI and NBS values allows for the standardized estimation of lateral streambank erosion rates in feet per year that can be converted to mass per unit length per year.

This component of the CUVA Headwater Stream Inventory was added to the SOW to provide physical stream channel integrity data that can be evaluated against the biological community assessment data. The quantification of values for BEHI and NBS can be directly correlated to relative bank erosion rate estimates for stream channels.

Staff who conducted the BEHI/NBS assessments were trained in the assessment procedures by Jeff Niehaus, who has received certification for Rosgen Level III stream geomorphic assessment procedures. Field Crew Leaders and the PI were responsible for assuring consistent practices during the field assessments conducted to complete the inventory and communicated regularly to assure quality control for the collection of field measurements.

The worksheet for completing the BEHI and NBS worksheets is provided in the supplemental appendix to this report (EnviroScience, 2023). Assessments were conducted for demarcated study banks along the stream within the assessment zone at each primary and secondary site. The number of study banks evaluated in the field at each site varied, but a minimum of two BEHI/NBS evaluations, one per side of the stream, were conducted at each assessment site. Data for the BEHI/NBS worksheets were input into a tablet computer using a ArcGIS Survey 1-2-3® application that emulated the worksheets provided in the PSP. All measurements followed the procedures described in the methodology (Rosgen, 2001; 2009).

Bank Erosion Hazard Index (BEHI) Evaluation

The BEHI evaluates the susceptibility to erosion by integrating multiple variables that relate to processes which may contribute to erosion of bank materials. Erosion risk is then established for the defined BEHI variables to obtain an overall BEHI rating for the stream bank. A diagram of a typical streambank and variables surveyed and calculated is depicted in Figure 9.

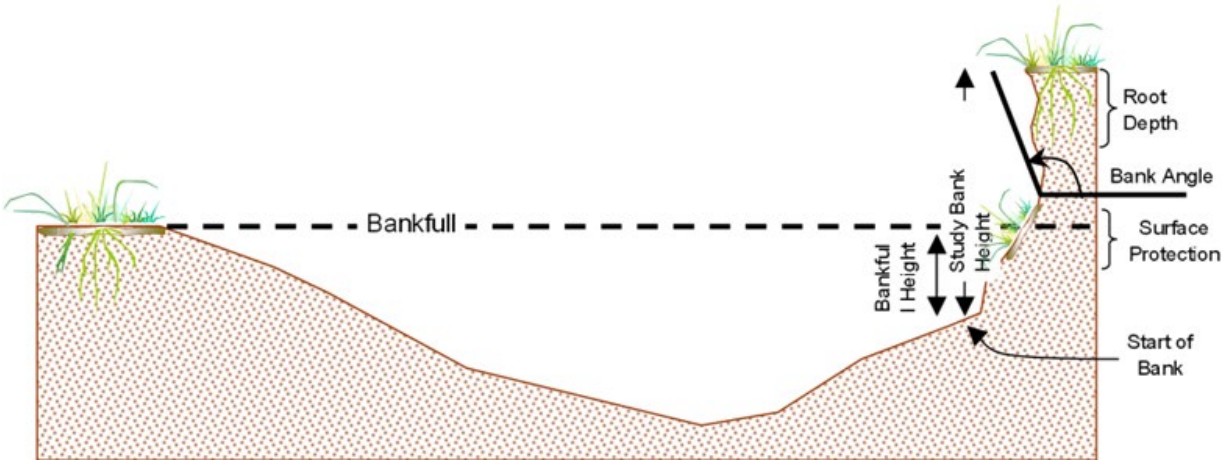


Figure 9. Streambank schematic of metrics measured for BEHI analysis. (© 2009 WILDLAND HYDROLOGY; Rosgen)

Five BEHI sub-metrics are evaluated to derive the total BEHI score to rank the erosion hazard:

1. Ratio of bank height to bankfull height: as bank height increases in relation to the bankfull height (high values for the ratio), the amount of erosive energy within the stream channel increases in high flow conditions.

2. Ratio of root depth to bank height: streambanks that are entrenched to the point where the stream channel lies below the depth of root penetration (low values of the ratio) are less stable under elevated flow conditions.

3. Root density (in percent): streambanks with higher root densities are less susceptible to erosion under high flow conditions.

4. Bank angle, (in degrees): streambanks with a low bank angle are more stable because the shear stress of the water upon the bank is dissipated over a larger surface area of the bank.

5. Surface protection (in percent): banks covered by vegetation, large rocks, boulders, and logs are more protected from erosion since these features dissipate energy from the flowing water under high flows.

Each of the five metrics listed above are scored on a scale with a maximum value of 10 points. The resulting scores are summed to give a total BEHI score.

The overall BEHI ranking is corrected under certain site-specific conditions based on the final two metrics:

1. Bank material: the overall BEHI score may be adjusted according to the bank material present based upon the susceptibility of the material to erosion (e.g., banks composed of sand are adjusted higher, those composed of bedrock or boulders are adjusted downward); and

2. Stratification of bank material: the overall BEHI may be adjusted upward by 5 to 10 points if the bank material is stratified, and unstable layers are exposed to bankfull flows.

The final total BEHI value has a maximum possible score of fifty points. Higher BEHI values are indicative of higher erosion hazard. The total BEHI score equates to a narrative rating of either Very Low, Low, Moderate, High, Very High, or Extreme (Table 3).

Table 3. BEHI and NBS adjective rating ranges.

Adjective NBS ranking	Total BEHI Score Range	NBS Value Range
Very Low	<10	<1.00
Low	10 - <20	1.00 - 1.50
Moderate	20 - <30	1.51 - 1.80
High	30 - <40	1.81 - 2.50
Very High	40 - 45	2.51 - 3.00
Extreme	>45	>3.0

Near-Bank Stress (NBS) Evaluation

The BANCS Model annual stream bank erosion rate prediction also includes the NBS assessment. Near Bank Stress is measured to estimate the amount of energy distributed against the streambank under high flow conditions. The NBS variables used in the prediction methodology indicate potential disproportionate energy distribution in the near-bank region, which can accelerate stream bank erosion. For example, in some instances the presence of a gravel bar directs the velocity vectors directly into a bank and increases the local energy slope; erosion rates are then higher.

Rosgen (2009) provides seven methodologies for the calculation of NBS values, each based on a different set of measurements. For the CUVA Headwater Stream Inventory, Method 5, the ratio of the near-bank maximum depth (D_{nb}) to the bankfull mean depth (D_{bkfl}), is used to calculate NBS. This method is deemed the most useful for small headwater streams because of their channel characteristics and ease of use in the field (Jeff Niehaus, pers. comm.).

As with the BEHI score, the total NBS rating for a study bank is equated to a narrative ranking of Very Low, Low, Moderate, High, Very High, or Extreme (Table 3). The result for each study bank / reach is a narrative rating of both BEHI and NBS (e.g., Very Low BEHI / Moderate NBS).

Streambank Erosion Rate Estimation

The results of BEHI and NBS ratings for individual study banks are used in the BANCS Model to estimate lateral streambank erosion rates (in feet per year) through comparison to documented field studies from similar stream settings. The BEHI / NBS ratings of the study banks are used to characterize entire reaches with similar characteristics and conditions. A reach is considered high-risk when the combination of BEHI and NBS are in the upper range of the narrative rating. For example, a reach can have a BEHI rating of "Very High," but if the NBS rating is "Very Low" the reach will not be an area of potential erosion risk. However, if a reach has a BEHI of "High," and the NBS is also "High," the reach has an overall high degree of erosion potential and poses risk.

Rosgen (2001a, 2001b, 2009) estimates lateral streambank erosion rates using relationships developed from western streams found in regions of alpine glaciation or alpine volcanism that have been statistically verified for these areas. He cautions that use of these relationships in other geological settings are likely to be inaccurate and states that similar regional relationships are necessary to validate the model. Unfortunately, regional data for the glaciated region of the State of Ohio in which CUVA lies does not presently exist. Therefore, for the analysis of data collected from the CUVA Headwater Stream Inventory sites, streambank erosion rate relationship curves for BEHI and NBS values developed from the eastern U.S.A. were used for the present study. The best currently available relationships for this purpose are those developed for North Carolina streams by the Natural Resource Conservation Service, North Carolina State University, and the North Carolina Division of Soil and Water Conservation (Patterson et. al, 1998; Doll, et. al, 2003) were selected for use for analysis of the CUVA data set. The erosion rate curves are presented in Figure 10 and were used for the analysis of the CUVA data set.

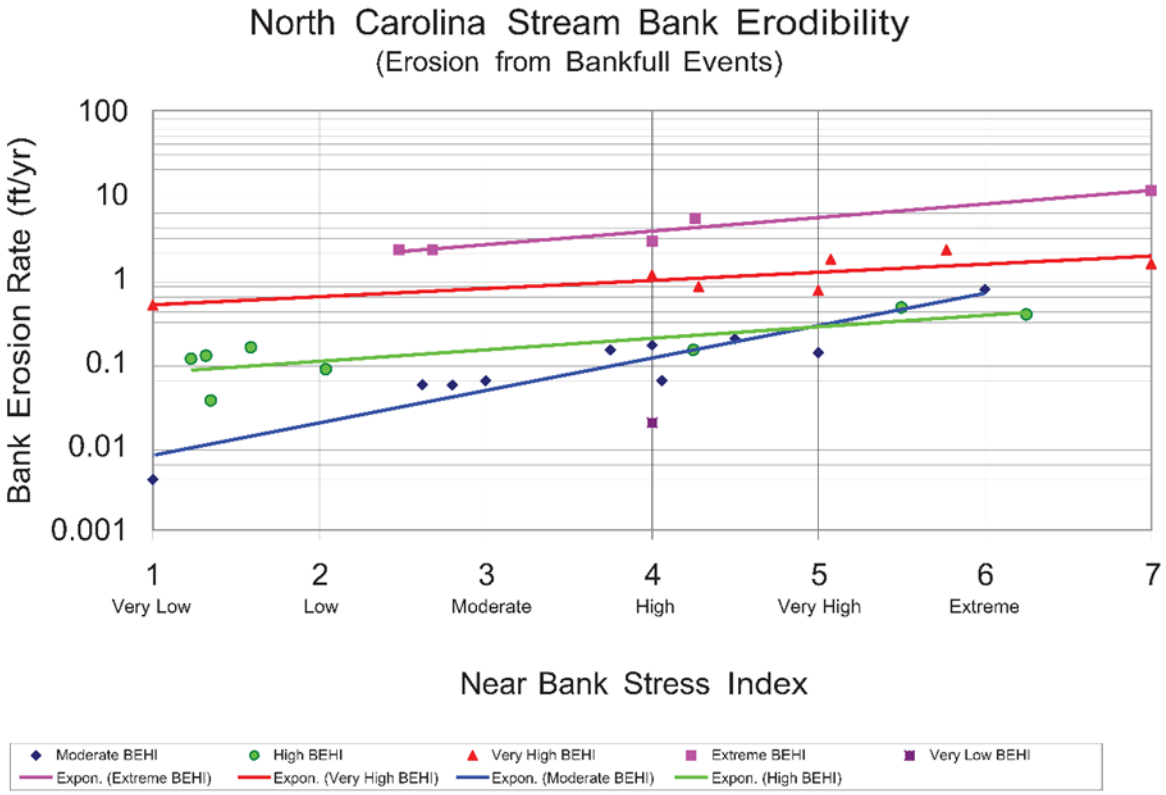


Figure 10. Erodibility relationships for NBS and BEHI values for North Carolina Piedmont region streams. (Source: Doll, et. al, 2003)

Lateral erosion rates are calculated using the numerical value for the study bank NBS result using the appropriate curve in Figure 10 that corresponds to the BEHI adjective ranking for that location. The lateral erosion rate in ft yr^{-1} is calculated based upon the NBS ranking using the following equations:

Extreme BEHI: $$E = 0.78081 \times e^{(0.3876 \times NBS)}$$

Very High BEHI: $$E = 0.35605 \times e^{(0.24411 \times NBS)}$$

High BEHI: $$E = 0.05223 \times e^{(0.33572 \times NBS)}$$

Moderate BEHI: $$E = 0.00300 \times e^{(0.90363 \times NBS)}$$

Where: E is the lateral streambank erosion rate in ft yr^{-1}; and
NBS is the numerical NBS value (unitless)

For study banks with BEHI adjective scores of Low and Very Low, a 0.0 ft yr^{-1} lateral erosion rate of is assumed. In these situations, the net streambank erosion rate is typically negligible and applicable erosion rate curves are not available (Jeff Niehaus, pers. comm.).

Biological Characterization Procedures

The headwater stream inventory study used the assessment procedures described in the Ohio EPA *Field Evaluation Manual for Primary Headwater Streams* (Ohio EPA, 2020). Biological assessments within the zones were conducted using the Level 3 biological sampling approaches outlined in Section 7.0 of the Ohio EPA PHW manual. Sampling was conducted for macroinvertebrates, fish, and salamanders.

In situations where the stream was found to be experiencing seasonally dry conditions and no surface water was found to be present, biological sampling was not conducted for fish or macroinvertebrates. However, in these situations, evaluation of the stream bed proceeded to determine whether adult salamanders were present and the species composition of the community. Where the surface water that was present consisted of isolated pools, with or without evident connected flow, sampling for all organisms was conducted.

Please note that the management of vertebrates captured during the CUVA Headwater Stream Inventory Study were guided by the procedures in the PSP and were designed to meet the guidelines and requirements of the NPS IACUC Animal Research Protocol Approval.

Macroinvertebrate Assessment

Macroinvertebrate community sampling was conducted using the qualitative assessment techniques described in the Level 3 sampling methods for PHW streams (Ohio EPA, 2020) and the *Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities* (Ohio EPA, 2015). Macroinvertebrates were collected by sampling all available habitats using kick net and hand picking of organisms from in situ substrates, debris, and plant materials. Sampling was conducted for a minimum of thirty minutes or until no new taxa were observed.

Field observations regarding the length of time spent sampling, the types of macroinvertebrates observed, their relative abundances, and habitat and water quality observations were recorded to a tablet computer or cell phone using an ArcGIS Survey 1-2-3® application that emulated the Ohio EPA Headwater Macroinvertebrate Field Evaluation Index (HMFEI) form. This form is included in a supplemental appendix to this report (EnviroScience, 2023). HMFEI scores for the sampling sites were computed in the field in accordance with the PHW protocols (Ohio EPA, 2020).

Field voucher organisms from all discernable taxa captured were preserved in 80% ethanol for laboratory identification. Sample container lids were sealed with electrical tape and the containers were labeled with the site identification number, collection date, collector initials, and a unique EnviroScience identification number. Samples were accompanied by a chain-of-custody document verifying delivery and receipt of the samples.

The voucher samples were examined in the laboratory and identified to the lowest practicable taxonomic level in accordance with Ohio EPA protocols.

Following the completion of the project, all preserved macroinvertebrate samples, including prepared microscope slides, were transferred to NPS for archival in accordance with the conditions established

within the Research Permit for the project and NPS regulations and guidelines for museum collections.

Amphibian Assemblage Assessment

Although all amphibians encountered during the headwater stream assessments were documented during the inventory, the surveys focused upon taxa of salamanders used in the PHW classification protocols. The presence and species composition of salamanders in the inventory sites was assessed by use of coincident capture during macroinvertebrate and fish sampling methods, as well as focused qualitative methods to search all available microhabitats within the stream and along the stream margins. In addition, a quantitative visual encounter survey (VES) for salamanders was conducted within a 10-meter channel reach within each assessment zone. Sampling followed the procedures outlined in the Ohio EPA PHW manual (Ohio EPA, 2020).

All salamander larvae and adults captured during the survey were identified to species, counted, and the data recorded were recorded to a tablet computer or cell phone using an ArcGIS Survey 1-2-3® application that emulated the Ohio EPA PHW Stream Biological Characteristics Field Sheet. This form is included in a supplemental appendix to this report (EnviroScience, 2023).

Representative photographs suitable to confirm taxonomic identification were taken of each amphibian taxon and life stage encountered during the site assessments. Photographs were taken with sufficient detail to positively identify the specimens to species, and all amphibian specimens collected during the inventory were positively identified in the field and released. Therefore, no voucher specimens of salamanders were preserved during the inventory. In addition, salamander egg masses were not removed from the stream or collected for laboratory examination. Egg masses were documented in the field through data entry and photographs and were replaced in the stream with as little disturbance as possible. Incidences of field mortality were rare and were recorded as part of the data collection process for reporting under the IACUC coordination protocol for the project.

Fish Community Assessment

Fish community surveys were conducted at sites with sufficient depth of water and flow conditions using a Smith-Root Model 20-LR Backpack Electrofisher. Voltage, amperage, and pulse rate settings for the electrofisher were adjusted as recommended by the manufacturer to assure high capture efficiency while minimizing mortality during the sample capture process. All available habitat types within each evaluated reach were sampled, and stunned fish were captured and held in a live well for identification and enumeration. Fish captured coincidentally during sampling efforts for macroinvertebrates and/or salamanders were also held temporarily in a separate live well prior to identification and enumeration. All fish collected during the inventory were identified to the species level of taxonomy.

Data for each site was recorded using tablet computer using customized forms created in Survey 1-2-3® format that emulated the Ohio EPA PHW Stream Biological Characteristics Field Sheet. This form is included in a supplemental appendix to this report (EnviroScience, 2023).

Digital photographs were taken of representative individuals of each fish species encountered for verification of the field identifications. Photographic vouchers for fish include features that permit definitive identification of the species and are the primary documentation for the species assemblage and quality assurance quality control procedures. The field crews found no need to preserve voucher specimens for laboratory identification during the inventory.

No State or Federally listed endangered or threatened fish species were encountered during the CUVA headwater stream inventory. The overwhelming majority of all fish captured during the inventory were returned alive to suitable micro-habitats within the stream from which they were found. Incidences of field mortality were rare and were recorded as part of the data collection process for reporting under the approved IACUC coordination protocol for the project.

Visitor Use Impact Assessment Procedures

A Visitor Use Impact Assessment (VUIA) questionnaire was completed at each inventory site using an emulated electronic form on a tablet computer using the ArcGIS Survey 1-2-3® app. This form is included in a supplemental appendix to this report (EnviroScience, 2023). The magnitude and types of visitor impacts were assessed by ranking the level of various anthropogenic stream disturbances within three zones associated with the assessment site: the riparian zone, the stream bank, and the stream channel and channel margin (Figure 11).

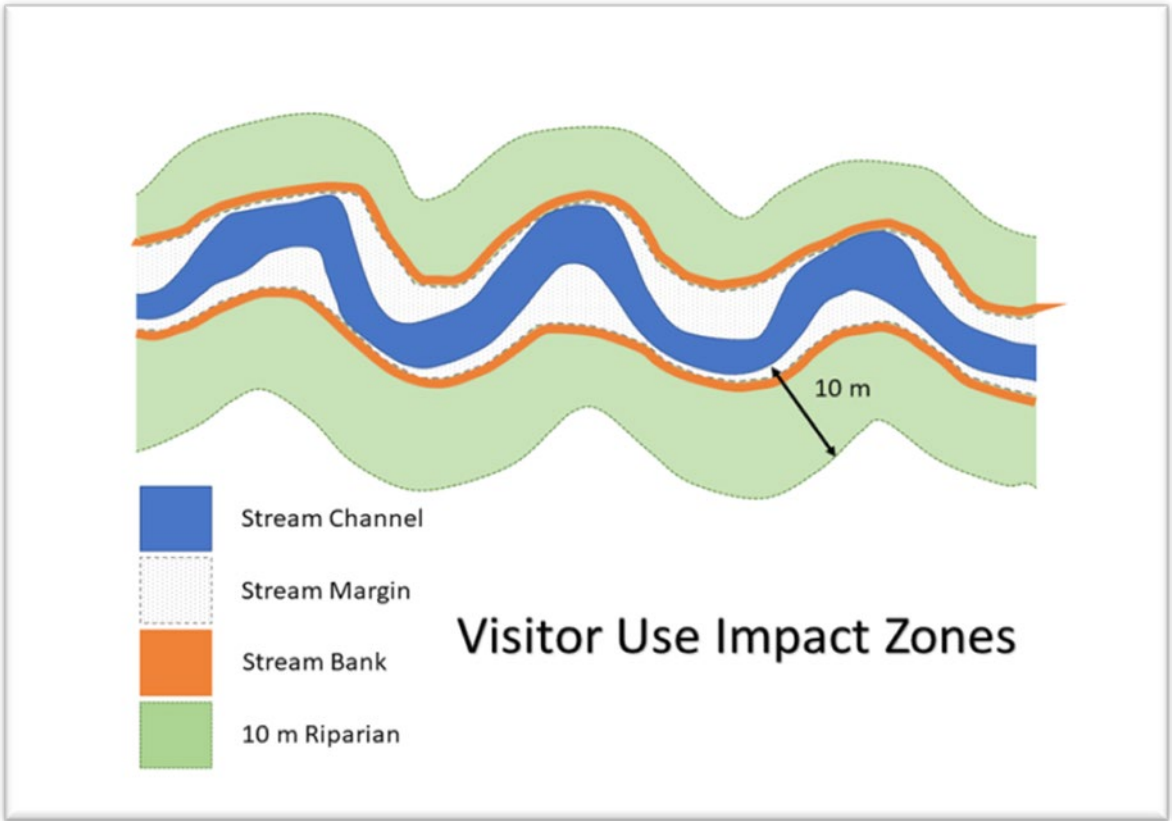


Figure 11. Schematic of visitor use impact assessment zones.

The **riparian zone** is defined as the land within a 10 m band adjacent to the stream, regardless of land use. In some cases, the riparian assessment area was less than 10 m wide. Examples include areas where the stream bank is vertical and of a height that precludes direct impact upon the channel or where constructed features (e.g., roadways) impinge upon the 10 m riparian corridor and where the impact assessment is deemed to be inapplicable.

The **stream bank** is defined as the distance along the length of the stream above the bankfull elevation but where slope, vegetation, or other factors clearly demarcate the zone as distinct from the riparian floodplain. This zone is variable in width and the area for this assessment zone dependent upon site-specific conditions.

The **stream channel** is defined as all areas within the stream that are below the bankfull elevation that is wetted under base flow conditions. The **stream channel margin** is defined as the gravel bars or depositional areas within the bankfull channel adjacent to the low flow wetted area which are exposed when the stream is at base flow. This zone typically is devoid of woody vegetation and is a transitional area within the bankfull channel.

Impact types assessed included those associated with the presence of litter or trash, access erosion, recreational uses, damage to vegetation, and stream substrate disturbances. The relative number of instances (observations) for each type of impact were recorded for the three impact assessment zones (riparian, stream bank, and channel/margin) as applicable for that zone as listed in Table 4. Categories for each observed impact used are None, 1-2 Instances, 3-4 Instances, and greater than 4 Instances). In addition, the total number of instances for litter and total impact instances noted during the assessment was quantified for each assessment zone.

For the litter impact category, the trash observed was noted as “recent”, “weathered” or both based upon the condition of the material present. This notation is included to assist in determining whether the source(s) are from activities within the near proximity to the site or whether the material is potentially flowing into the site from a far-field upstream source.

The types of trails and the approximate length of trails within each stream zone were identified through visual examination of each area. For purposes of the VUIA, “designated” trails consist of NPS maintained and marked trails, where “social” trails are all other identified pathways that carry visitor traffic, regardless of the mode of access (walking, bicycles, or horses). Impacts to the stream channel from visitor trail use were documented by noting where trails cross the stream channel or result from other activities within the channel that cause disturbance. Impacts on the channel condition from trails were identified by noting points of ingress and egress from the stream via examination of the stream bank, stream margins, and the associated riparian area.

Based upon site observations and measurements of the field habitat and biological conditions, a determination of the degree of severity of each type of impact was assigned as follows:

1 = No negative impacts on functional habitat observed

2 = Noted but no observed effect on functional habitat

3 = Noted; localized effects (<5% of functional habitat)

4 = Common; moderate loss of functional habitat (5% - 10%)

5 = Pervasive; significant degradation of functional habitat (>10%)

Following the assessment of all visitor use impacts, the field crew convened to qualitatively rank each stream assessment site regarding the ecological and aesthetic condition of the stream within the environs of the assessed location. The ranking is based upon a relative scoring from 1-10, with 1 being “Very Poor” and 10 being “Excellent”.

Table 4. Applicability of impact types by VUIA assessment zone.

Impact Category	Impact Types	Riparian	Stream Bank	Stream Channel and Margin
Litter	• Animal Waste (Dogs) • Animal Waste (Horses) • Plastic • Glass • Paper & Cardboard • Metals • Tires • Other	X	X	X
Access Erosion	• Bicycles • Hiking • Equestrian • Excavation	X	X	X
Recreation	• Picnicking • Fires • Fishing • Wading	X	X	X
Vegetation Damage	• Defaced trees • Trampling • Removal	X	X	–
Trails (Designated) & Trails (Social)	• Hiking • Bicycles • Equestrian	X	X	X

Analysis Methods

Stream Classification Procedures

Stream classifications were conducted using Ohio EPA methodologies for PHW streams according to the processes described in the PHW field manual (Ohio EPA, 2020). In addition, biological and habitat data was screened for the applicability of Aquatic Life Uses (ALUs) defined in the Ohio Water Quality Standards (WQS) in OAC Rule 3745-1-07. These designations supersede PHW classifications where applicable because sufficient data is available to meet the requirements of a "Use Attainability Analysis" (UAA) as that term is defined in OAC Rule 3745-1-02 from the Ohio WQS.

Assignment of Final Level 3 PHW Stream Classes

The procedure for classification of PHW streams for the headwater stream inventory uses the Level 3 biological assessment procedures outlined in the decision flow chart (Figure 12) provided in the PHW field evaluation manual (Ohio EPA 2020). Biological assessment results from each CUVA headwater stream inventory site collected using Level 3 PHW methodologies are evaluated using this methodology to classify the streams. Each organism group (macroinvertebrates, fish, and amphibians) must be assessed independently to ascertain the correct PHW classification. The highest classification result among the three organism groups was used to assign the final PHW classification for each site.

Classifications Based on Aquatic Life Uses Listed in OAC 3745-1-07

The Level 3 PHW biological assessment methods for fish and macroinvertebrates during the CUVA Headwater Inventory also adhered to Ohio EPA protocols for conducting UAAs as described within the following documents: *Biological Criteria for the Protection of Aquatic Life Volume I-II, Addenda and Updates* (Ohio EPA, 1987, 1989a), *2006 Updates to Biological Criteria for the Protection of Aquatic Life: Volume II and Volume II Addendum* (Ohio EPA, 2006a), and *Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities* (Ohio EPA, 2015). Therefore, this data can be used to assign ALUs to inventoried locations where the results confirm that the Ohio EPA biological water quality criteria are met for specific beneficial uses.

Qualitative Habitat Evaluation Index (QHEI) forms were not completed in the field during the CUVA headwater stream inventory. However, QHEI scoring is constructed for select sites using stream channel data collected during the inventory including habitat assessments using the HHEI (including stream drawings), channel gradient measurements, stream channel dimension measurements, and bank condition assessments for calculation of BEHI and NBS values. The resulting QHEI scoring data were also confirmed by analysis of site photos. All QHEI scoring was completed by biologists holding Level 3 Qualified Data Collector status for Fish Community Biology under the Ohio EPA Credible Data Program. Therefore, the resulting data set is suitable for providing accurate scoring for the QHEI in accordance with Ohio EPA guidance documents (Ohio EPA, 1989b; Ohio EPA, 2006b).

Index of Biotic Integrity (IBI) values for the fish communities were calculated for all the CUVA Headwater Inventory sites where three or more fish species were documented using electrofishing collection techniques. Scoring for the IBI was based upon the methodology for headwater sites

(drainage areas <20mi^2) as described in Ohio EPA guidance (Ohio EPA 1987a, 1987b, 1989a, 2006a, and 2015) for twelve metrics (Table 5). Resulting scores for the IBI can range from 12 to 60. The Ohio WQS list ecoregional criteria for IBI scores necessary to support the Exceptional Warmwater Habitat (EWH), Warmwater Habitat (WWH), and Modified Warmwater Habitat (MWH) ALUs. Applicable IBI criteria for the EOLP Ecoregion are listed in Table 6.

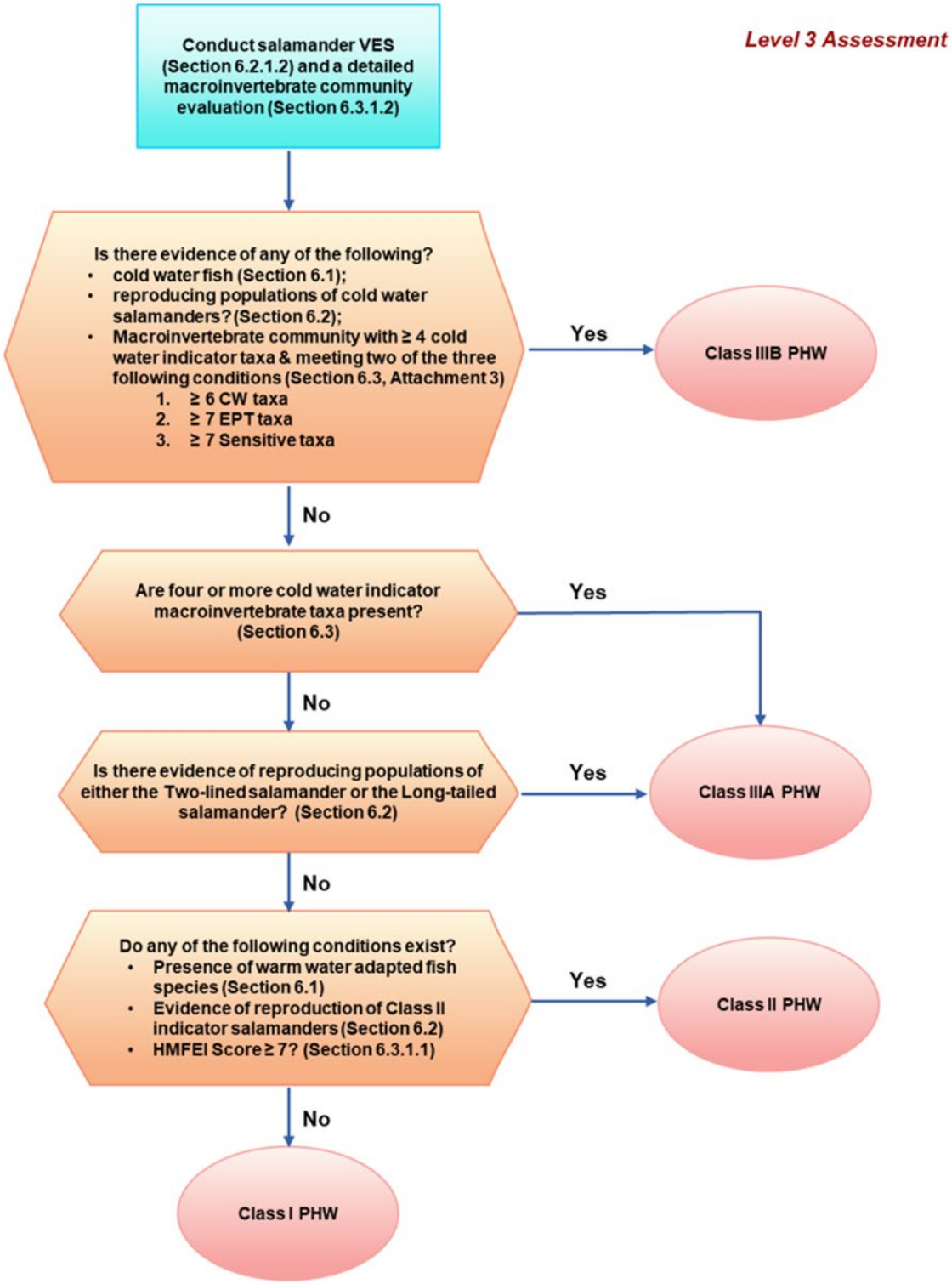


Figure 12. Classification flow chart for Level 3 PHW biological assessment chart. (Source: Fig. 22, Ohio EPA, 2020)

Table 5. Headwater IBI metrics.

Metric Number	IBI Metrics: Headwater Sites
1	Number of indigenous fish species
2	Number of darter species
3	Number of headwater species
4	Number of minnow species
5	Number of sensitive species
6	Percent tolerant species
7	Percent omnivores
8	Percent insectivores
9	Percent pioneering species
10	Number of individuals per 300 meters
11	Number of simple lithophil species
12	Percent DELT* anomalies

*Deformities Erosion, Lesions, and Tumors

Table 6. Narrative ranges for IBI scores applicable to the WWH use for headwater sites (<20 mi^2 drainage) in the Erie Ontario Lake Plain Ecoregion. Source: Table 8-3 in Ohio EPA, 2015. EWH = Exceptional Warm Water Habitat; WWH = Warm Water Habitat.

Headwater IBI Scoring Range	Narrative Evaluation	Scoring Decision Criteria	WQS Attainment Status*
50 - 60	**Exceptional**	Meets statewide EWH biocriterion	Attainment EWH and WWH
46 - 49	Very Good	Non-significant departure range for EWH; attainment for WWH	
40 - 45	**Good**	Meets Ecoregional WWH Biocriterion	Attainment WWH; Non-Attainment EWH
36 - 39	Marginally Good	Non-significant departure range for WWH	
28 - 35	Fair	Significant departure from ecoregional WWH biocriterion	Non-Attainment
18 - 27	Poor	Significant departure from ecoregional WWH biocriterion	Non-Attainment
12 - 17	Very Poor	Significant departure from ecoregional WWH biocriterion	Non-Attainment

* Values and narratives that indicate applicable biocriteria (also in bold)

There is no numerical water quality criterion with respect to the IBI for the Cold Water Habitat (CWH) ALU. Evidence that a stream supports a population of one or more cold-water indicator fish species (Table 7) in conjunction with the presence of cold-water indicator macroinvertebrate taxa and stream thermal regimes indicative of groundwater-fed cold-water conditions is used as evidence for support of the CWH ALU (Ohio EPA, 2018). Cuyahoga Valley National Park lies within the known ranges for all the species listed in Table 7 except for Brown Trout (*Salmo trutta*) and the native Brook Trout (*Salvelinus fontinalis*). Brown Trout are typically associated with put-and-take fishery stocking and have not been recorded from within the Cuyahoga River watershed, while the range of native Ohio Brook Trout is restricted to the Chagrin River watershed (Rice and Zimmerman, 2019; Trautman, 1987).

Table 7. Fish species listed as cold-water indicators in Ohio. Sources: Ohio EPA (1987a, 2020).

Family	Common Name	Species Epithet
Salmonidae	Brown Trout*	*Salmo trutta*
	Rainbow Trout*	*Oncorhynchus mykiss*
	Brook Trout	*Salvelinus fontinalis*
Cottidae	Northern Mottled Sculpin	*Cottus bairdi bairdi*
Gasterosteidae	Brook Stickleback	*Culaea inconstans*
Cyprinidae	Redside Dace	*Clinoostomus elongatus*
	Southern Redbelly Dace	*Chrosomus erythrogaster*

*Introduced non-native species

Numerical biological criteria promulgated by Ohio EPA for macroinvertebrate communities are based upon scores for the Invertebrate Community Index (ICI). The ICI is a multi-metric estimate of community condition derived similarly to the IBI. However, the ICI is based upon the use of an artificial substrate sampling method that typically cannot be used in small headwater streams such as PHWs. These systems do not typically have sufficient water depths and flow velocities necessary to allow for successful colonization of the artificial substrates over the six-week period required by the method (Ohio EPA, 1987, 1989a, 2006b, and 2015). In these situations, qualitative macroinvertebrate samples are collected using the methodologies described earlier. Narrative rankings for macroinvertebrate assemblages collected using the qualitative field sampling method are assigned based upon the assemblage of taxa present in the sample (Ohio EPA, 2015). Macroinvertebrate communities meeting the narrative ranking of "Good" and Exceptional" are considered in attainment of the WWH and EWH ALU, respectively. Similarly, communities meeting the ranking of "Very Good" and "Marginally Good" are considered within a "non-significant departure" range of the EWH and WWH ALUs, respectively. Narrative rankings of "Fair", "Poor", and "Very Poor" for qualitative macroinvertebrate samples are in non-attainment of the WQS for the WWH ALU.

The assignment of narrative rankings to qualitative macroinvertebrate communities in warmwater streams is somewhat subjective, being based upon comparative results to other similar communities

and ecological conditions. Ohio EPA has quantified the process through both published and unpublished tools to assist in standardization of the decision-making process. Published guidelines are provided in the document *Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities* (Ohio EPA, 2015).

Ohio EPA has also developed a numerical index for qualitative samples collected from headwater streams (<20mi^2) to emulate the ICI in the absence of quantitative data from artificial substrates. The procedure uses a set of statistically derived algorithms based upon statewide results for the presence or absence of specific taxa groups collected using established qualitative macroinvertebrate sampling procedures. This methodology was developed to aid Ohio EPA staff in the assignment of narrative ranks to standardize the process of evaluating monitoring data on a statewide basis (Robert Miltner, Ohio EPA, pers. comm.). The resulting "Headwater Macroinvertebrate Index", or HWMI, uses groupings of macroinvertebrate taxa within taxonomic, pollution tolerance, and functional groups to generate six metrics (Table 8), each with a maximum value of 10 and a minimum value of 0, which when added together provide a single HWMI score with a maximum score of 60 points. Metric scoring assignment is adjusted based upon stream size (represented as the log10 of upstream drainage area) based upon statistical correlations (Ohio EPA, unpublished manuscript). Macroinvertebrate groupings for specific taxa are based upon Ohio EPA's "Macroinvertebrate Taxa List" published on the agency's website.
(URL: https://epa.ohio.gov/static/Portals/35/bioassess/MasterTaxaList_123119.pdf)

Table 8. Metrics for the Ohio EPA Headwater Macroinvertebrate Index.

Metric Grouping	HWMI Metric
Pollution Tolerance	Percent Sensitive Taxa
	Percent Tolerant Taxa
Taxonomic Group	Percent Mayfly Taxa
	Percent Caddisfly Taxa
	Percent Non-Insect Taxa
Functional Group	Percent Predator Taxa

Assignment of final narrative rankings for macroinvertebrates collected from the CUVA Headwater Inventory stream sites to determine if established ALUs are appropriate uses a weight of evidence approach based upon the community assemblage (Table 9). This approach relies upon a combination of thresholds established in the Ohio EPA biological criteria guidance (Ohio EPA, 2015) and the HWMI score resulting from the macroinvertebrate taxa collected during the inventory.

Table 9. Chart for assignment of macroinvertebrate community narrative scores and aquatic life use attainment status for headwater streams (<20 mi^2) based upon qualitative samples.

Narrative Score	No. EPT Taxa [a]	No. Sensitive Taxa [a]	Headwater Macroinvertebrate Index	Attainment Category [b]
Exceptional	≥ 13	≥ 15	45+	EWH/WWH: Attainment
Very Good	See Note [c]	See Note [c]	40 - 44	EWH: Non-Significant Departure [d] WWH/CWH: Attainment
Good	9 - 12	10 - 14	32 - 39	WWH/CWH: Attainment
Marginally Good	See Note [c]	See Note [c]	25 - 31	WWH/CWH: Non-Significant Departure [d] MWH: Attainment
Fair	5 - 8	5 - 9	12 - 24	WWH: NON-Attainment MWH: Attainment
Poor	2 - 4	2 - 4	5 - 11	Non-Attainment for all uses except LRW
Very Poor	<2	<2	0 - 4	Non-Attainment for all uses except LRW

[a] Source: Ohio EPA, 2015

[b] Attainment status refers to designated aquatic life uses listed in OAC Rule3745-1-07; for CWH, the presence of cold-water indicator fauna is also required (see text); these criteria do not convey to Primary Headwater Stream classifications not promulgated in rule.

[c] Best technical judgment; not specifically stated in Ohio EPA guidance.

[d] Non-significant departures from threshold values considered to be in attainment of the aquatic life use.

With respect to the CWH ALU, two categories are defined using narratives in OAC Rule 3745-1-07(B)(1)(f): “Coldwater Ha bitat, Inland Trout Streams” and “Coldwater Habitat, Native Fauna”. None of the headwater streams found in CUVA meet the definition of Inland Trout Streams. The definition of CWH, Native Fauna is as follows:

> *“…these are waters capable of supporting populations of native coldwater fish and associated vertebrate and invertebrate organisms and plants on an annual basis.”*

Assignment of the CWH ALU based upon numeric criteria (e.g., IBI, MIwb, and ICI scores) is not clearly defined in either the Ohio WQS or in a single-source Ohio EPA guidance document. Therefore, recommendations for assignment of the CWH ALU to the CUVA Headwater Inventory sites is based upon a weight of evidence approach using a compilation of Ohio EPA practices available at the time of the writing of this report (Ohio EPA, 2006a, Ohio EPA, 2015; Ohio EPA 2020). The following criteria are used herein:

- Documentation of the presence of the following fish species listed as cold-water indicator taxa in Table 4 of the Ohio EPA PHW manual (Ohio EPA, 2020); and
- Either,
- Documentation of the presence of four or more cold-water indicator taxa of macroinvertebrates and water temperatures less than 21.1°C (70°F); or
- Documentation of the presence of nine or more cold-water indicator macroinvertebrate taxa.

Note that these are recommendations based upon best technical judgement and are not legally binding unless accepted by Ohio EPA and established in the Ohio WQS.

Statistical Analysis Methods

The study design used for the selection of sites for the CUVA headwater stream inventory was not constructed with statistical analysis of the data as a foremost priority. The study was biased to select Primary Sites that were known aforehand to be perennial or likely to be perennial and were not grouped in a stratified manner to allow for equal sample sizes for the analysis of factors of interest. Instead, the inventory was designed to catalog the headwater resources within the park to optimize the gathering of data regarding their biological and physical characteristics. The process to select Secondary Sites was carried out in a similar manner. Therefore, the ability to use statistics to detect causation for the results observed during the inventory is limited.

Single and Two-Factor Statistical Tests

A uniform approach was used for the statistical analysis of selected stream characteristics within the CUVA headwater stream inventory data set to examine differences between the final stream classes as determined using Level 3 PHW procedures. Pooled data for Class II, Class IIIA, and Class IIIB streams within CUVA were compared using the Kruskal-Wallis rank sum test (Seigel and Castellan, 1988; Zar, 1999). This non-parametric statistical test was chosen in favor of analysis of variance (ANOVA) because assumptions for normal data distributions were typically not met for all data sets and because of the unequal sample sizes between data sets. All single and two-factor statistical analyses were conducted using the statistical calculation functions incorporated in KaleidaGraph© Ver. 4.5 graphics software (Synergy Software).

In cases where there were no statistically significant differences between the stream classes noted using the Kruskal-Wallis procedure at $p<0.05$, no further analysis was conducted. Where statistically significant differences are noted between the stream classes using the Kruskal-Wallis procedure, data from the stream classes were examined in a pair-wise fashion (i.e., Class II vs. Class IIIA, Class II vs. Class IIIB, and Class IIIA vs. Class IIIB) as a post hoc testing procedure using the Wilcoxon-Mann-Whitney rank sum test (Seigel and Castellan, 1988; Zar, 1999).

Class I PHWH streams were excluded from the statistical analyses since only two sites of this type were assessed during the study. In addition, for parameters where the presence of certain characteristics within the biological communities are determinate in classifying a site, tests for the three stream categories using the Kruskal-Wallis procedure were not deemed appropriate since

differences are assumed as part of the classification procedure. Examples are the number of age classes for Class III indicator salamander species and the number of EPT and Sensitive macroinvertebrate taxa for discerning Class IIIB vs. Class IIIA communities.

Multivariate Test Procedures

Biotic and Abiotic Variables

A total of 104 variables based on both qualitative and quantitative scales were selected for further analysis for each sampled CUVA headwater site. Categorical qualitative data were converted to dummy variables so they could be included as continuous variables in subsequent multivariate analyses. For example, the variable, 'surficial deposit unit name' had a total of eight potential categories or responses (i.e., alluvium, ravines, outwash and lacustrine deposits, etc.) and therefore this variable was split into seven dummy variables.

Prior to conducting any statistical analyses, the data were screened for potential outliers and anomalies as well as missing values. For those sites with missing water chemistry data (e.g., water temperature, dissolved oxygen saturation etc.), data from the nearest geographical location were used as surrogate values.

Multivariate Analyses

To determine the abiotic parameters that drive the differences among the four PWH classes within the CUVA dataset, a series of multivariate statistical techniques, including factor analysis and discriminant function analysis, were used. Factor analysis was used to assess multicollinearity and remove redundancy in the environmental data comprising habitat, landscape, and physico-chemical variables. Discriminant function analysis (DFA) was used to determine the variable(s) that were significant in differentiating among the classes to which each sampled stream belonged, based on the underlying biological community results.

All environmental variables on a continuous scale were $\log_{10}(Y+1)$ transformed to improve normality and homogeneity of variances. Variables that represented count data were square root transformed and variables that represented percentages or proportions were arcsine square root transformed. A factor analysis based on principal components was conducted on a suite of 36 environmental variables to reduce dimensionality and identify redundancy in the data. Variables with the highest factor loadings within each factor were chosen for further analyses. In the case where two variables were grouped into one factor but were not intuitively related to each other, both variables were selected for further analyses.

The reduced suite of environmental variables was subsequently used in a DFA with the PWH classes serving as the *a priori* groups for the analysis. A forward stepwise DFA was performed to identify the set of environmental variables that would best separate the four PWH classes, by reviewing and evaluating each variable step-by-step, using corresponding F and p values, to identify the variable(s) that would contribute most to the discrimination among groups. Ten randomly selected sites were reserved to be used later for testing the DFA model.

Results and Discussion

The SOW for the CUVA headwater stream inventory prioritizes the classification of the selected sites in accordance with the Ohio EPA PHW protocols. To facilitate the discussion regarding the data sets used to classify the streams included in the inventory, the final classification results are included early in this section of the report rather than at the end. In this way, results for the biological community assessments for macroinvertebrates, fish, and salamanders can be presented in the context of the final classification results. One faunal group can be determinant in the assignment of the final PHW classification. Therefore, each organism group is interpreted independently.

Site Location and Characterization

Geolocation

Site geolocation data were successfully collected using sub-meter Geode™ GNS2™ GNSS receivers paired with an Apple iPad, Android tablets, or smartphone devices. Geolocation data and photos were collected using the ArcGIS Survey 1-2-3® web application paired with the Geode™ device. GeodeConnect™ software provided real-time accuracy readings, including PDOP and estimated horizontal error. There was an estimated range of <1m to 30m horizontal coordinate uncertainty and coordinates are precise to 0.00001 degrees. GPS field data were then exported from Survey 1-2-3® to a file geodatabase for mapping and analysis using ArcGIS Pro and ArcMap software. All geolocation data are provided and the electronic data delivery package submitted to NPS for the project.

Site Photographs

A total of 1,406 georeferenced site photographs were taken at the 125 CUVA Headwater Inventory locations. At each site, a minimum of five standard stream locations were used to document conditions within the assessment zone: the upstream terminus (UST), the mid-point of the zone (MID), the downstream terminus (DST), the upstream limit of the 10m salamander census zone (SAL_UP), and the downstream limit of the census zone (SAL_DN). Two photographs were taken at each locale to capture both the upstream and downstream aspect. Additional photographs were also collected by the field crews to document other pertinent stream geomorphological features.

All salamander and fish species observed during the inventory were photo-vouchered in the field for taxonomic reference. A total of 385 voucher photographs for were taken for amphibians and 325 were taken for fish. Where collected in combination with the ArcGIS Survey 1-2-3® web application, photographs were automatically named for cataloging and were bulk downloaded and saved to the EnviroScience network drive. Digital photos collected using other digital camera applications were compiled, re-named as appropriate for the subject matter, cataloged, and saved directly to the EnviroScience network drive. All photographs and photograph catalogs have been transferred to NPS as part of the electronic data package in accordance with the project SOW.

Stream Classification Results

Primary Headwater Classification Results

Site specific PHW classification results for each organism group (macroinvertebrates, fish, and amphibians) are listed in Table 10 for Primary Sites and in Table 11 for Secondary Sites. The basis

for PHW class assignment for each site is also listed with respect to the organism groups(s) that determine the final classifications.

Final PHW classification results for pooled Primary and Secondary sites are summarized in Table 12. Most of the stream sites in the inventory (103 sites or 82.4%) were found to support Class IIIA or Class IIIB biology indicative of perennial flow conditions. Of these, roughly half of the sites met the characteristics for Class IIIB PHW streams supporting cold water adapted fauna. The macroinvertebrate community was the primary driver for distinguishing between Class IIIA and Class IIIB stream types within the inventory data set. Thirteen of 52 Class IIIB streams (25%) support cold water fish species, but only five of these sites did not also have a Class IIIB macroinvertebrate community. Forty-seven (90.3%) of the Class IIIB sites support a Class IIIB macroinvertebrate community. It should be noted that 31 (69%) of the Class IIIB sites also had reproducing populations of the Northern Two-line Salamander (*Eurycea bislineata*). However, these populations did not factor into the final PHW classification since this species is a Class IIIA indicator.

For Class IIIA stream sites, the presence of reproducing populations of *E. bislineata* was the predominant determining factor assignment of the final PHW classifications. At 46 of 51 Class IIIA sites (90.2%), reproducing populations of *E. bislineata* were present, and this species was the sole factor for the classification decision at 38 sites (74.5% of the total). The macroinvertebrate community played a role in assignment of the final PHW classification at eight (15.7%) of the Class IIIA locations and was the sole factor in the final classification assignment at three sites. Fish community composition was the sole determinate at only one Class IIIA site and was found to be a factor at an additional five locations. Note that the presence of fish communities meeting the IBI ecoregional WWH criterion were assumed to meet the definition of Class IIIA even though this is not expressly stated in Ohio EPA guidance.

Biological indicators revealed streams with intermittent or low flow warm water Class II PHW characteristics at 20 of the CUVA Headwater Inventory sites. These sites either lacked salamanders entirely or did not support reproducing populations of *E. bislineata*. Fish communities at these locations were either absent or were comprised of one to five species, with assemblages being dominated by Creek Chub (*Semotilus atromaculatus*) and Blacknose Dace (*Rhinichthys atratulus*). Macroinvertebrate community composition was key to assignment of the PHW classification at all Class II sites, with communities lacking sufficient cold water macroinvertebrate taxa to be indicative of perennial flow with cool or cold thermal conditions.

Table 10. Level 3 PHW bioassessment results for Primary Headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020403/ Furnace Run S-Oak Hill NZ	Furnace Run	CUVA-102	Class IIIB	Class IIIA	Indeterminate	Class IIIB	Macroinvertebrates
	Furnace Run	CUVA-103	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
	Furnace Run	CUVA-104A	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates
	Furnace Run	CUVA-131	Class IIIB	Class IIIA	Class IIIA	Class IIIB	Macroinvertebrates
	Furnace Run	CUVA-132	Class IIIB	Class IIIA	Class IIIA	Class IIIB	Macroinvertebrates
041100020403/ SMP Furnace Run	Furnace Run	CUVA-111	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Furnace Run	CUVA-112	Class I	Indeterminate	Indeterminate	Class I	No indicators for higher classes
	Furnace Run	CUVA-113	Class II	Class IIIA	Class IIIA	Class IIIA	Salamanders and Fish
041100020404/ Stanford-Hines Hill HVE	Brandywine Creek	CUVA-52A	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Brandywine Creek	CUVA-54	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Brandywine Creek	CUVA-55	Class II	Class II	Class IIIA	Class IIIA	Salamanders
041100020405/ Adams Run NZ	Adams Run	CUVA-129	Class II	Indeterminate	Indeterminate	Class II	Macroinvertebrates
041100020405/ A-P North NZ	Boston Run	CUVA-70	Class II	Class IIIB	Class IIIA	Class IIIB	Fish
	Stanford Run	CUVA-56	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates

Table 10 (continued). Level 3 PHW bioassessment results for Primary Headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020405/ Blossom Woods NZ	Dickerson Run	CUVA-80	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Langes Run	CUVA-82	Class II	Class IIIA	Indeterminate	Class IIIA	Fish
	Langes Run	CUVA-83	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Robinson Run	CUVA-87	Class II	Class IIIA	Indeterminate	Class IIIA	Fish and Macroinvertebrates
	Robinson Run	CUVA-88	Class IIIA	Class II	Indeterminate	Class IIIA	Macroinvertebrates
	Robinson Run	CUVA-89	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates
	Unnamed 12	CUVA-90	Class IIIA	Indeterminate	Indeterminate	Class IIIA	Macroinvertebrates
	Unnamed 12	CUVA-91	Class II	Indeterminate	Indeterminate	Class II	Macroinvertebrates
041100020405/ Botzum NZ	Unnamed 15	CUVA-93A	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 15	CUVA-93B	Class IIIB	Indeterminate	Indeterminate	Class IIIB	Macroinvertebrates
	Unnamed 15	CUVA-94	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
041100020405/ Columbia NZ	Columbia Run	CUVA-58	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
	Columbia Run	CUVA-60	Class II	Class II	Class IIIA	Class IIIA	Salamanders
041100020405/ Everett Cultural HVE	Ira Creek	CUVA-96	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 12	CUVA-98A	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates

Table 10 (continued). Level 3 PHW bioassessment results for Primary Headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020405/ S-Oak Hill NZ	Oak Hill Creek	CUVA-68A	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
	Slipper Run	CUVA-62A	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 11	CUVA-65	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 11	CUVA-66	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
041100020405/ Interstate NZ	Peninsula Creek	CUVA-64	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Spring Creek	CUVA-126	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
041100020405/ Snowville Woods NZ	Unnamed 10	CUVA-47A	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
041100020405/ Stanford-Hines Hill HVE	Stanford Run	CUVA-124A	Class II	Class II	Class IIIA	Class IIIA	Salamanders
041100020405/ Virginia Kendall HVE	Boston Run	CUVA-69	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Haskell Run	CUVA-127A	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Ritchie Run	CUVA-75A	Class II	Indeterminate	Indeterminate	Class II*	Macroinvertebrates
	Salt Run	CUVA-76	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Salt Run	CUVA-77A	Class II	Class II	Class IIIA	Class IIIA	Salamanders

*Site with Recovering Channel based on HHEI

Table 10 (continued). Level 3 PHW bioassessment results for Primary Headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020503/ CMP Brecksville	Chippewa Creek	CUVA-118	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Chippewa Creek	CUVA-119	Class IIIB	Class IIIA	Class IIIA	Class IIIB	Macroinvertebrates
	Chippewa Creek	CUVA-34	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Chippewa Creek	CUVA-35	Class IIIB	Indeterminate	Indeterminate	Class IIIB	Macroinvertebrates
041100020504/ CMP Bedford	Tinker's Creek	CUVA-115	Class II	Indeterminate	Indeterminate	Class II	Macroinvertebrates
	Tinker's Creek	CUVA-133B	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates
	Tinker's Creek	CUVA-24A	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Tinker's Creek	CUVA-25A	Class IIIB	Indeterminate	Indeterminate	Class IIIB	Macroinvertebrates
041100020505/ CMP Brecksville	Unnamed 4	CUVA-37A	Class IIIB	Class IIIB	Class IIIA	Class IIIB	Fish and Macroinvertebrates
	Unnamed 4	CUVA-38	Class IIIB	Class IIIB	Class IIIA	Class IIIB	Fish and Macroinvertebrates
041100020505/ Northern NZ	Unnamed 3	CUVA-19	Class II	Indeterminate	Indeterminate	Class II	Macroinvertebrates
	Unnamed 9	CUVA-18	Class II	Class IIIB	Indeterminate	Class IIIB	Fish

Table 10 (continued). Level 3 PHW bioassessment results for Primary Headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020505/ Old Carriage NZ	Unnamed 9	CUVA-31	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-42	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-45	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 9	CUVA-49A	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-50A	Class II	Class II	Class IIIA	Class IIIA	Salamanders
041100020505/ Pinery Narrows/Twin Sisters SRZ	Unnamed 9	CUVA-27	Class II	Class IIIA	Class IIIA	Class IIIA	Salamanders and Fish
	Unnamed 9	CUVA-28	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-29	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-30	Class II	Indeterminate	Indeterminate	Class II	Macroinvertebrates
041100020505/ Snowville Woods NZ	CMA Creek	CUVA-120	Class IIIB	Class IIIB	Indeterminate	Class IIIB	Fish and Macroinvertebrates
	CMA Creek	CUVA-121	Class IIIB	Class IIIB	Class IIIA	Class IIIB	Fish and Macroinvertebrates
	CMA Creek	CUVA-122	Class IIIB	Class IIIB	Class IIIA	Class IIIB	Fish and Macroinvertebrates
	CMA Creek	CUVA-39	Class IIIB	Class IIIB	Indeterminate	Class IIIB	Fish and Macroinvertebrates
	CMA Creek	CUVA-43	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates
	Unnamed 5	CUVA-123	Class IIIB	Class IIIB	Class IIIA	Class IIIB	Fish and Macroinvertebrates
	Unnamed 5	CUVA-46A	Class II	Class IIIB	Class IIIA	Class IIIB	Fish

Table 10 (continued). Level 3 PHW bioassessment results for Primary Headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020505/ Twin Sisters-Mudcatcher SRZ	Sagamore Creek	CUVA-22	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
	Sagamore Creek	CUVA-26A	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates
	Unnamed 9	CUVA-20A	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates
041100020602/ Northern NZ	Brookside Creek	CUVA-13A	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Stone Road Creek	CUVA-17	Class II	Class IIIA	Class IIIA	Class IIIA	Salamanders and Fish
	Unnamed 1	CUVA-5	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 2	CUVA-11	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Unnamed 2	CUVA-6	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Unnamed 2	CUVA-7	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Unnamed 2	CUVA-8	Class IIIA	Class II	Class IIIA	Class IIIA	Salamanders and Macroinvertebrates
	Unnamed 2	CUVA-9	Class IIIA	Class II	Class IIIA	Class IIIA	Salamanders and Macroinvertebrates
	Unnamed 7	CUVA-16	Class II	Class IIIB	Class IIIA	Class IIIB	Fish
	Unnamed 7	CUVA-16B	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates

Table 11. Level 3 PHW bioassessment results for secondary headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020403/ Everett Cultural HVE	Perkins Run	CUVA-X73	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Perkins Run	CUVA-X74	Class II	Class II	Class IIIA	Class IIIA	Salamanders
041100020403/ Furnace Run S-Oak Hill NZ	Furnace Run	CUVA-X45	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Furnace Run	CUVA-X46	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Furnace Run	CUVA-X47	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
041100020404/ Boston-Brandywine HVE	Brandywine Creek	CUVA-52B	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Brandywine Creek	CUVA-52C	Class I	Indeterminate	Class IIIA	Class IIIA	Salamanders
041100020405/ Blue Hen Falls NZ	Spring Creek	CUVA-X60	Class IIIB	Class IIIA	Class IIIA	Class IIIB	Macroinvertebrates
	Spring Creek	CUVA-X61	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Spring Creek	CUVA-X63	Class IIIA	Indeterminate	Class IIIA	Class IIIA	Salamanders and Macroinvertebrates
	Spring Creek	CUVA-X9	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
041100020405/ Columbia NZ	Columbia Run	CUVA-X52	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Columbia Run	CUVA-X53	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Columbia Run	CUVA-X54	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Spring Creek	CUVA-X51	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates

Table 11 (continued). Level 3 PHW bioassessment results for secondary headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020405/ Everett Cultural HVE	Ira Creek	CUVA-X10	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Ira Creek	CUVA-X11	Class IIIB	Class II	Indeterminate	Class IIIB	Macroinvertebrates
	Unnamed 12	CUVA-X72	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
041100020405/ Furnace Run S-Oak Hill NZ	Unnamed 11	CUVA-X16	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 11	CUVA-X17	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
041100020405/ Interstate NZ	Grannys Run	CUVA-X64	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
041100020405/ Stanford-Hines Hill HVE	Stanford Run	CUVA-X6	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	UT Cuyahoga R RM 26.65	CUVA-X50	Class IIIA	Indeterminate	Indeterminate	Class IIIA	Macroinvertebrates
041100020405/ Virginia Kendall HVE	Ritchie Run	CUVA-75B	Class II	Indeterminate	Indeterminate	Class II	Macroinvertebrates
	Ritchie Run	CUVA-75C	Class II	Indeterminate	Class_II	Class II	Macroinvertebrates and Reproduction of *D. fuscus*
041100020505/ Old Carriage NZ	Unnamed 9	CUVA-X27	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-X28	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-X29	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-X30	Class IIIA	Class II	Class IIIA	Class IIIA	Salamanders and Macroinvertebrates
	Unnamed 9	CUVA-X48	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-X49	Class II	Indeterminate	Class IIIA	Class IIIA	Salamanders

Table 11 (continued). Level 3 PHW bioassessment results for secondary headwater stream inventory sites.

HUC12 Watershed/ CUVA Mgmt. Zone	Sub-Watershed	Site Name	Macro-invertebrates	Fish	Amphibians	Final PHW Class	Basis for PHW Classification
041100020505/ Snowville Woods NZ	CMA Creek	CUVA-X43	Class IIIB	Class IIIB	Class IIIA	Class IIIB	Fish and Macroinvertebrates
	CMA Creek	CUVA-X44	Class II	Class IIIB	Indeterminate	Class IIIB	Fish
	Unnamed 5	CUVA-X65	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 5	CUVA-X66	Class IIIB	Class II	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 5	CUVA-X69	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
	Unnamed 5	CUVA-X70	Class IIIB	Indeterminate	Class IIIA	Class IIIB	Macroinvertebrates
041100020505/ Twin Sisters-Mudcatcher SRZ	Unnamed 9	CUVA-X23	Class II	Class II	Class IIIA	Class IIIA	Salamanders
	Unnamed 9	CUVA-X24	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates
	Unnamed 9	CUVA-X25	Class II	Class IIIA	Class IIIA	Class IIIA	Salamanders and Fish
	Unnamed 9	CUVA-X26	Class I	Indeterminate	Indeterminate	Class I	No indicators for higher classes
041100020602/ Terra Vista	UT Cuyahoga R RM 15.11	CUVA-X71	Class II	Class II	Indeterminate	Class II	Fish and Macroinvertebrates

Table 12. Summary of PHW classification results based on Level 3 PHW biological assessments.

Basis for Classification	Class I	Class II	Class IIIA	Class IIIB	Total Sites	Percent of Total
No PHW indicators	2	0	0	0	**2**	**1.6%**
Fish	0	0	1	5	**6**	**4.8%**
Fish & Macroinvertebrates	0	12	1	8	**21**	**16.8%**
Macroinvertebrates	0	7	3	39	**49**	**39.2%**
Salamanders	0	0	38	0	**38**	**30.4%**
Salamanders & Fish	0	0	4	0	**4**	**3.2%**
Salamanders & Macroinvertebrates	0	1	4	0	**5**	**4.0%**
Total Sites	**2**	**20**	**51**	**52**	**125**	–
Percent of Total	**1.6%**	**16.0%**	**40.8%**	**41.6%**	–	–

Two sites, CUVA-112 and CUVA-X26, were assigned to the Class I PHW classification because of aquatic biological communities indicative of ephemeral flow conditions. Although Creek Chub (*S. atromaculatus*) were present at site CUVA-112, this species by itself is not an indicator of Class II biology. The Creek Chub is an opportunistic pioneering fish species that can rapidly populate and abandon ephemeral and intermittent stream habitats during the inundation-desiccation cycles encountered in these ecosystems. The macroinvertebrate community found at both Class I PHW sites was characteristic of temporarily wet Class I PHW streams.

Stream Classifications for Aquatic Life Uses in the Ohio Water Quality Standards

A total of eighteen stream sites assessed during the CUVA Headwater Stream Inventory were found to have fish and macroinvertebrate community characteristics sufficient to meet one or more of the ALU criteria established in OAC Rule 3745-1-07. Relevant data supporting the ALU designation recommendations for the sites in question are summarized in Table 13. These sites represent 14.4% of the total sites assessed for the inventory.

A total of eight sites were found to support communities of fish and macroinvertebrates that meet the narrative criteria for CWH, with one or two species of cold-water indicator fish species present in conjunction with sufficient numbers of cold-water macroinvertebrate taxa and thermal conditions indicative of the ALU. One of these sites, CUVA-37A, also meets the EWH criteria for both organism groups and is therefore recommended for a dual use designation of EWH and CWH. The other seven sites recommended for CWH designation also meet the criteria for the WWH ALU. Four of these sites also meet the EWH criterion for the fish community (IBI $\geq$ 50). However, these sites have macroinvertebrate community composition scored as either Marginally Good or Good, which are insufficient to demonstrate EWH attainment. Dual assignment of CWH and WWH is not recommended because of the ambiguity associated with correlations to applicable water quality

criteria for chemical and physical parameters. It should be noted that assignment of the CWH use is recommended only for sites that are demonstrated to meet the ALU definition for both organism groups.

The remaining ten inventory sites recommended for higher ALU designation meet the biological criteria for the WWH use for both fish and macroinvertebrates. The fish communities at seven of the ten sites scored within the ecoregional non-significant departure range for the IBI (scores of 36-38), with the overall range from 36 (Marginally Good) to 48 (Very Good). The macroinvertebrate communities at these sites were rated from Marginally Good (non-significant departure from WWH) to Very Good, with five of the ten sites rated in the Good category. Seven of the ten sites recommended for the WWH use supported a community meeting the CWH use for one organism group but not the other. Two sites support cold-water fish species and five meet the CWH threshold for macroinvertebrates. Since only one organism group is supported for CWH, these sites do not appear to meet the threshold for this ALU. However, this determination is at the discretion of Ohio EPA. Specifics regarding community composition and evaluative data are provided in the Biological Assessment Results section below.

General Site Characterization

Stream Flow Characteristics

Throughout the sampling period, base flow conducive to aquatic life use was maintained for most sites. The overwhelming majority (97.6%) of the inventoried sites were found to have observable streamflow conditions, with only three of the sites (2.4%) observed to have ephemeral or intermittent flow characteristics at the time of the assessment. These sites are located in HUC 0404 (CUVA-52C) and 0405 (sites CUVA-X17 and CUVA-X54). Surprisingly, all three of these sites supported two life stages of Two-lined Salamanders (*E. bislineata*) and had a final PHW designation of Class IIIA based on Salamanders. It is possible that interstitial flows were present at these locations within the hyporheic zone (saturated substrate layer) below a depth that could be ascertained by the field crews, and the that these flows can support more diverse biological communities than can be detected using the existing PHW sampling protocols.

Streams were actively flowing at 110 sites (88%), with interstitial flow (observable flow in pools and runs with subsurface flow in riffles) observed at twelve additional sites (9.6%). Of the twelve sites where interstitial flows were observed, one site supported a Class IIIB biological community (site CUVA X44), eight supported Class IIIA communities, one site supported Class II biology (Site CUVA-56), and two sites had very low biological diversity meeting the Class I PHW definition (Sites CUVA-112 and CUVA-X26). Most of the sites with interstitial flow conditions were found in HUC 0405 (eight of twelve sites).

Table 13. Recommended aquatic life use designations and summary data for CUVA Headwater Inventory streams meeting biological criteria listed in OAC Rule 3745-1-07.

HUC12 Watershed	Stream	Ohio EPA River Code	Station	River Mile	Drain. Area (mi^2)	Aquatic Life Use [a]	IBI	Macro-invert. Narr.	QHEI	Attain-ment Status
041100020403	Riding Run	19-020-003	CUVA-131	0.70	0.60	WWH (CWH_M)	44	V. Good	54.00	FULL
	UT Riding Run RM 0.59	Unassigned	CUVA-132	0.10	0.60	WWH (CWH_M)	36 [b]	Good	53.50	FULL
	UT Furnace Run RM 3.49	Unassigned	CUVA-102	0.40	0.88	WWH (CWH_M)	42	V. Good	65.00	FULL
041100020405	Langes Run	19-018-000	CUVA-82	2.00	0.76	WWH	36 [b]	M. Good [b]	56.50	FULL
	RM 1.80 Trib Boston Run	Unassigned	CUVA-70	0.10	0.84	WWH (CWH_F)	48	Good	65.00	FULL
	Robinson Run	19-019-000	CUVA-87	0.65	0.59	WWH	36 [b]	Good	55.00	FULL
	Spring Creek	19-001-002	CUVA-X60	0.34	1.43	WWH (CWH_M)	38 [b]	Good	55.50	FULL
041100020503	UT RM 0.80 Trib Chippewa Cr	19-009-001	CUVA-119	0.10	0.47	WWH (CWH_M)	36 [b]	V. Good	68.25	FULL
041100020505	UT Cuy R RM 21.40	Unassigned	CUVA-37A	0.30	0.73	EWH/CWH	50	V. Good [b]	62.00	FULL
	UT Cuy R RM 21.40/RM 0.4 Trib (S)	Unassigned	CUVA-38	0.10	0.58	CWH (WWH)	54	Good	47.75	FULL
	UT Cuy R RM 21.70	Unassigned	CUVA-39	0.15	0.60	CWH (WWH)	56	Good	56.50	FULL
	UT Cuy R RM 21.70	Unassigned	CUVA-120	1.05	0.60	CWH (WWH)	56	Good	60.50	FULL
	UT Cuy R RM 21.70/0.55 Trib	Unassigned	CUVA-121	0.50	1.02	CWH (WWH)	52	M. Good [b]	63.75	FULL
	UT Cuy R RM 21.70/0.55 Trib/0.42 Trib	Unassigned	CUVA-122	0.15	0.29	CWH (WWH)	44	M. Good [b]	65.25	FULL
	UT Cuy R RM 21.70/RM 1.31 Trib	Unassigned	CUVA-X43	0.05	0.27	CWH (WWH)	44	V. Good	62.00	FULL
	UT Cuy. R. RM 23.40	Unassigned	CUVA-123	0.90	0.39	CWH (WWH)	44	Good	65.00	FULL
	UT Cuy. R. RM 23.40/RM 0.72 Trib	Unassigned	CUVA-46A	0.25	0.42	WWH (CWH_F)	36 [b]	Good	59.50	FULL
041100020602	Stone Road Cr. (RM 14.33 Trib Cuy R)	Unassigned	CUVA-17	0.85	0.47	WWH	36 [b]	M. Good [b]	63.00	FULL

[a] ALU abbreviations listed in parentheses indicate situations where secondary aquatic life use(s) are also met for either fish (subscript F), macroinvertebrates (subscript M), or both organism groups (no subscript)

[b] Non-Significant departure from the ecoregional biocriterion

Riparian Width and Land Use

The riparian zones adjacent to the inventoried streams were typically wide and floodplain land use was predominantly mature forest with very little human influence. These results make sense in the context that all sites lie within the national park boundaries. Overall, 117 (93.6%) sites had wide wooded riparian widths (>10m) on both right and left banks. There were no instances where riparian widths were moderate or narrow on both banks. Narrow (<5m) riparian widths were observed on at only three locations: CUVA-38, CUVA-52A, and CUVA-90. In these instances, the floodplain land use consisted of a powerline right of way, fenced pasture, and immature forest, respectively.

Instances where mature forest land use comprised both right and left banks were observed at 108 sites (86.4%). Other land use categories observed included: immature forest, residential/park, fenced pasture, conservation tillage, residential/forest, powerline right of way, old field, wetland/mature forest, and mixed wetland habitat. Overall, there were 17 sites that had at least one bank with a different floodplain category than mature forest.

Water Quality Measurements

Water quality data meeting the PSP data quality objectives was collected using field monitoring equipment at 122 of the stream inventory sites. At two locations, sites CUVA-133B and CUVA-X24, equipment malfunction prevented data collection. Site CUVA-X54 had insufficient water present to collect a reliable sample for field measurements. Another field meter malfunction occurred at site CUVA-62A, where specific conductance data could not be collected because of a probe malfunction. Water clarity data using the transparency tube were not collected at sites CUVA-52C, CUVA-X17, and CUVA-X54. Insufficient water depth and flows were present during the field visit to meet the data quality objectives for this parameter at these locations.

Detailed water chemistry data for the inventory sites are provided in the electronic data package submitted to NPS. Discussion and summary data for water temperature, specific conductance, dissolved oxygen concentrations, dissolved oxygen percent saturation, pH, and water clarity are provided for each parameter.

Water Temperature

Water temperatures ranged from 11.9°C to 24.4°C for all sites throughout the assessment period for the headwater stream inventory (Figure 13). Water temperature in PHW streams is one of the key environmental factors, along with annual streamflow characteristics, that determine the type of biological communities that can be supported on an ongoing basis by these systems. This is reflected within the Ohio EPA PHW classification system which uses biological indicators for both streamflow and temperature dynamics in these systems.

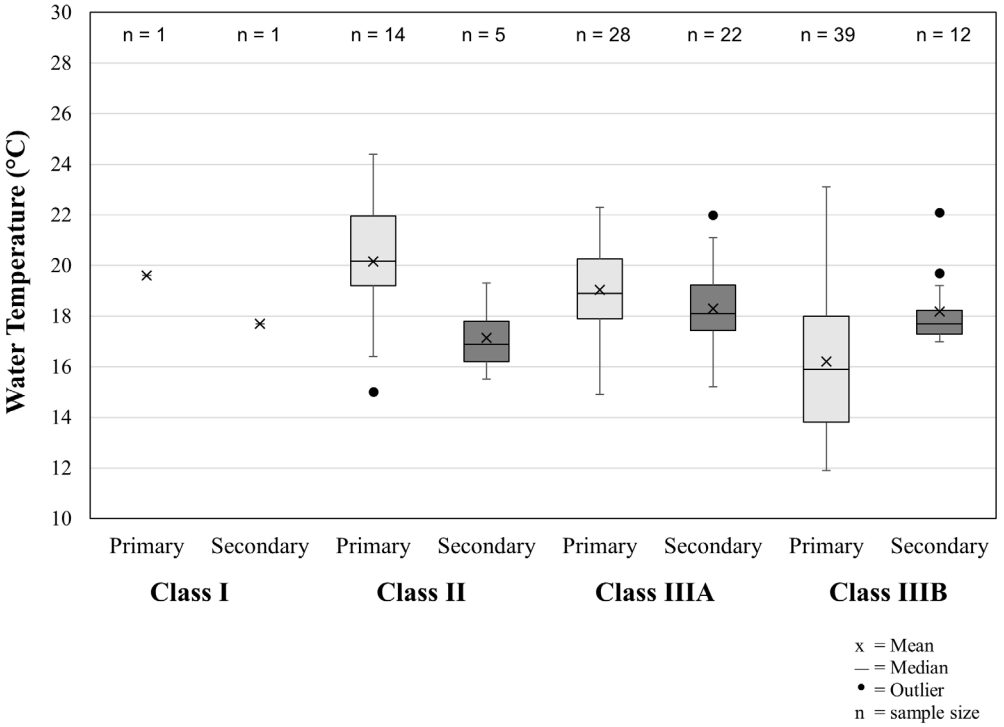


Figure 13. Water temperatures for the CUVA Headwater Inventory sites organized by Level 3 PHW class and site category.

Non-parametric statistical comparisons of pooled survey water temperature were conducted comparing stream PHW classes. Class I PHW sites excluded because of the small sample size (n=2). Results of a Kruskal-Wallis rank sum test comparing water temperatures reveal a statistically significant difference between Class II, Class IIIA, and Class IIIB using pooled data collected during the inventory (Kruskal-Wallis Statistic = 21.26, $p<0.0001$). Results of pairwise comparison of data sets among the three PHW classes using the Wilcoxan-Mann-Whitney rank sum test (Table 14) revealed that the median water temperatures for Class IIIB streams was significantly lower than both Class II and Class IIIA streams, while there was no significant difference between Class II and Class IIIA streams.

Table 14. Summary of Wilcoxan-Mann-Whitney rank sum test comparisons of water temperatures between CUVA PHW stream classes.

Test Number	Group 1	Group 2	Median Difference	p Value	Result
1	Class II	Class IIIA	0.95	0.2824	*NS*
2	Class IIIA	Class IIIB	1.45	<0.0001	*
3	Class II	Class IIB	2.40	0.0010	*

* Values significantly different at $p < 0.05$; NS Values not significantly different.

The DQOs for the CUVA inventory study included grab sample temperature readings rather than continuous monitoring over the summer season. Therefore, overall stream temperature characteristics depicted in Figure 13 account for neither seasonal nor diurnal fluctuations in water temperature but are instead a summary of snapshots of conditions at the time the assessments were performed. This difficulty is somewhat overcome through pooling water temperature data from streams based upon the biological classification using the PHW protocol and the month in which the sites were assessed. Analysis of the water temperature data comparing pooled data sets for each PHW stream class parsed by the months when monitoring was performed is depicted in Figure 14. Class I PHW sites are again excluded. The Ohio EPA benchmark temperature of 21.1°C for CWH streams is included in the figures for comparison purposes. The graphical analyses demonstrate a seasonal pattern for water temperatures among all three stream classes, with maximum water temperatures occurring in the month of July and cooler temperatures observed in May and September.

Statistical comparisons of the water temperature data for sites meeting Class II, Class IIIA, and Class IIIB PHW stream classes between months in which assessments were conducted are summarized in Tables 15 and 16. In addition to exclusion of data from Class I sites, comparisons could not be made for the months of May and August for Class II sites because of a lack of data for those months (n=0 and n=1, respectively). Statistical analyses relied upon non-parametric ranked sum tests for comparing the data based upon differences in the number of observations between months and because the data sets were not normally distributed.

The seasonality of the water temperature data depicted in Figure 14 is borne out by the statistical analyses. Kruskal-Wallis rank sum test results showed significant differences between the data sets for sampling months for all three stream classes. Pairwise comparison of months based upon consecutive time periods (e.g., May vs. June, etc.) coincided with the graphical evidence, with significantly lower temperature readings collected in May for both Class IIIA and Class IIIB stream types. No significant differences in stream water temperatures were found between June and July for Class II and Class IIIA sites, but temperatures at Class IIIB sites were significantly higher in July than those recorded in June. July and August temperatures were not significantly different for either Class IIIA or Class IIIB sites. September water temperatures were significantly lower at both Class II and Class IIIA sites as compared to July and August temperatures, respectively. However, the water temperature data for Class IIIB sites were not significantly different between the months of August and September. It is likely that the high degree of variation in temperature readings for the month of August statistically masks the lower temperatures observed in September that is evident using graphical analysis (Figure 14).

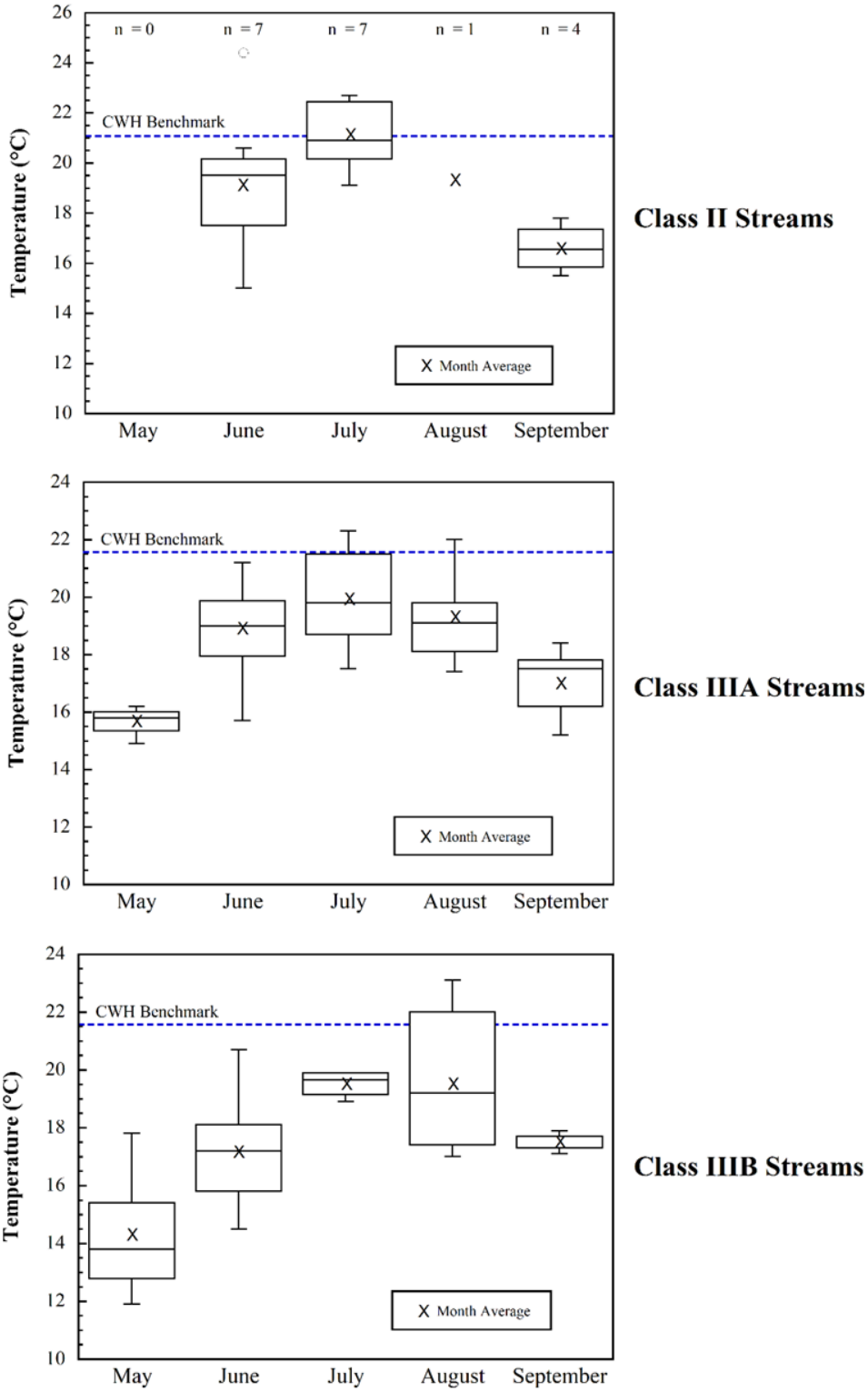


Figure 14. Comparison of grab sample stream water temperatures organized by assessment month for Class II, Class IIA, and Class IIIB inventory sites. The horizontal line depicts the benchmark temperature used by Ohio EPA in evaluating assignment of the CWH ALU.

Table 15. Results of statistical comparisons of monthly median water temperatures for Class II, Class IIIA, and Class IIIB inventory sites using the Kruskal-Walis ranked sum test.

Stream PHW Class	Groups (n)	Statistically Different at p<0.05	K-W Statistic	p Value	p Value Method
Class II	• June (7) • July (7) • September (4)	Yes	7.867	0.01957	Chi Squared Approximation
Class IIIA	• May (3) • June (11) • July (9) • August (18) • September (9)	Yes	19.984	0.005	Chi Squared Approximation
Class IIIB	• May (20) • June (13) • July (4) • August (9) • September (3)	Yes	30.301	<0.0001	Chi Squared Approximation

Table 16. Results of pairwise comparisons of monthly median water temperatures for Class II, Class IIIA, and Class IIIB inventory sites using the Wilcoxon-Mann-Whitney ranked sum test.

Stream PHW Class	Group 1	Group 2	Median Difference	Statistically Different at p<0.05	p value	p Value Method
Class II	June	July	-1.4	No	0.1282	Exact
	July	September	4.35	Yes	0.0061	Exact
Class IIIA	May	June	-3.2	Yes	0.0291	Normal Approximation
	June	July	-0.8	No	0.2537	Normal Approximation
	July	August	0.7	No	0.4398	Normal Approximation
	August	September	1.6	Yes	0.0010	Normal Approximation
Class IIIB	May	June	-3.4	Yes	0.0004	Normal Approximation
	June	July	-2.45	Yes	0.0148	Normal Approximation
	July	August	0.45	No	0.6993	Normal Approximation
	August	September	1.5	No	0.2043	Normal Approximation

A final analysis of the water temperature data was conducted comparing the 18 sites which meet higher Ohio EPA ALU criteria, including 8 sites that meet either the definition of CWH or CWH and EWH and 10 sites that meet WWH criteria (Table 13) to the remaining 36 sites that meet the

definition of Class IIIB PHW but do not meet the definition of the higher ALU uses. Statistical analysis comparing the water temperature data for these three classes of sites found no statistically significant difference between the data sets ($p = 0.4445$).

Although other factors likely also affect the ability of PHW streams within CUVA to support Class IIIB and CWH biological communities, it is evident that water temperature is a key factor in sustaining these ecosystems. These findings are further supported by the multivariate statistical analyses presented later in this report. Given that average differences in summer water temperatures for Class IIIB streams are only 2.0°C and 3.0°C as compared to Class IIIA and Class II streams, respectively (Table 16), it is evident that minor changes to the thermal regimes could result in degradation of these cold water adapted stream ecosystems within CUVA. Practices that protect water temperature regimes by sustaining hydrologic conditions with respect to groundwater recharge and discharge, protect and enhance wooded riparian corridors to provide shading of the stream channels, and which maintain or enhance stable runoff conditions from upstream portions of the PHW watersheds are critical to maintain the stability of these streams. When compounded by the potential long-term impacts of climate change to the thermal dynamics of aquatic ecosystems, efforts to protect stream resources implemented at the local watershed scale becomes even more critical.

Specific Conductance

Specific conductance data was obtained at 121 sites. In addition to the three sites where no water chemistry readings were collected for other parameters, specific conductance could not be measured at site CUVA-62A because of a probe malfunction. Results are depicted graphically in Figure 15 for sites organized by PHW stream class and site category.

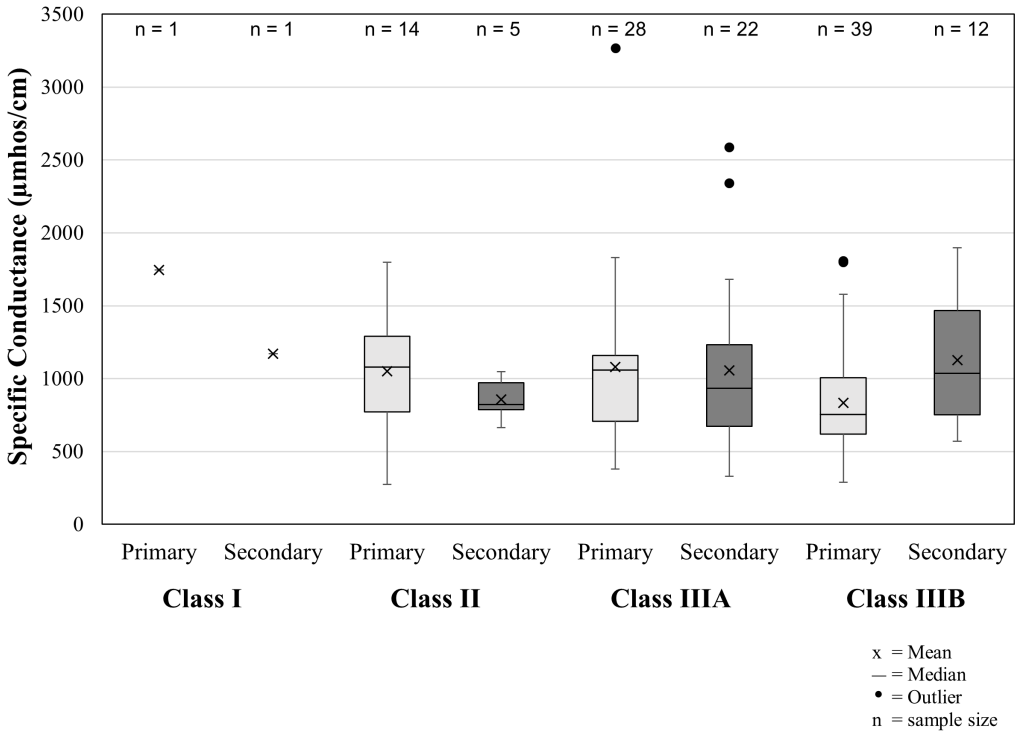


Figure 15. Specific conductance readings for the CUVA Headwater Inventory sites organized by Level 3 PHW class and site category.

Statistical analyses were conducted using the non-parametric Kruskal-Wallis rank sum test to compare sites organized both by PHW stream class and by HUC12 watershed. The comparison of PHW classes excluded Class I PHW sites because of the small number of sites in this category assessed during the inventory. The statistical tests found no significant differences between PHW stream classes (K-W Statistic = 2.681, p = 0.2617) nor between the data for the HUC12 watersheds (K-W Statistic = 4.715, p = 0.5809).

The Ohio WQS for specific conductance of 2,400 µmhos/cm (Table 35-1 in OAC Rule 3745-1-35) was exceeded at two sites. The specific conductance reading at Primary site CUVA-111 was 3,267 µmhos/cm and Secondary site CUVA-X50 was recorded at 2,588 µmhos/cm. Median and average values for specific conductance were well below the WQS both when sites were grouped by PHW stream class and by HUC12 watershed.

Specific conductance data gathered for the CUVA headwater stream inventory were equivalent to data gathered for larger drainage area Cuyahoga River tributaries by Ohio EPA in 2018 and 2019 for the same HUC12 watersheds (Ohio EPA, 2022). Median specific conductance values for sites assessed for the CUVA inventory ranged from 781 µmhos/cm (HUC 0404) to 1,099 µmhos/cm (HUC 0403), while median HUC12 watershed survey samples collected by Ohio EPA in 2018 – 2019 ranged from 799 µmhos/cm (HUC 0602) to 1,029 µmhos/cm (HUC 0505).

Dissolved salts are a ubiquitous pollutant associated with land development, stormwater runoff from urban and agricultural areas, wastewater discharges, and especially from runoff associated with road

networks. Salts used for roadway deicing are a dominant loading source to aquatic systems in northeast Ohio. Unimpacted background values for dissolved salts as measured using specific conductance readings within headwater streams in CUVA can be ascertained from analysis of the assessment data set. This analysis is helpful to demonstrate the degree to which the headwater stream water quality is affected by dissolved salt pollution to surface runoff and groundwater. The values associated with the data percentiles for specific conductance values are listed in Table 17. Figure 16 depicts the frequency distribution of specific conductance values for all CUVA headwater stream inventory sites.

Table 17. Specific conductance percentile values for CUVA headwater stream inventory sites.

Percentile rank	Specific Conductance (µmho/cm)
5th	410.4
10th	559
25th	699
50th	906
75th	1,141
90th	1,658
95th	1,800

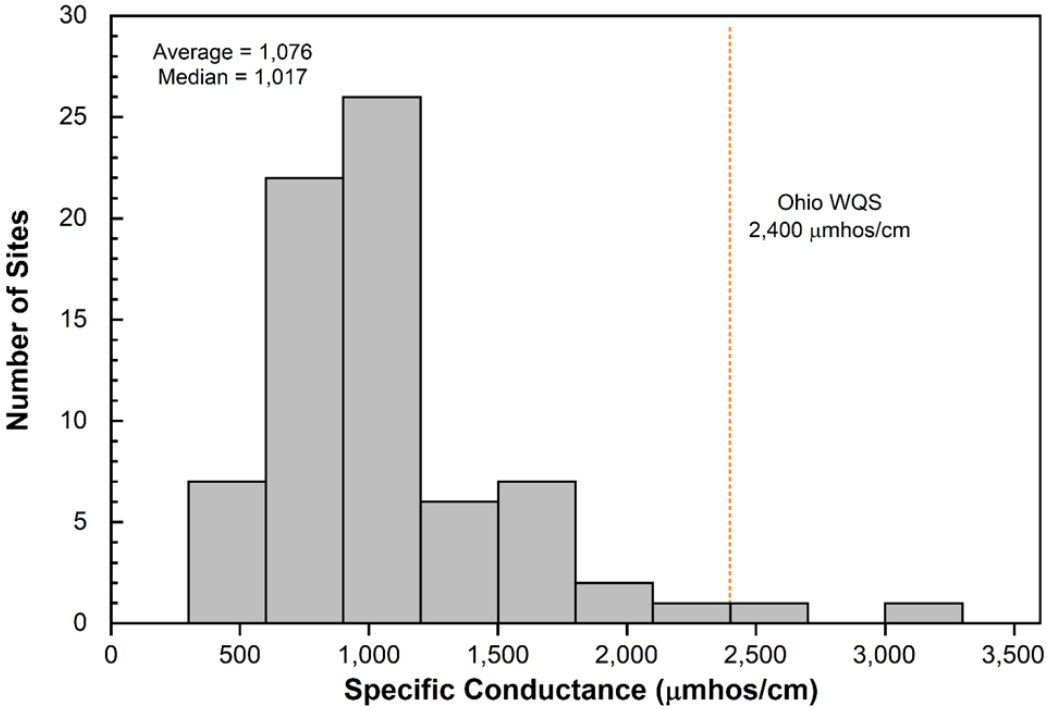


Figure 16. Histogram of frequency of occurrence for specific conductance results for headwater stream inventory sites (The Ohio WQS of 2,400 µmhos/cm is superimposed for comparison).

Values at or below the 10th percentile for specific conductance can be considered reference background conditions for PHW streams within CUVA that are fed with unimpacted groundwater discharges to surface water. The 14 sites falling within this category include ten Primary sites and four Secondary sites (Table 18). Additional discussion regarding the potential influences of dissolved salts or the lack thereof upon the headwater stream biota are discussed below within sections related to the results for the macroinvertebrates, fish, and amphibian communities.

Table 18. Headwater stream inventory sites with specific conductance readings at or below the 10th percentile.

HUC12	Site Name	Site Type	PHW Class	Basis for PHW Classification	Sub-Watershed	Specific Conductance (µmhos/cm)
041100020403	CUVA-103	Primary	Class IIIB	Macro-invertebrates	Furnace Run	410.4
	CUVA-X45	Secondary	Class IIIA	Salamanders	Furnace Run	422.0
041100020405	CUVA-129	Primary	Class II	Macro-invertebrates	Adams Run	559.0
	CUVA-58	Primary	Class IIIB	Macro-invertebrates	Columbia Run	499.2
	CUVA-68A	Primary	Class IIIB	Macro-invertebrates	Oak Hill Run	287.0
	CUVA-75A	Primary	Class II	Macro-invertebrates	Ritchie Run	287.9
	CUVA-65	Primary	Class IIIB	Macro-invertebrates	Unnamed 11	296.2
	CUVA-66	Primary	Class IIIB	Macro-invertebrates	Unnamed 11	314.5
	CUVA-93A	Primary	Class IIIB	Macro-invertebrates	Unnamed 15	559.0
	CUVA-X53	Secondary	Class IIIA	Salamanders	Columbia Run	474.5
	CUVA-X17	Secondary	Class IIIA	Salamanders	Unnamed 11	329.0
041100020504	CUVA-24A	Primary	Class IIIA	Salamanders	Tinker's Creek	549.0
041100020505	CUVA-29	Primary	Class IIIA	Salamanders	Unnamed 9	378.5
	CUVA-X48	Secondary	Class IIIA	Salamanders	Unnamed 9	533.0

Dissolved Oxygen

Dissolved Oxygen Concentrations

The DO concentrations (mg/L) recorded for the 122 sites ranged from 1.9 mg/L to 12.2 mg/L, with a median and average DO level of 8.1 mg/L and 7.8 mg/L, respectively, and a standard deviation of 1.8

mg/L (Figure 17). The Ohio WQS for dissolved oxygen promulgated in Table 35-1 of OAC Rule 3745-1-35 are listed in Table 19. The standards for DO vary by ALU and are based both upon Outside Mixing Zone Minimum (OMZM) concentration and Outside Mixing Zone Average (OMZA) concentrations based on a thirty-day average. A "mixing zone," as defined by Ohio EPA in OAC 3745-1-02, is "an area of a water body contiguous to a treated or untreated wastewater discharge. This discharge is in transit and progressively diluted from the source concentration to the receiving system concentration. The mixing zone shall be considered a place where wastewater and receiving water mix, not a place where wastes are treated". None of the headwater stream inventory sites assessed within CUVA were located within any regulatory mixing zones. Therefore, the outside mixing zone criteria are applicable for all locations assessed for this report.

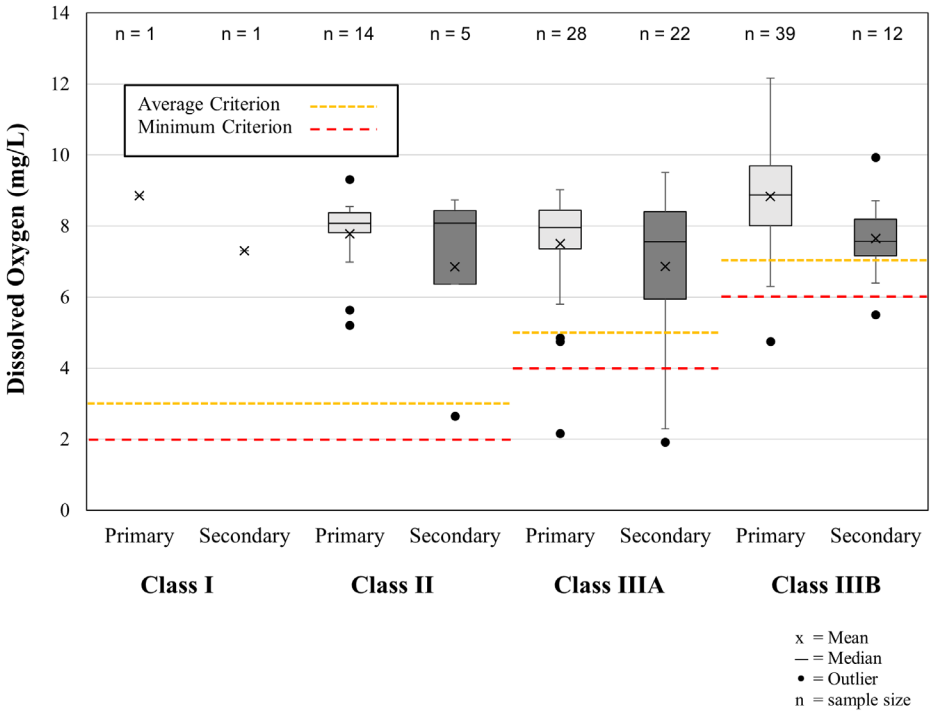


Figure 17. Dissolved oxygen concentrations for the CUVA Headwater Inventory sites organized by Level 3 PHW class and site category. Horizontal dashed lines depict the average (OMZA) and minimum (OMZM) Ohio Water Quality Standards.

Table 19. Dissolved oxygen water quality standards applicable to the EOLP ecoregion (Source: Table 35-1 in OAC Rule 3745-1-35).

Aquatic Life Use	Units	Outside Mixing Zone Minimum	Outside Mixing Zone Average
Warm Water Habitat (WWH)	mg/l	4.0	5.0
Exceptional Warm Water Habitat (EWH)	mg/l	5.0	6.0
Modified Warm Water Habitat (MWH)	mg/l	3.0	4.0
Cold Water Habitat (CWH)	mg/l	6.0	7.0
Limited Resource Waters (LRW)	mg/l	2.0	3.0

Primary Headwater streams or other streams that have not been assigned to an ALU in OAC Chapter 3745-1 are considered to be General High Quality Waters under the Ohio WQS (OAC Rule 3745-1-05). The WQS for WWH are applied to these streams to be protective of aquatic life in the absence of a use attainability analysis (UAA). However, where a UAA has been conducted, as in the case of the CUVA headwater stream inventory, the following WQS applicability is in order: Class I and Class II PHW, LRW criteria; Class IIIA, WWH criteria; Class IIIB, CWH criteria. Four channel-modified PHW streams were assessed during the CUVA headwater stream inventory (sites CUVA-16, CUVA-17, CUVA-75A, and CUVA-X10). Of these sites, only site CUVA-75A was found to support Class II PHW biological communities. Therefore, the MWH criteria apply only to this location within the inventoried sites. Note that in instances where the UAA results indicate that a stream meets one or more of the ALU definitions found in OAC Rule 3745-1-07 (i.e., the sites listed in Table 13), the most stringent WQS associated with the ALU applies.

Twelve of the headwater stream inventory sites had DO concentrations below the applicable WQS for their PHW class (Table 20). These sites were equally divided between Primary and Secondary sites. All 12 sites had concentrations falling below the applicable OMZA criteria, and at six sites the concentrations were also below the applicable OMZM. Of the sites with DO concentrations below the applicable WQS, one site was determined to be Class II PHW based upon the assessments of the biological communities, seven of the sites met Class IIIA characteristics, and four sites supported Class IIIB biology. In addition, site CUVA-38 listed in Table 20 also met the biological criteria for CWH (Table 13), having both cold-water indicator fish species and a macroinvertebrate community meeting the CWH ALU despite the observation of a DO concentration of 4.76 mg/L.

Table 20. Data summary for sites with dissolved oxygen concentrations below applicable water quality standards. OMZA - Outside Mixing Zone Average; OMZM - Outside Mixing Zone Minimum.

PHW Class	Site Name	Site Category	HUC12 Watershed	OMZA/OMZM WQS (mg/L)	Observed DO (mg/L)
Class IIIA	CUVA-27	Primary	0505	5.0/4.0	4.76 [a]
Class IIIA	CUVA-31	Primary	0505	5.0/4.0	2.16 [b]
Class IIIA	CUVA-64	Primary	0405	5.0/4.0	4.86 [a]
Class IIIB	CUVA-25A	Primary	0504	7.0/6.0	6.77 [a]
Class IIIB	CUVA-38	Primary	0505	7.0/6.0	4.76 [b]
Class IIIB	CUVA-43	Primary	0505	7.0/6.0	6.3 [a]
Class II	CUVA-75B	Secondary	0405	3.0/2.0	2.65 [a]
Class IIIA	CUVA-X10	Secondary	0405	5.0/4.0	1.92 [b]
Class IIIA	CUVA-X17	Secondary	0405	5.0/4.0	2.29 [b]
Class IIIA	CUVA-X27	Secondary	0505	5.0/4.0	3.77 [b]
Class IIIA	CUVA-X53	Secondary	0405	5.0/4.0	4.73 [a]
Class IIIB	CUVA-X16	Secondary	0405	7.0/6.0	5.51 [b]

[a] Below the OMZA WQS

[b] Below both the OMZA and OMZM WQSs.

The DO concentrations at the two Class I sites were 8.9 mg/L (site CUVA-112) and 7.3 mg/L (site CUVA-X26). For Class II sites, DO concentrations ranged from 2.7 mg/L to 9.3 mg/L, with median and average DO concentrations of 8.1 mg/L and 7.5 mg/L, respectively. Class IIIA sites showed the highest range of DO concentrations, with a maximum of 9.5 mg/L and a minimum of 1.9 mg/L, and median and average DO concentrations of 7.9 mg/L and 7.2 mg/L, respectively. Class IIIB sites had a maximum DO concentration of 12.2 mg/L, a minimum of 4.8 mg/L, and median and average DO concentrations of 8.5 mg/L and 8.6 mg/L, respectively.

The median DO values varied little between HUCs, ranging from 7.5 mg/L (HUC 0404) to 8.6 mg/L (HUC 0403). Of 13 data outliers for DO concentration, eight occurred in HUC 0405. Most low outliers corresponded with low DO percent saturation, and in some instances corresponded with low pH (CUVA-X17, CUVA-75B) or elevated erosion rates (CUVA-64, CUVA-7). High DO values corresponded with high DO percent saturation. Six sites had DO levels that were below the minimum WQS of 4.0 mg/L for warmwater habitat (Table 19). These included one site in HUC 0404 and five sites in HUC 0405.

Eight Class IIIB sites had a potential macroinvertebrate ALU assignment of CWH or EWH (Table 13). These included one from HUC 0404 (CUVA-102) and seven from HUC 0405 (CUVA-X52, CUVA-65, CUVA-126, CUVA-47A, CUVA-66, CUVA-68A, and CUVA-58). DO from all these sites

were above the average WQS expected for CWH (7.0 mg/L) and EWH (6.0 mg/L), with a range of 8.62 mg/L to 10.38 mg/L.

Dissolved oxygen concentrations were also compared between primary (n=82) and secondary (n=40) sites. Overall, primary Class IIIB sites had a higher DO range, with a median of 8.5 mg/L, compared to Secondary sites (range: 7.9-8.1 mg/L). Notably, seven of the sites determined to be meeting CWH/EWH biological criteria (Table 13) were primary sites.

Dissolved Oxygen Percent Saturation

The total quantity of oxygen that can be dissolved in water varies directly with water temperature and atmospheric pressure at the location in question. The percent DO saturation is calculated as the measured DO concentration divided by the theoretical maximum saturation concentration at the time of the observation times 100. Factors affecting the theoretical DO saturation concentration for the measurement include water temperature and the site-specific barometric pressure at the time of the observation. In-stream conditions that are determinate of DO saturation values include the amount of mixing (turbulence of the water) and biochemical characteristics within the stream that either consume or produce oxygen via respiration (consumption) or photosynthesis (production) by organisms living in the stream or via abiotic chemical reactions within the water column or stream sediment. High levels of oxygen consumption may be tied to loading of organic compounds from the watershed and the respiration of organisms within the stream using these compounds for energy. Conversely, high concentrations of nutrients (mainly phosphorus and nitrogen compounds) or intense sunlight may stimulate photosynthesis of aquatic plants and algae that produce dissolved oxygen through the production of organic compounds.

The DO percent saturation was measured at 119 sites (Figure 18). The DO percent saturation values did not vary greatly between HUC's, with medians ranging from 89.8% (HUC 0403) to 82.6% (HUC 0503).

For the CUVA Headwater Inventory sites, low percent DO saturation values corresponded directly to low DO concentrations. Based upon site observations, these instances appear to correlate with low flow rates, lack of turbulence, and respiration within the streams. Shading of the stream channel from riparian vegetation likely also plays a role by inhibiting in-stream primary productivity (photosynthesis) and biomass of algae and aquatic plants. Of the 12 sites with DO percent saturation values less than 60%, the average percentage of openness of the overlying canopy was 24.6% and exceeded 50% at only one site. Finally, groundwater typically has very low DO concentrations (less than 4.0 mg/L). Streams with a high percentage of their flow consisting of expressed groundwater have naturally lower concentrations of DO near the spring sources of water flow.

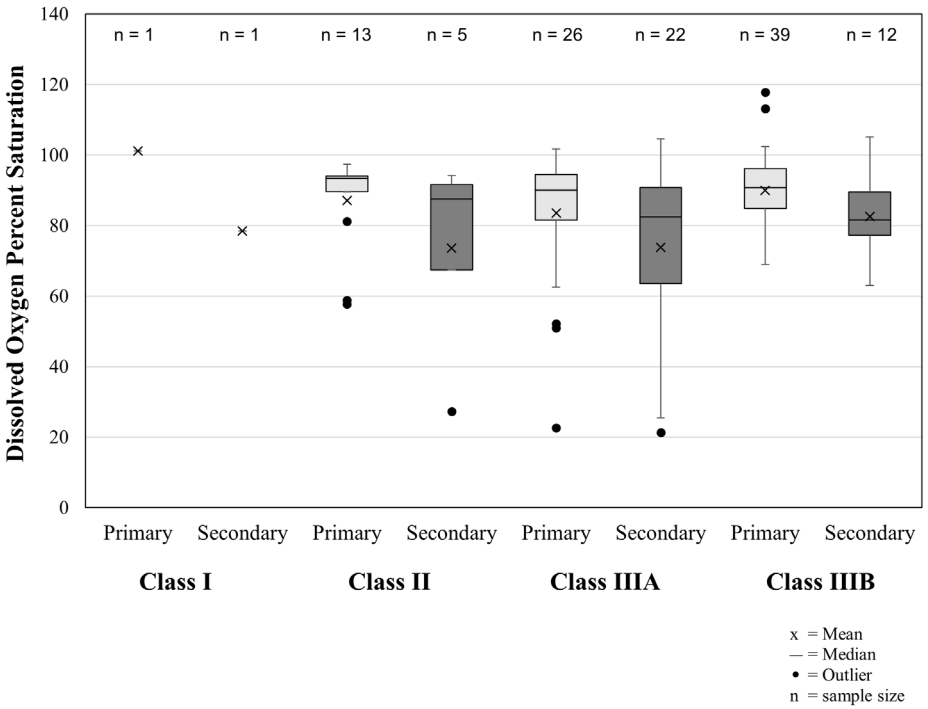


Figure 18. Dissolved oxygen percent saturations values for the CUVA Headwater Inventory sites organized by Level 3 PHW class and site category.

Two of the lowest percent saturation measurements recorded coincided with high *E. bislineata* density. Both sites, site CUVA-X10 (21.3% DO saturation, 204 *E. bislineata*/100 m^2) and site CUVA-X17 (25.5% DO saturation, 303.2 *E. bislineata*/100 m^2) are Secondary Class IIIA sites located in the HUC 0405 watershed. These sites were unusual in that all other sites with high *E. bislineata* densities (greater than 70 *E. bislineata*/100 m^2) had much higher DO percent saturation (average = 82.1%, n=15). Both sites with low percent DO saturation also had very high width/depth ratios (44.6 and 66.8 respectively) compared to other sites with high *E. bislineata* densities (average width/depth ratio = 26.0). It is possible that the flow velocities within the higher width/depth ratio channels are lower resulting in less mixing in these streams. Two other notably low outliers occurred in HUC 0405 at CUVA-31 (primary Class IIIA), which corresponded with high impervious area (19.90%) and high urban land use (85.0%), and at CUVA-75B (secondary Class II), which corresponded with a low HMFEI score (3) and low pH (6.95).

Only three sites within the inventory were found to have super-saturated DO concentrations with DO percent saturation values greater than 110% (sites CUVA-16, CUVA-96, and CUVA-98A). All three of these streams supported Class IIIB biological communities, and none were noted as having eutrophic conditions with respect to plant or algae growth. None of the sites within the headwater stream inventory appeared to suffer from nutrient enrichment from their surrounding watersheds.

pH Measurement Results

The pH of the stream water was measured at the same 122 sites where water temperature measurements were collected. All pH readings fell within the acceptable range for the support of

aquatic life set in the Ohio WQS of 6.5 to 9.0 SU (Figure 19). The pH values did not vary greatly when grouped by HUC12 watershed or by stream PHW class, and there were no significant differences between pH values among the Class II, Class IIIA, and Class IIIB stream classes (Kruskal-Wallis rank sum test, p = 0.1303). For the two Class I stream sites, CUVA-112 and CUVA-X26, the recorded pH values were 7.7 and 7.9 SU, respectively.

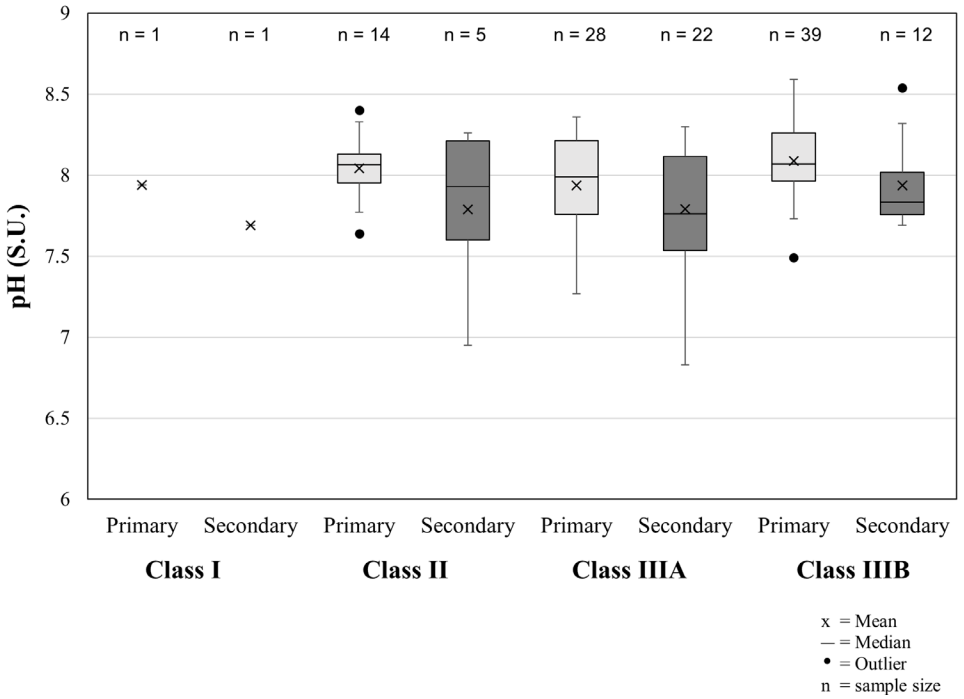


Figure 19. pH readings for the CUVA Headwater Inventory sites organized by Level 3 PHW class and site category.

Two outlier data points for pH were identified, both occurring at sites associated with HUC 0405. Both low pH readings coincided with low DO concentrations. Despite having observable stream flow, site CUVA-75B had a low pH of 6.95 which corresponded with a DO concentration of 2.65 mg/L and DO percent saturation of 27.3%. This site was classified as Class II PHW based upon the macroinvertebrate community present. Although the HMFEI score was very low (3) and the macroinvertebrate community ranking was Poor, the overall community was found to meet Class II PHW benchmarks. Vertebrates at site CUVA 75B consisted of one fish species (*S. atromaculatis*), and amphibians represented by a single adult *E. bislineata*. At CUVA-X17, the low pH (6.83) corresponded to low values of DO (2.29 mg/L), DO % saturation (25.5%). Despite these conditions, this site met the conditions for Class IIIA PHW, with a reproducing population (three age classes) of *E. bislineata* present and a macroinvertebrate community ranked as Fair using Ohio EPA protocols.

Water Clarity

Water clarity in inches was measured at 122 sites, with three sites having insufficient water for measurement. Results are summarized in Figure 20. The reported water clarities ranged from 3 to 38 inches and the median clarity for all sites was 36 inches. Note that the length of the water clarity tube

is 36 inches. Therefore, readings of 36 inches should be interpreted as greater than or equal to 36 in. Also, in cases where the maximum depth of water was greater than 36 inches, the field crew may have reported clarity depths greater than the tube length if the bottom of the stream was visible at the maximum depth. This practice was not followed consistently.

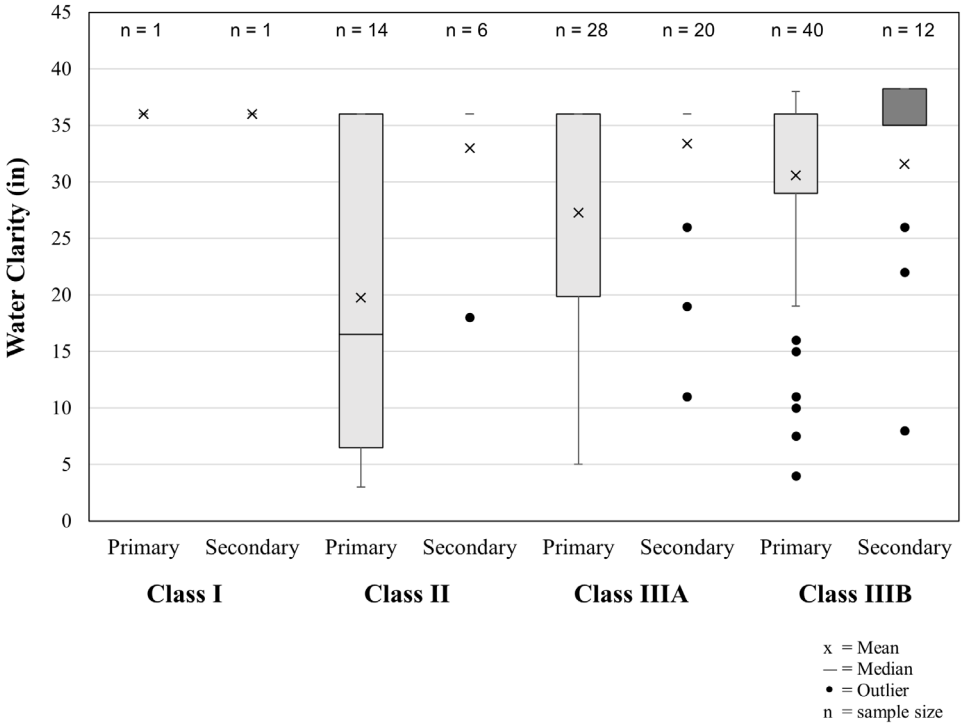


Figure 20. Water clarity measurement data for the CUVA Headwater Inventory sites organized by Level 3 PHW class and site category.

Out of the 122 sites, 78 of the sites (63.9%) had water clarity of 36 inches or greater. Both Class I PHW sites had a water clarity of 36 inches. The results for the other PHW stream classes were as follows:

- Class II: n=20, median = 28.3 in., average = 23.7 in., range = 3.0 to 36.0 in.;
- Class IIIA: n=48, median = 36.0 in., average = 29.3 in., range = 5.0 to 36.0 in.; and
- Class IIIB: n=52, median = 36.0 in., average = 30.8 in., range = 4.0 to 36.0 in.

Outlier observations for water clarity occurred at 19 sites in HUCs 0403, 0404, 0405, and 0505, and ranged from 3 in. to 26 in. Both CUVA-89 (HUC 0505 [16 in.]) and CUVA-X46 (HUC 0405 [18 in.]) had high erosion rates of 19.73 kg/m/yr. and 309.77 kg/m/yr. respectively. Additionally, sites CUVA-X46 and CUVA-X69 (HUC 0505 [22 in.] had high channel gradients, with values of 3.62% and 3.97%, respectively.

Headwater Habitat Evaluation Index (HHEI) Assessment

Habitat evaluations using the HHEI were conducted at all 125 headwater stream inventory sites. The range for HHEI scores was 56 to 93 with an average of 75.6 points. The HHEI results parsed by PHW stream class and site categories are presented in Figure 21. Scans of completed field HHEI substrate and site mapping forms are included in a supplemental appendix to this report (EnviroScience, 2023). Detailed data tables for field measurements and metric scores are provided within the electronic data package for the project delivered to the NPS. For purposes of HHEI data evaluation, the two Class II – Modified sites (site CUVA-6 and CUVA-75A) are included within the Class II PHW data set.

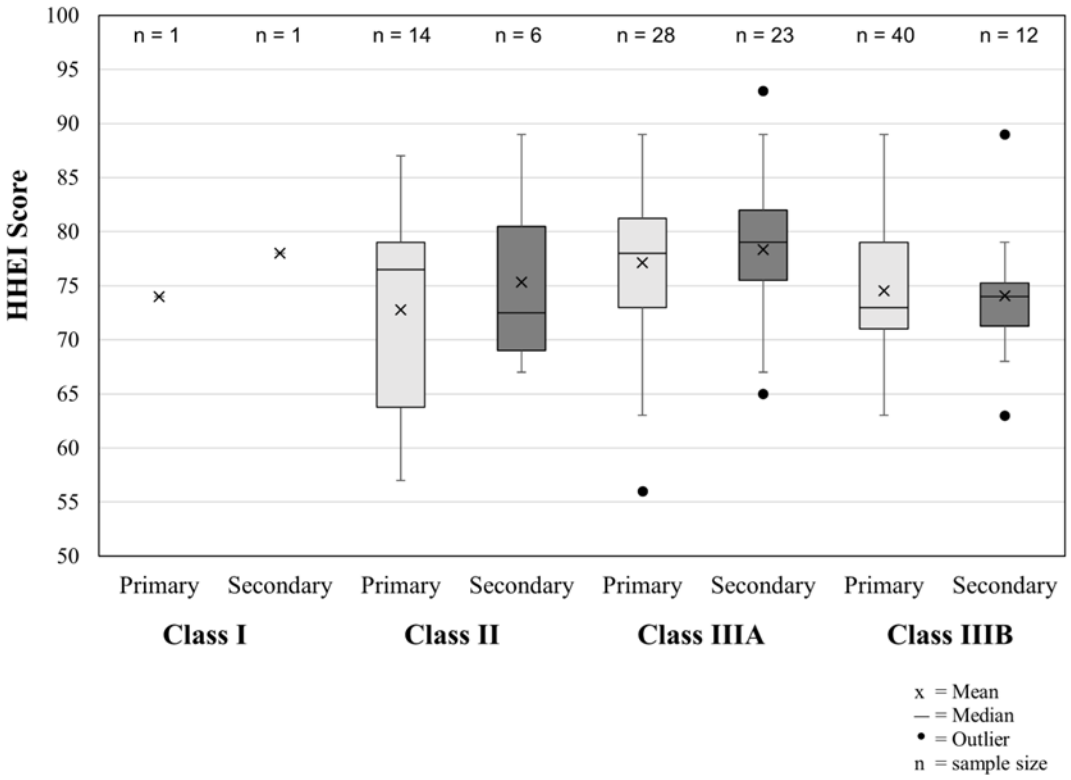


Figure 21. HHEI Results for Primary and Secondary sites parsed by PHW stream class.

Although statistical evaluation of the data set for differences between results grouped by HUC12 watershed was not possible because of unequal sample sizes, there is very little deviation in median and average HHEI scores between the HUC12 watersheds. However, there were enough sites within data sets available to conduct statistical comparison of data between site categories (Primary and Secondary sites) and PHW classes other than Class I PHW sites (n=2).

Statistical analysis first examined the data sets for each site type-PHW stream class to ensure that the data was normally distributed using the Shapiro-Wilk goodness of fit test using ProUCL Version 5.1 (Singh and Maichle, 2015). The resulting analyses found that all six data sets as well as the pooled data set appeared to be normally distributed (p values ranging from to 0.148 to 0.539). Analysis using

one-way ANOVA of the data sets found no significant difference between the stream PHW class/site category data groups (Table 21).

Table 21. One-way ANOVA results for comparison of HHEI scores for six groups: Class II P., Class II S., Class IIIA P., Class IIIA S., Class IIIB P., Class IIIB S; (P = Primary sites; S = Secondary sites).

Source of Variance	DF	SS	MS	F	p
Total	122	6562.26	53.78	–	–
Group	5	423.11	84.62	1.612	0.162
Error	117	6139.15	52.47	–	–

The HHEI scores were subjected to the Ohio EPA HHEI Level 1 classification flow chart (Figure 18 in Ohio EPA, 2020) to assign PHW stream classes without reference to biological data. Of the 125 habitat assessments, over 80% (100 sites) yielded HHEI scores greater than or equal to 70 points, which predicts Class III PHW biology. Only 25 sites (20%) had HHEI scores below 70 points. Of these sites, 17 had HHEI scores greater than 50 points while also having greater than 10% of the total substrate composition consisting of large substrates (bedrock, boulder, boulder slabs, and cobble). Therefore, these sites were also classified as Class III PHW based upon the Ohio EPA Level 1 decision flow chart. Large substrates percentages ranged from 0.0 to 6.0% at the remaining eight sites with HHEI scores between 50 and 70 points, resulting in a Level I classification of Class II PHW based upon the HHEI evaluation.

Most sites were characterized by full complement of positive channel, substrate, and riparian features typical of the biologically diverse PHW streams located in northeast Ohio. The channel configuration of most assessed streams was in a natural or recovered state. Where evidence of previous channel modification was found, the process of natural restoration or recovery of complex channel features showed progression. For all sites there were an average of eight substrate types encountered with 32% being large substrates. Dominant substrates were typically gravel-cobble, comprised of a mix of native stone and glacial alluvium, and were largely unencumbered with deposits of sand/silt. Well-developed riffle-run complexes were commonly observed as were associated pools. Pool depths ranged from 3 to 120cm with an average depth of 35.7cm. In general, there was an increase in pool depth with stream classification gradient of increasing biological diversity (Class I < Class II < Class III), as predicted by the HHEI. Average bankfull width was 4.09m across all sites and was relatively consistent across stream classes other than Class I (where only 2 streams were assessed).

The HHEI is used to provide a Level 1 classification to predict PHW stream class in the absence of biological data using metrics based upon physical measurements of stream substrates, maximum pool depth, and bankfull width according to the Level 1 classification chart found in the Ohio EPA PHW manual (Figure 15 in Ohio EPA, 2020). The HHEI was designed to provide a very conservative classification of PHW potential because in a regulatory context, it is often used as a standalone stream classification tool. Since definitive classification of PHW streams relies upon Level 3

biological assessments, when such data is available, the HHEI score is used primarily to provide a standardized method to compare characteristics for the site. The conservative nature of the Level 1 classification process using the HHEI is demonstrated through comparison of the Level 1 results from those obtained through the Level 3 PHW biological assessments in Table 22. In the table, "Under" means the Level 1 classification a site was classified by one PHW class below the Level 3 result for the site (e.g., a Class III stream classified as a Class II) while "Under x 2" refers to results under classified by two PHW classes (e.g., Class III classified as a Class I). The same assignments apply for over-classifications.

Within the CUVA headwater stream inventory data set, the Level 1 HHEI classifications coincided with the Level 3 biological PHW classifications for 79.2% of the sites. However, the total percentage of sites that were under-classified (e.g., a Class III site being classified as a Class II site, etc.) was limited to 4.8% of the total sites and 5.8% for Class III PHW sites. The overwhelming majority of the "errors" within the Level 1 classifications, accounting for 16% of all sites, were the result of over-classifications (e.g., a Class I site being classified as Class II or Class III). Errors in this direction are resource protective in nature when no biological data are available and are readily corrected through assessment of the stream biology. In the context of the management of stream resources within CUVA, the conclusion is that the use of the HHEI alone (Level 1 PHW assessment) is a rapid assessment tool with a resource protective accuracy of 95.2% that can be reliably used to provide data to assist in management planning. The Level 1 assessment data (HHEI scores) can be effectively used to direct efforts in an efficient manner to locations where additional information provided by biological assessments is needed.

Table 22. Comparison of Level 1 PHW classification results to biological (Level 3) PHW results for CUVA headwater stream sites.

Biological (Level 3) PHW Class	Correct	Under x 2	Under	Over	Over x 2	Total Sites
Class IIIB	51	0	4	NA	NA	55
Class IIIA	46	0	2	NA	NA	48
Class III Total	97	0	6	NA	NA	103
Class II	2	NA	0	18	NA	20
Class I	0	NA	NA	0	2	2
Totals	**99**	**0**	**6**	**18**	**2**	**125**

Stream Geomorphology

Stream geomorphology measurements were collected at 123 of the CUVA Headwater Inventory sites. Measurements were not taken at Sites CUVA-X54 and CUVA-X60. The field crew leaders for these assessments excluded this data collection because it was determined that the settings did not meet the data quality objectives for this portion of the inventory. Site CUVA-X54 was found to be an ephemeral (Class I PHW) stream with only isolated pools and therefore did not meet the data quality

objective for assessment of perennial PHW streams. Site CUVA-X60, located downstream of Buttermilk Falls, is the most downstream site located on Spring Creek and has a drainage area of 1.43 mi^2 and is the most downstream natural obstacle for fish passage on the stream. Spring Creek at this point was deemed by the field crew leader and PI to be a WWH stream and not a PHW stream. Therefore, this site also was deemed to be outside of the data quality objectives for the headwater stream inventory channel assessment protocols.

Stream Geomorphology Measurement Results

Stream channel dimensions measurement data for the inventoried headwater stream sites are summarized in Table 23. Site-specific measurement results are included in the electronic data package deliverables provided to NPS. Stream gradient measurements represent the sum of sequential measurements along the 200 ft assessment zone as described in the methods for this parameter. Average depth, and maximum depth data refers to channel depth measurements relative to the bankfull flow elevation averaged based upon the number of locations indicated in the table for the respective sites. At least two cross-sections were measured for each stream inventory site, with three cross-sections measured at 34 sites. Values for bankfull, intermediate, and floodprone widths are site averages based on the number of locations where measurements were taken.

Stream channel measurement data for entrenchment ratio, width to depth ratio, and channel sinuosity are used in subsequent channel type classifications using the Rosgen stream classification system and are summarized in Figures 22, 23, and 24. Some of these data are also used in the evaluation of streambank condition and erosion hazard including BEHI and NBS calculations described later in this report.

Table 23. Summary of stream channel cross section measurement data.

Measurement	Statistic	Class I	Class II	Class IIIA	Class IIIB
Average Bankfull Depth (ft)	Sites	2	20	50	51
	Maximum	0.60	0.94	1.07	1.03
	Minimum	0.44	0.23	0.17	0.14
	Average	0.52	0.48	0.48	0.50
	Std Dev	0.11	0.20	0.18	0.22
Maximum Bankfull Depth (ft)	Sites	2	20	50	51
	Maximum	0.98	1.26	1.76	1.63
	Minimum	0.60	0.38	0.36	0.29
	Average	0.79	0.78	0.81	0.83
	Std Dev	0.27	0.25	0.27	0.31

Table 23 (continued). Summary of stream channel cross section measurement data.

Measurement	Statistic	Class I	Class II	Class IIIA	Class IIIB
Bankfull Width (ft)	Sites	2	20	51	52
	Maximum	9.50	23.20	30.30	26.60
	Minimum	7.70	6.80	4.10	6.70
	Average	8.60	13.49	13.35	13.67
	Std Dev	1.27	4.77	4.74	4.44
Intermediate Width (ft)	Sites	2	20	50	51
	Maximum	13.25	25.95	32.04	51.37
	Minimum	8.08	8.50	4.49	7.83
	Average	10.67	16.66	16.34	18.42
	Std Dev	3.66	5.42	6.06	8.56
Flood Prone Width (ft)	Sites	2	20	50	51
	Maximum	14.75	100.94	130.15	82.70
	Minimum	8.57	9.85	5.25	8.52
	Average	11.66	24.72	21.95	22.18
	Std Dev	4.37	20.89	17.99	12.79

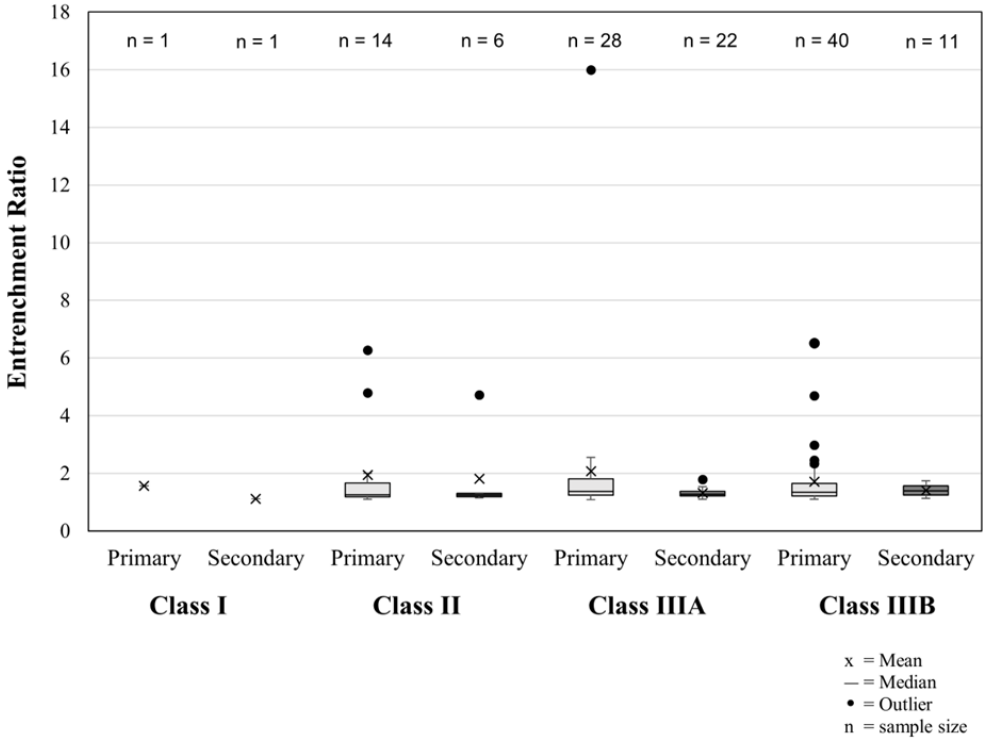


Figure 22. Comparison of entrenchment ratio for primary and secondary sites parsed by PHW stream class.

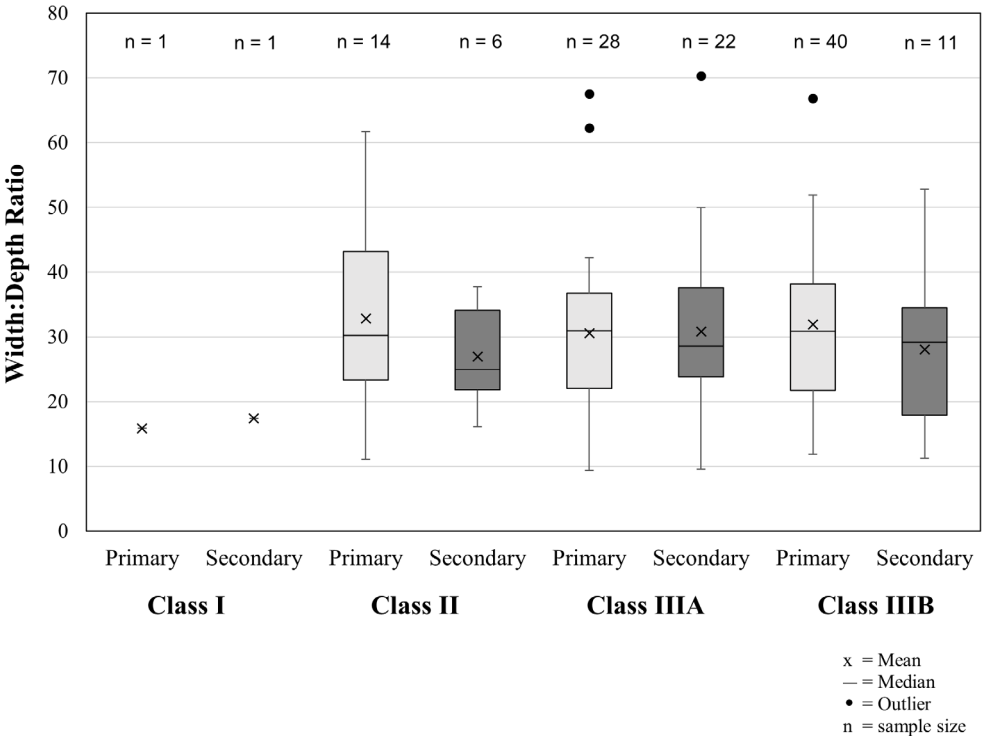


Figure 23. Comparison of width to depth ratios for primary and secondary sites parsed by PHW stream class.

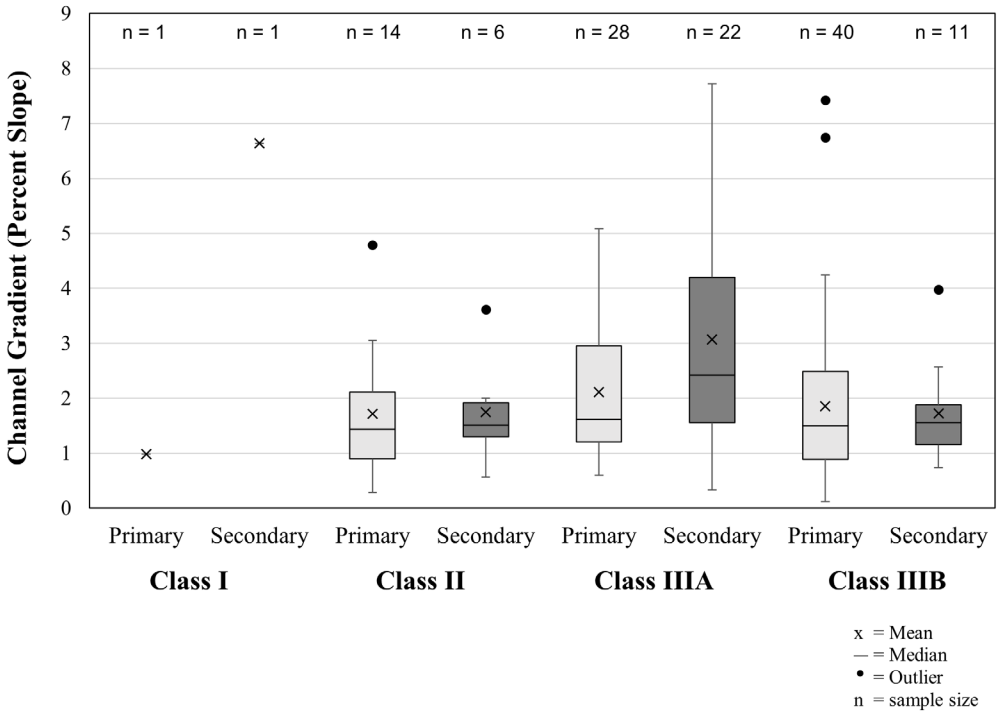


Figure 24. Comparison of channel gradient (percent slope) for primary and secondary sites parsed by PHW stream class.

Rosgen Stream Channel Classification Results

The results for the classification for the 123 headwater stream inventory sites using the Rosgen Stream Channel Classification System (Figure 5) are summarized in Table 24 and depicted graphically in Figure 25. Site-specific classification results are provided in the electronic submittal package to NPS. Channel classifications are comprised of a letter (i.e., B, C, F, and G), a number indicative of the dominant channel material (1-bedrock, 2-boulder, 3-cobble, 4- gravel, 5-silt/clay, 6-sand). A lower-case letter, and in some cases a + or – sign, may also be assigned to differentiate between channel slope categories. Example photographs of sites meeting the various Rosgen stream channel classifications are provided in Appendix D.

Most of the CUVA Headwater Inventory sites (61%) classified within entrenched channel stream types F and G (entrenchment ratios < 1.4). The definition for F type stream channels provided by Rosgen (1996) describes them as "…associated with deeply entrenched, structurally controlled, gentle gradient valleys and gorges … with highly weathered bedrock…." Stream type G channels are differentiated from F type streams in that they are down cut channels situated within alluvial or colluvial valleys rather than in bedrock-controlled valleys. Although both stream types are highly entrenched, the W/D of F stream type channels is higher than G stream type channels because vertically down cutting is controlled by an underlying bedrock channel foundation. Stream channel type G streams were rare within the CUVA Headwater Inventory, with only three locations classifying under this category (2.4% of all sites).

Table 24. Tally of sites for Rosgen stream channel classes categorized by Level 3 PHW stream class.

Channel Type	Channel Class	Class I	Class II	Class IIIA	Class IIIB	Totals	Percent
Channel Type B	B1a	0	0	1	0	1	0.8%
	B3	0	0	2	1	3	2.4%
	B3a	0	1	3	1	5	4.1%
	B3c	1	0	5	6	12	9.8%
	B4	0	0	1	3	4	3.3%
	B4c	0	1	4	6	11	8.9%
	B6	0	1	0	0	1	0.8%
Total Channel Type B	–	1	3	16	17	37	30.1%
Channel Type C	C3	0	1	1	1	3	2.4%
	C3b	0	0	1	0	1	0.8%
	C4	0	1	1	3	5	4.1%
	C4c-	0	0	0	1	1	0.8%
	C6	0	1	0	0	1	0.8%
Total Channel Type C	–	0	3	3	5	11	8.9%
Channel Type F	F1	0	3	2	0	5	4.1%
	F1b	0	1	6	0	7	5.7%
	F2b	1	0	0	1	2	1.6%
	F3	0	0	8	6	14	11.4%
	F3b	0	2	8	7	17	13.8%
	F4	0	5	2	13	20	16.3%
	F4b	0	2	3	1	6	4.9%
	F5b	0	1	0	0	1	0.8%
Total Channel Type F	–	1	14	29	28	72	58.5%
Channel Type G	G3	0	0	1	1	2	1.6%
	G4	0	0	1	0	1	0.8%
Total Channel Type G	–	0	0	2	1	3	2.4%
Grand Totals	–	2	20	50	51	123	–

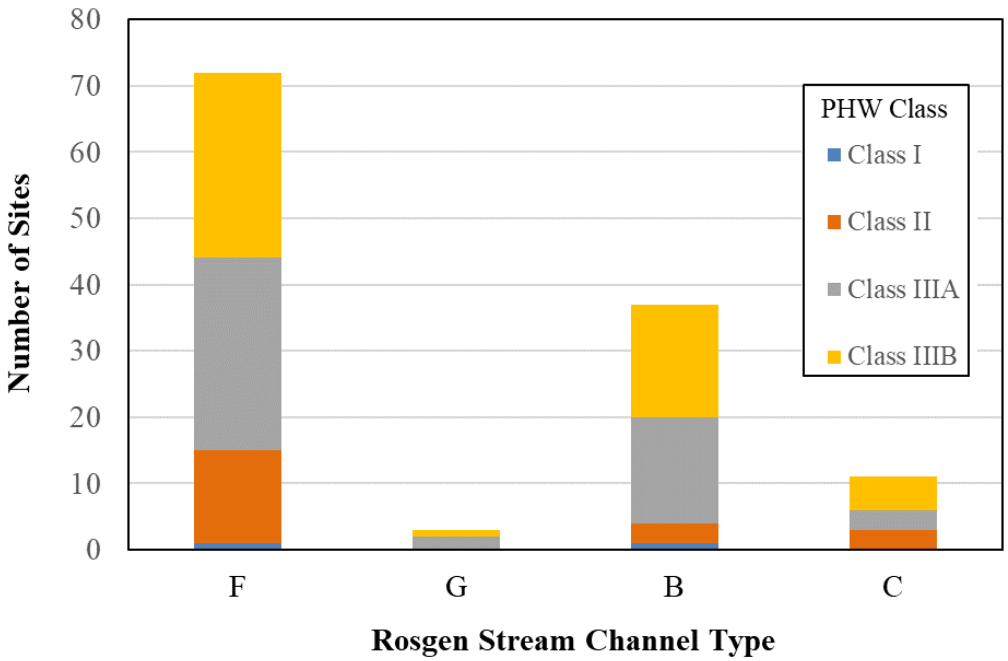


Figure 25. Comparison of site frequencies among PHW stream classes parsed by Rosgen stream channel sites.

Less entrenched sites within the B and C stream channel types comprised the remaining 31% of the inventoried locations. Stream channel type B sites were the second most common stream type encountered during the inventory and are characterized by moderately entrenched channels, more gently sloping valleys, and moderate sinuosity. These site locations are more highly associated with alluvial or colluvial deposits rather than areas of exposed bedrock. The sites classifying as B channel type streams within the CUVA headwater stream inventory were equally split between cobble and gravel as the dominant channel material (20 and 15 sites, respectively). Stream channel type C streams either are not entrenched or only slightly entrenched, have moderate to high sinuosity, and are typically found in alluvial valleys. As with the B stream channel type sites, the streams assessed at most of the C stream channel type sites had cobble or gravel as the dominant substrate type within the channel.

Channel entrenchment, W/D, and slope measurements used for stream channel classification were examined statistically using the Kruskal-Wallis rank sum test to determine whether differences could be noted between PHW stream classes. Results for these analyses found that entrenchment and W/D were not significantly different between the stream classes ($p=0.963$ and $p=0.075$, respectively). Channel slope was found to be significantly different between stream classes using the Kruskal-Wallis rank sum test ($p=0.045$). However, follow up pairwise testing using the Wilcoxon-Mann-Whitney rank sum test found no discernible pattern of significant differences between the PHW stream classes.

The lack of association of PHW L3 classifications to any of the Rosgen stream channel classification types was unexpected. In addition, no apparent difference could be discerned between entrenched (F and G channel type streams) versus moderately and slightly entrenched (B and C channel type

streams) stream categories with respect to PHW classification. Therefore, it is postulated that local hydrology (perennial flow), water temperatures, and the availability of suitable habitat features (substrate types, presence of pools, etc.), are better predictors of the biological communities that can be supported within PHW streams than the physical channel characteristics used in the Rosgen stream channel classification system.

Stream Bank Characterization

Field measurements for BEHI and NBS were collected at 123 of the 125 CUVA Headwater Inventory sites. Data for all measurements obtained during these assessments is included as part of the electronic data submittal for the project. A total of 413 study banks were assessed in the field, with an average of 3.6 study banks measured at each site.

A preliminary evaluation of the data set for BEHI and NBS calculations was conducted in conjunction with examination of site photos and site drawings following the completion of field work. Based upon this evaluation, it was determined that data gaps existed for several of the CUVA Headwater Inventory sites with respect to stream bank coverage for BEHI and NBS measurements. For these sites, additional study bank information was derived from the site photographs, field stream drawings, and site data to construct "interpreted" study banks. These interpreted banks were associated with unassessed reaches of the stream banks and were used to derive adjective BEHI and NBS severity rankings based upon these data. A total of 68 interpreted banks were generated among 24 sites to provide a more complete data set for the analysis of streambank condition, annual lateral erosion rates, and sediment export. On average, 2.8 study banks were constructed for sites where interpreted study banks were used for BEHI and NBS estimations. The use of interpreted banks increased the total number of study banks to 511 for the inventory which increased the average number of study banks to 4.2 per site.

The BANCS method for calculation of lateral erosion rates requires the use of numerical values for NBS. Therefore, average NBS values for the adjective severity rankings derived from the measured study banks were used for the calculations for interpreted study banks. The NBS values assigned for the adjective severity rankings for the interpreted study banks were as follows:

- Very Low = 0.746
- Low = 1.278
- Moderate = 1.635
- High = 2.029
- Very High = 2.905

There were no measured study banks encountered during the headwater stream inventory with NBS values in the Extreme range. Therefore, no interpreted study banks were assigned to this severity ranking for NBS.

Weighted site average values for both total BEHI scores and NBS values were calculated for each site as the sum of the products for each study bank BEHI or NBS value multiplied by the length of the study bank divided by the sum of the lengths of all study banks for the site. Use of this procedure allowed for normalization of the data set to provide accurate single value comparisons between headwater stream inventory sites.

BEHI Results and Adjective Classifications

Total BEHI scores for measured study banks are determined using two factors with higher values indicative of high erosion severity risk. The first is the total score calculated by adding the scores for the five BEHI metrics determined through field measurements, each with a maximum value of 10. The second factor determining final BEHI scores are adjustments based upon the composition of the dominant bank material and stratification of material. For the CUVA headwater stream inventory sites, scoring adjustments were appropriate for 222 of the measured study banks (50.1% of the total). Adjustments in scores ranged from -10 to +10 points and averaged +6.8 points for sites where adjustments were necessary and +3.1 points when all sites are included in the calculation. The breakdown for the numbers of measured study banks where BEHI scores were thus modified by adjustment category is provided in Table 25.

Table 25. Summary of total BEHI score adjustments for measured study banks.

BEHI Adjustment Category	Description	Number of Measured Study Banks
Bedrock as dominant bank material	Overall Very Low BEHI. Total BEHI score adjusted to score of 7 pts.	18
Boulders as dominant bank material	Overall Low BEHI. Total BEHI score adjusted to score of 14 pts.	4
Uniform medium to large cobble as dominant bank material	10 pts subtracted from total BEHI score	4
Gravel or composite matrix as dominant bank material	5-10 pts added to the total BEHI score dependent upon the percentage of sand in the matrix	180
Sand as dominant bank material	10 pts added to the total BEHI score	16
Silt or clay as the dominant bank material	No adjustment to total BEHI score	221
Stratification	5-10 pts added if the bank material is stratified with unstable material exposed to bankfull flows	0
Total BEHI score adjustments	–	**222**
Total measured study banks	–	**443**

Results for site weighted average BEHI scores for inventoried sites are compared for HUC12 watersheds in Figure 26 and by site category and PHW class in Figure 27. The bounds for adjective

BEHI severity categories are depicted in the figure. As evident through graphical analysis, statistical comparisons using the Kruskal-Wallis rank sum test found no significant differences between of weighted site average BEHI scores between sites grouped using both HUC 12 watersheds and PHW stream classification results (p = 0.747 and p = 0.335, respectively).

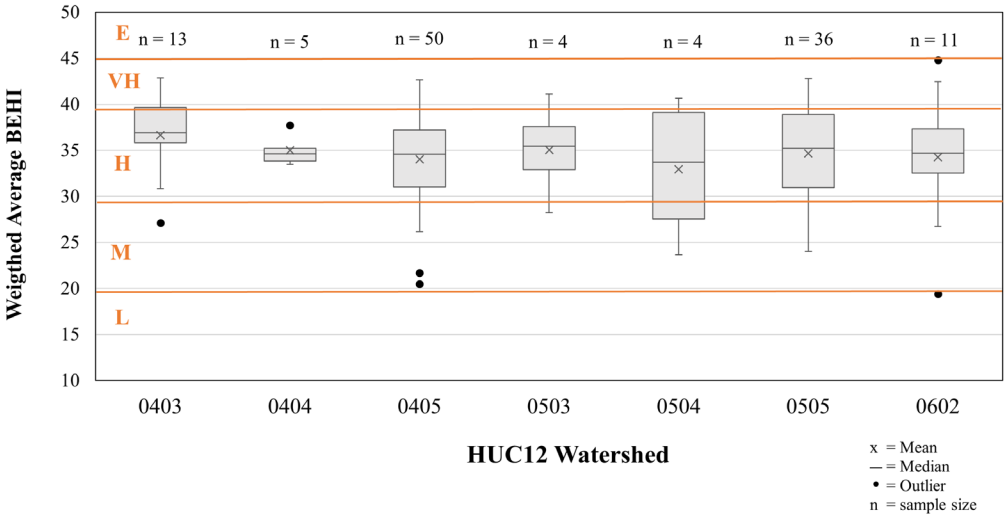


Figure 26. Comparison of weighted average BEHI scores by HUC12 watershed. Thresholds for the boundaries between adjective severity categories are superimposed.

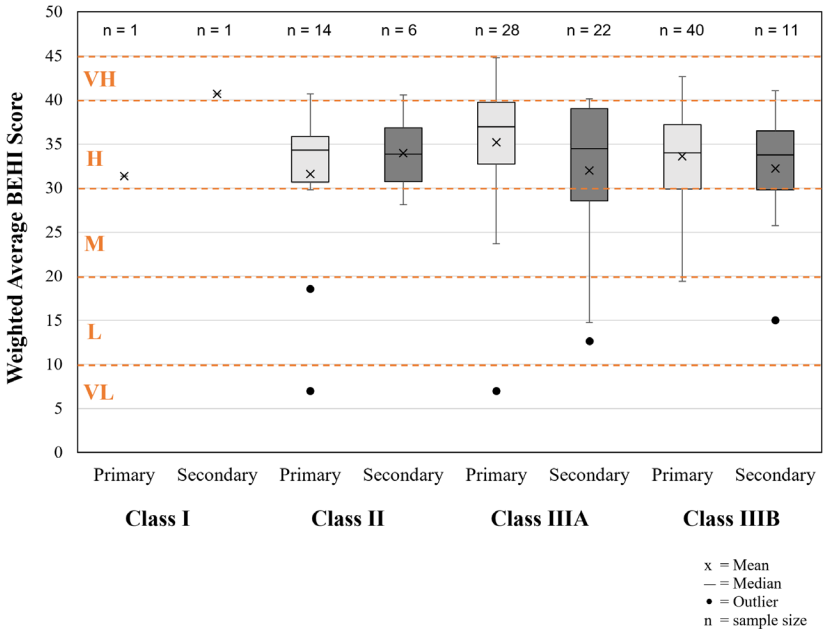


Figure 27. Comparison of weighted average BEHI scores for primary and secondary sites by stream class. Thresholds for the boundaries between adjective severity categories are superimposed.

Site weighted average BEHI scores for headwater streams throughout CUVA demonstrate a universally high potential for bank erosion, with both the upper and lower quartile values for

inventory sites falling within the High adjective severity category range (30 - 40 pts.). This susceptibility to erosion is further demonstrated when frequencies for the adjective BEHI rankings are examined. The frequencies are similar whether the results are presented for either individual study banks (Figure 28) or for site weighted average results (Figure 29). Adjective severity rankings of High, Very High, or Severe equaled 68.1% for individual study banks and 71.5% for site weighted average BEHI scores.

Examination of BEHI metrics and their frequencies of occurrence among the adjective severity rankings is presented in Figure 30. Metrics important within the determination of study banks with Very Low to Moderate erosion risk were related to lower bank angles, higher root depth ratios, and higher percentages of surface protection. These characteristics reduce erosion risk through the reduction of shear stress (low bank angle) and reinforcement of bank resistance to erosion (high root depth as compared to study bank height and surface protection). Study banks with High to Extreme severity ranks were associated with higher BEHI scores for bank height ratio, low root densities within the bank, and low values for the percentage of surface protection along the banks. These negative factors all relate to banks that are more susceptible to erosive forces.

The importance of BEHI scoring adjustments based upon the dominant bank material associated with the study banks is demonstrated in Figure 31. All study banks ranked as having Very Low adjective BEHI severity had bedrock as the dominant bank material. Study banks with Low and Moderate BEHI severity ranks were associated with dominant bank material consisting of boulder, cobble, or silt/clay materials with low percentages of sand in the matrix. BEHI severity rankings in the Moderate to Extreme range were associated with study banks with dominant bank materials consisting of silt/clay or gravel composite matrices with higher percentages of sand or with sand as the dominant bank material.

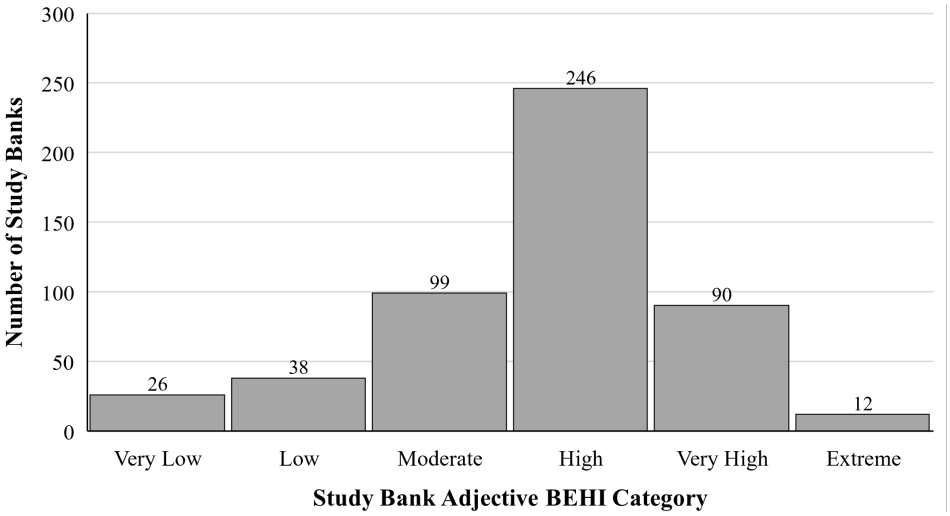


Figure 28. Adjective severity ranking frequencies based on individual study bank BEHI scores.

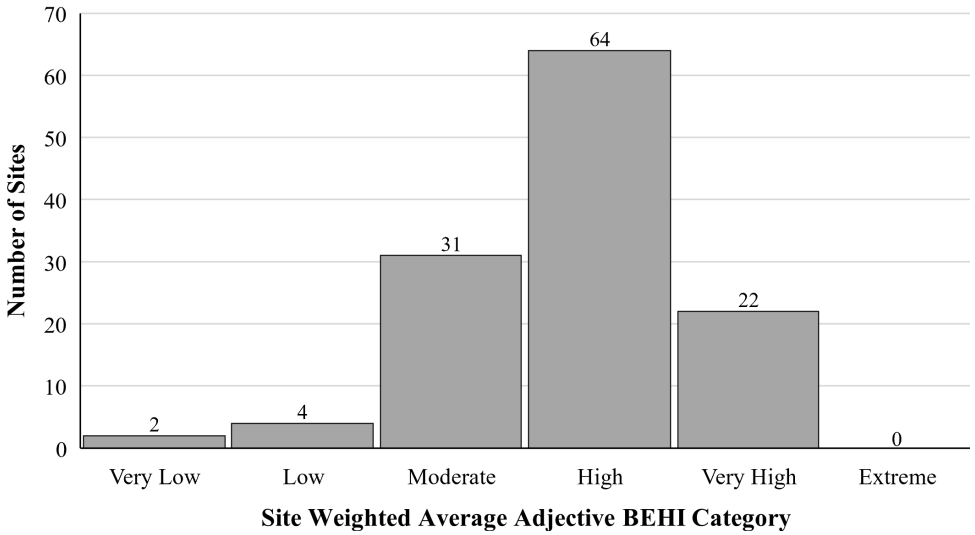


Figure 29. Adjective severity ranking frequencies based on site weighted average BEHI scores.

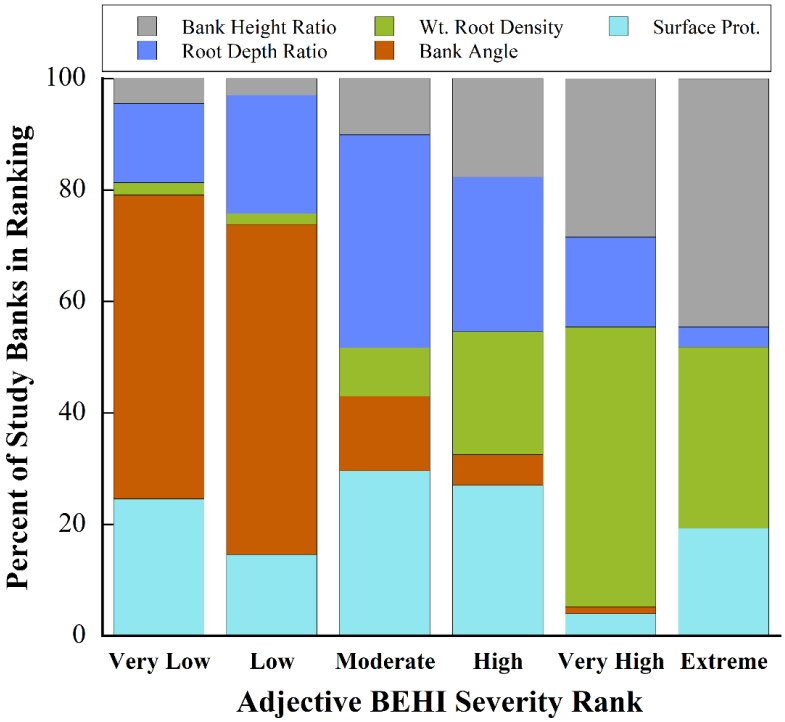


Figure 30. Percent of occurrences of study bank BEHI metric scores among adjective severity rankings.

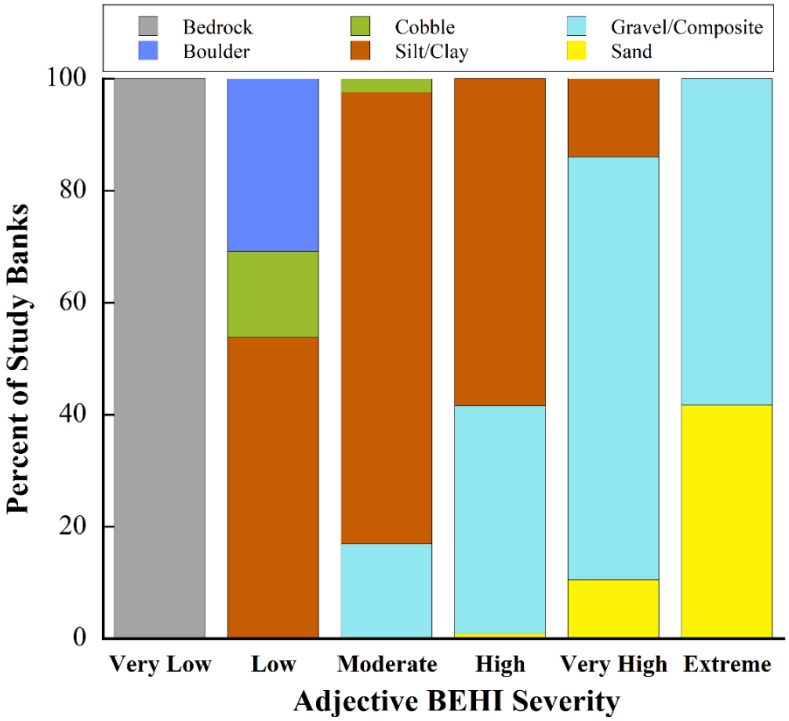


Figure 31. Percent of occurrences of dominant bank materials for study banks among adjective severity rankings.

Near-Bank Stress Results and Adjective Classifications

Site weighted average NBS values for the headwater stream inventory sites are summarized for sites by site category and PHW class in Figure 32 and by HUC12 watershed in Figure 33. Results of note based upon the graphical analysis of the NBS data sets are the uniformity of distributions of values within the Low adjective range for severity and the equivalencies of the mean and median values when sites are parsed either by watershed locations or by PHW classification. Statistical comparison of the data using the Kruskal-Wallis rank sum test found that there were no significant differences between HUC12 watersheds ($p = 0.51$), but that there was a significant difference between the PHW classes. Follow up testing of the data grouped by PHW class using the Wilcoxon-Mann-Whitney rank sum test found that the weighted average NBS values for Class II sites were significantly lower than those for both Class IIIA sites ($p = 0.028$) and for Class IIIB sites ($p = 0.006$). However, there was no significant difference detected between Class IIIA and Class IIIB sites ($p=0.491$). These results make sense in the context of the differences in stream waterpower expected during high streamflow events when comparing intermittent to perennial streams.

The frequency distribution for adjective severity rankings for study bank NBS values was the opposite to that observed for BEHI scores. Near Bank Stress values at over two thirds of the individual study banks (345 of 511 study banks) ranked in the Very Low and Low ranges with an additional 103 study banks with values in the Moderate range. Only 63 study banks (12.3% of the total) had NBS values in the High and Very High adjective ranges.

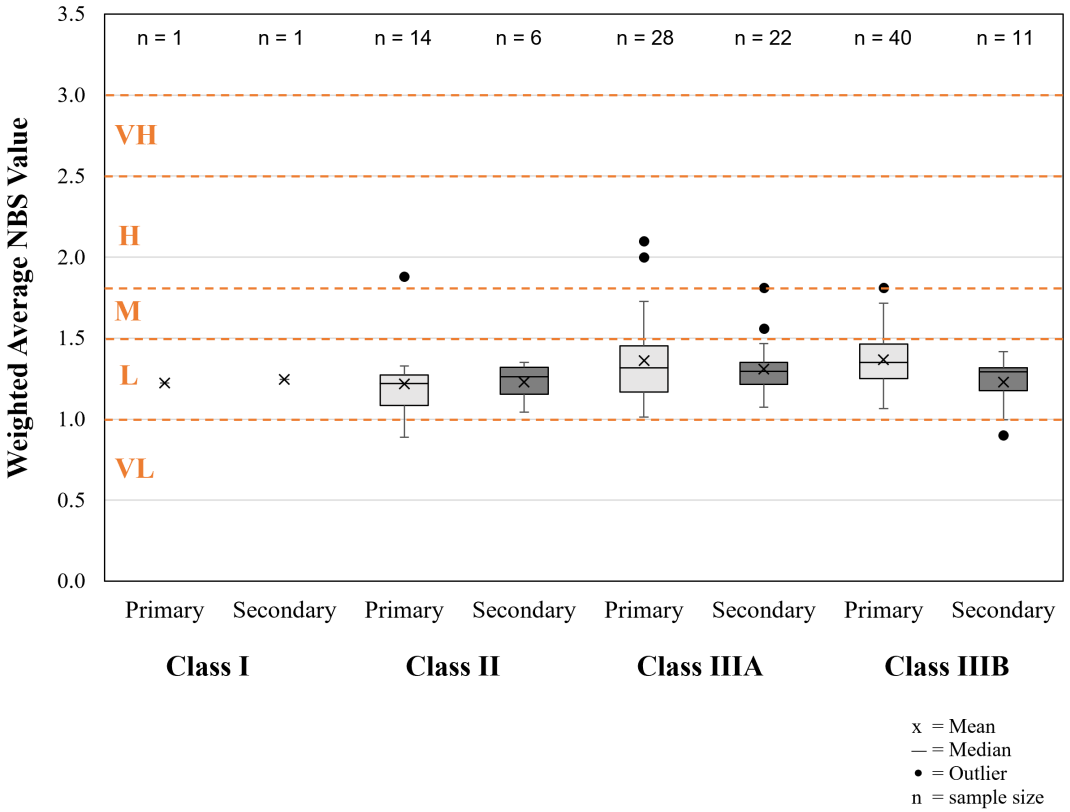


Figure 32. Comparison of weighted average NBS values for primary and secondary sites by stream class. Threshold values for NBS severity categories are superimposed to demonstrate adjective rankings.

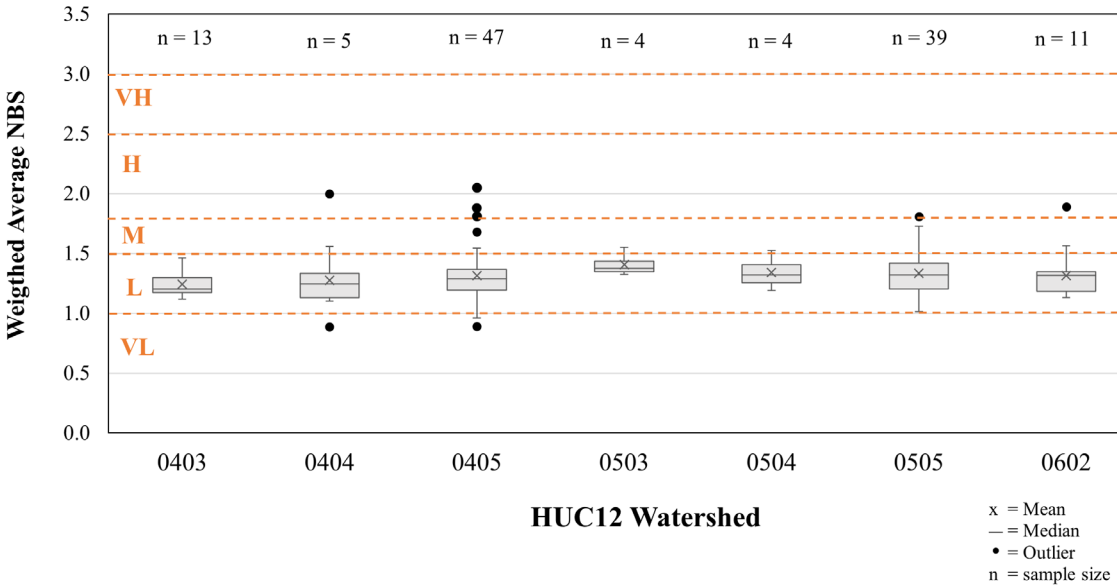


Figure 33. Comparison of weighted average NBS values for primary and secondary sites by HUC12 watershed. Threshold values for NBS severity categories are superimposed to demonstrate adjective rankings.

When NBS values were normalized through calculation of site weighted averages, this distribution became even more pronounced, with 82.1% of the 123 CUVA Headwater Inventory sites resulting in NBS values in the Low adjective category (Figure 34). Only 5 of the sites (4.1%) had weighted average NBS values within the High adjective category, and no sites fell within the ranges of the Very High or Extreme adjective categories for NBS.

Low NBS values are indicative of stream banks where erosive energy is low during high flow events. These results for the CUVA headwater streams assessed for this study result from the high width to depth ratios for most of the sites. Under these conditions, stream flows are distributed over a greater surface area, thereby reducing the shear strength or erosive power of these events upon the stream banks.

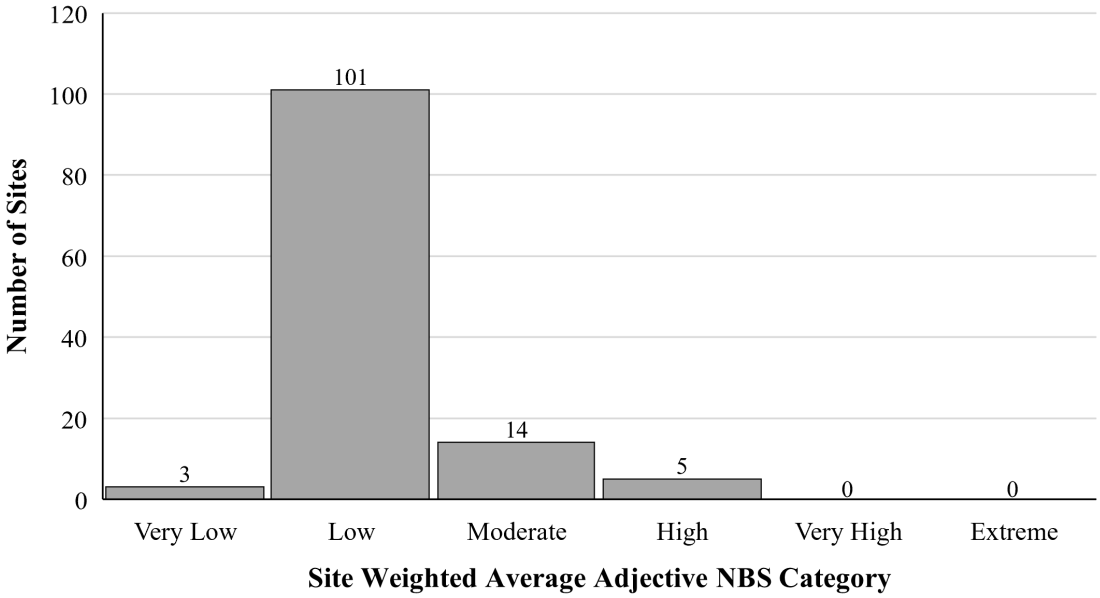


Figure 34. Frequencies of adjective severity rankings for CUVA headwater stream inventory sites based on weighted average NBS scores for each site.

Streambank Erodibility and Erosion Rate Estimate Results

As stated previously, the BANCS Model (Rosgen, 2001; 2009) used to calculate streambank erosion rates uses study bank NBS values to calculate lateral bank erosion rates in feet per year based upon regional erosion curves developed for adjective BEHI scores. Since regional lateral streambank erosion curves do not exist for streams within CUVA or the glaciated region of Ohio, the best-known approximation of streambank erosion rates for CUVA using the BANCS model are erosion rate curves developed for North Caolina streams (Doll, et al., 2003). These curves (Figure 10) are used herein to calculate erosion rates for the CUVA headwater stream inventory sites. Note that neither the work to develop the BANCS Model for western streams nor the data relationships developed from North Carolina streams include erosion rate curves for streambanks rated as having Very Low or Low adjective rankings for BEHI. The assumption that no erosion is occurring along streambanks with these rankings is obviously not accurate but must be used simply because of the lack of available data.

The sediment export calculation values presented below should therefore be interpreted with caution and are most appropriately interpreted as relative values for comparison against each other (site-wise comparisons within the data set) rather than precise measures of rates for streambank erosion loads to the streams. It should also be noted that although the BEHI method assigns the Very Low adjective rank for BEHI to study banks where bedrock is the dominant bank material, erosion rates for siltstone and shale bedrock are likely much higher than for sites where bank material is comprised of sandstone bedrock. A final caution with respect to these calculations is that the erosion rate curves available in the literature were measured using much larger streams with respect to drainage area. The difference in waterpower between the small headwater streams included in the present inventory and the studies used to derive the values used in the BANCS model are significant and cannot be ignored as a factor of uncertainty with respect to the results presented herein.

Calculated erosion rates and sediment export values for the 413 study banks evaluated in the field for BEHI and NBS pooled with those for the 68 interpreted study banks are provided in the electronic data package submitted to NPS. The data package also includes calculated weighted site average sediment export rates for each headwater stream inventory site.

Weighted site average erosion rates grouped by site average BEHI severity rankings are compared for the inventory sites in Figure 35. The impact of higher severity rankings for study bank BEHI scores is evident in the erosion rate calculation results, with relative percentage differences between the mean estimated erosion rates increasing from 75% between Low and Moderate ranked sites to 101% when Moderate and High ranked sites are compared, to 127% between High and Very High severity sites.

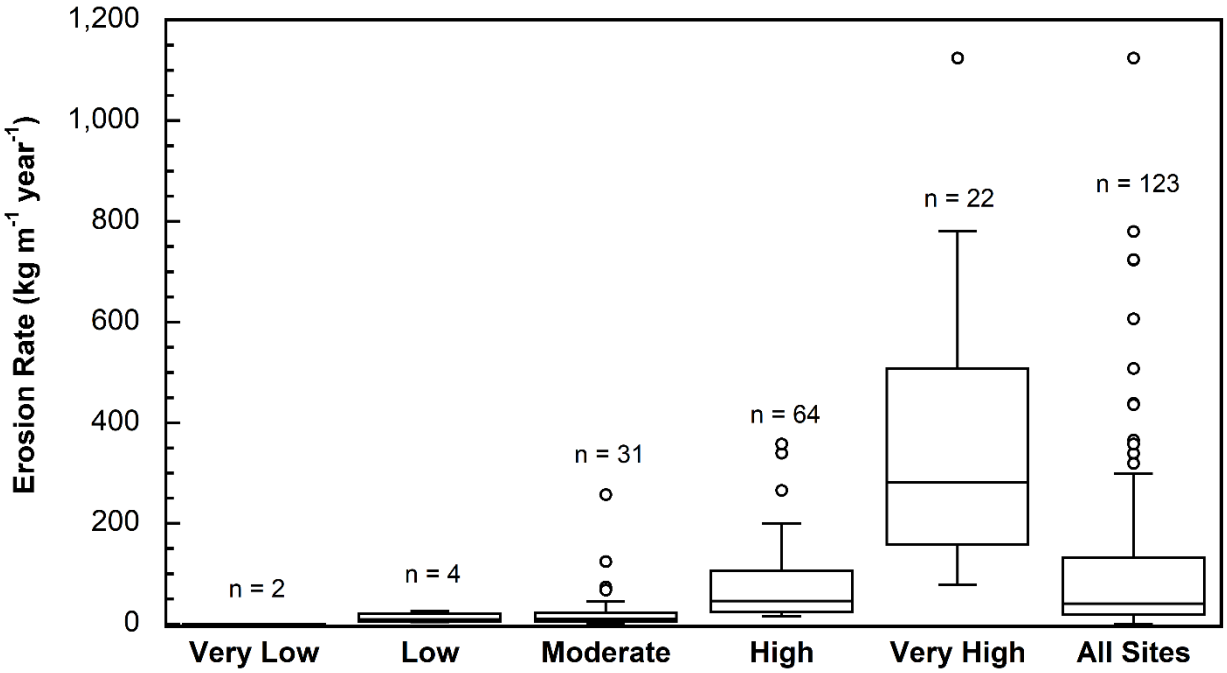


Figure 35. Comparison of calculated weighted average site streambank erosion rates (kg m^{-1} yr^{-1}) between adjective BEHI severity ranks. Data pooled for all site categories and PHW classes.

Calculated weighted average erosion rates for the assessed sites are presented in Figure 36 for locations sorted by HUC12 watershed and in Figure 37 for sites sorted by the combination of site type (Primary or Secondary) and PHW Class. Statistical comparisons of data grouped by both HUC12 watershed and PHW class using the Kruskal-Wallis rank sum test found no significant differences between groupings ($p = 0.671$ and $p = 0.148$, respectively). A similar statistical analysis was also conducted grouping the sites by Rosgen stream channel categories (Types B, C, F, and G). This test also found no significant differences between the site groupings ($p = 0.494$).

Very high calculated streambank erosion rates, exceeding 400 kg m^{-1} yr^{-1}, were identified for twelve sites. The sites in question, grouped by PHW class, are listed in Table 26. An additional seven sites (not listed) had elevated calculated streambank erosion rates between 200 and 400 kg m^{-1} yr^{-1}. Surprisingly, 17 of the 19 sites with elevated or very high calculated erosion rates supported Class IIIA and Class IIIB biological communities. Fourteen of these sites lie within the 0405 and 0505 HUC12 watersheds, with seven sites within each HUC12 unit. Both the Blossom Woods and the Twin Sisters – Mudcatcher Natural Zones had four high erosion rate sites within them and the Pinery Narrows and Northern Natural Zones had two high erosion sites each.

When using the streambank erosion rates estimated using the BANCS model, it should be noted that the length of the assessment zone for individual inventory sites is very limited in comparison to the overall reaches of the streams. Therefore, findings of high or very low erosion rates at a specific site cannot necessarily be extrapolated for the entirety of the sampled streams to define conditions with respect to streambank erosion. Additional longitudinal study of individual stream corridors would be necessary to properly document these issues to determine overall erosion severity.

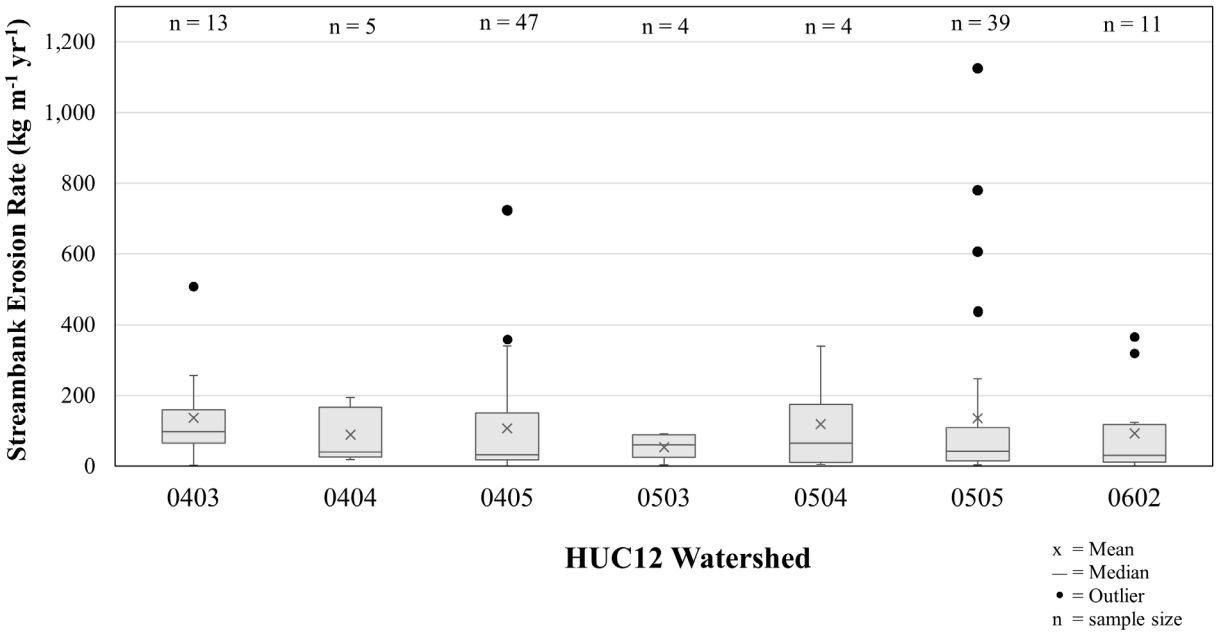


Figure 36. Comparison of weighted average streambank erosion rates between HUC 12 watersheds.

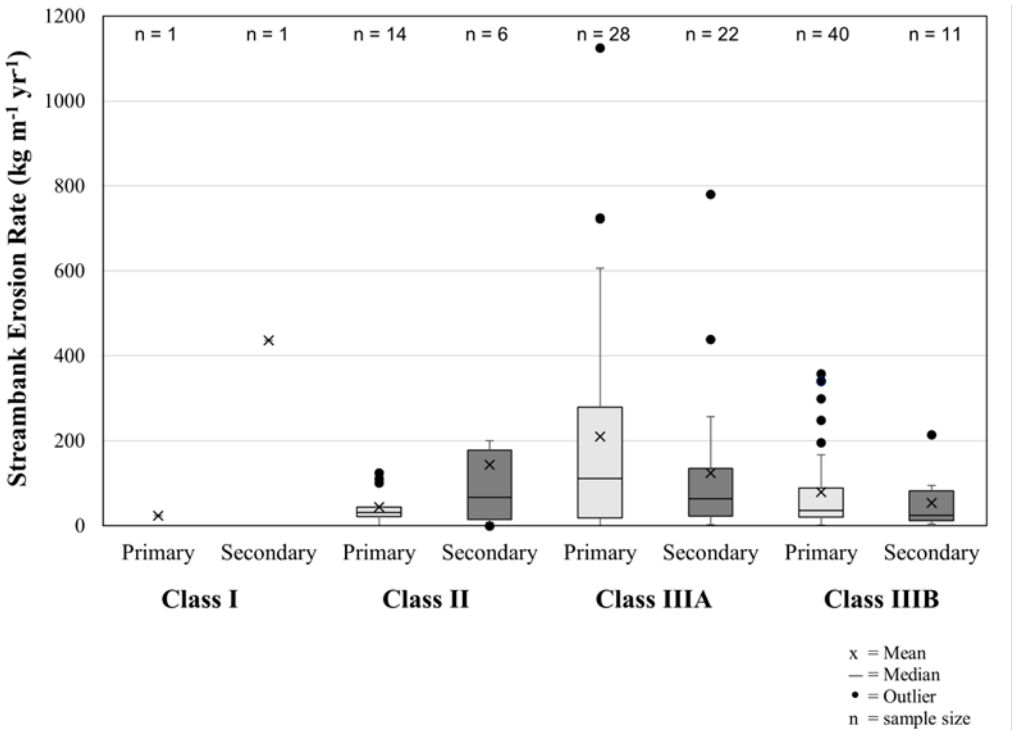


Figure 37. Comparison of weighted average streambank erosion rates parsed by site category and PHW class.

Table 26. Listing of sites with very high erosion rates identified through use of the BANCS Model.

PHW Class	Primary Sites	Secondary Sites	Totals	Sites
Class I	0	1	1	CUVA-X26
Class II	0	1	1	CUVA-X46
Class IIIA	3	9	12	CUVA-8, CUVA-9, CUVA-28, CUVA-29, CUVA-60, CUVA-64, CUVA-87, CUVA-88, CUVA-90, CUVA-X23, CUVA-X25, CUVA-X73
Class IIIB	4	1	5	CUVA-22, CUVA-25A, CUVA-89,CUVA-93A, CUVA-X43
Totals	7	12	19	–

Biological Assessment Results

Macroinvertebrates

Qualitative macroinvertebrate sampling was successfully completed at all 125 inventory sites. The average time spent collecting qualitative samples in the field was 79.7 minutes and ranged from 35 to 180 minutes. Field calculations of the HMFEI were conducted immediately following the completion of sampling and preservation of representative voucher specimens following the approved PSP. Preserved samples of voucher macroinvertebrate specimens were transported to the laboratory for

examination and identification at the bench to lowest practical taxonomic level. All preserved specimens were accompanied by a signed chain-of-custody document, catalogued, and transferred to NPS for museum archival purposes.

Supporting metadata for HMFEI and HWMI data calculations, taxa reporting, voucher photos, and laboratory findings for taxonomic identification are included in the electronic data deliverables package submitted to NPS in accordance with the SOW. Scans of laboratory bench sheets for the examination and identification of preserved macroinvertebrate samples are included in a supplemental appendix to this report (EnviroScience, 2023).

The sections below discuss the results of the various aspects of the macroinvertebrate community data assessment that were relied upon to complete the final determinations for both the PHW classifications and the assignment of higher ALU designation recommendations under the Ohio WQS as discussed below.

Level 2 PHW assessment using the HMFEI

Field HMFEI scores calculated immediately following macroinvertebrate sampling ranged from 4 to 52 for the headwater stream inventory sites (Figure 38). The four sites assessed within the Headwaters Chippewa Creek HUC12 watershed (HUC 0503) had the highest median HMFEI score (26 pts.) among the CUVA HUC12 watersheds. These sites are all located within the Cleveland Metroparks Brecksville Reservation. The lowest median HMFEI score of 12 pts. was observed for sites within the Brandywine Creek HUC12 watershed (HUC 0404). These sites lie within the Stanford Run – Hines Hill HVE and Boston Brandywine HVE resource management zones.

Statistical comparison of Field HMFEI scores grouped by pooled Level 3 PHW classification results combining Primary and Secondary site scores depicted in (Figure 39) using the Kruskal-Wallis rank sum test detected a significant difference between Class II, Class IIIA, and Class IIIB stream classes ($p<0.0001$). Follow up pairwise testing using the Wilcoxon-Mann-Whitney rank sum test found no significant difference between HMFEI scores compared between Class II and Class IIIA sites ($p = 0.2010$) but did detect significant differences between both Class II and Class IIIB sites and Class IIIA and Class IIIB sites ($p < 0.001$ for both tests).

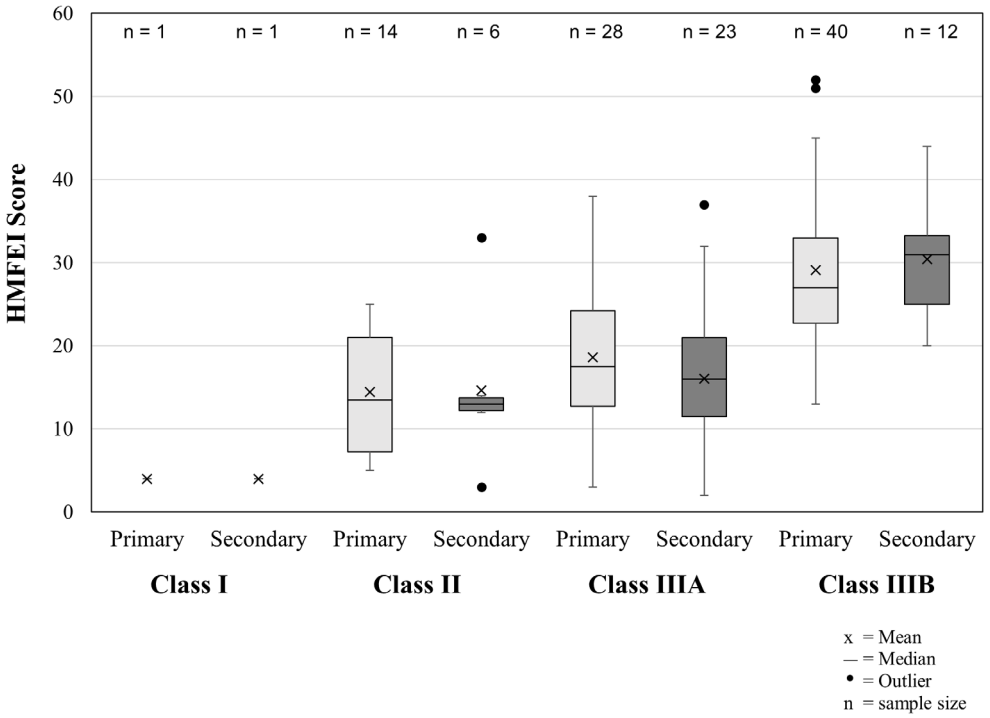


Figure 38. Comparison of field HMFEI scores grouped by site category and Level 3 PHW classification results.

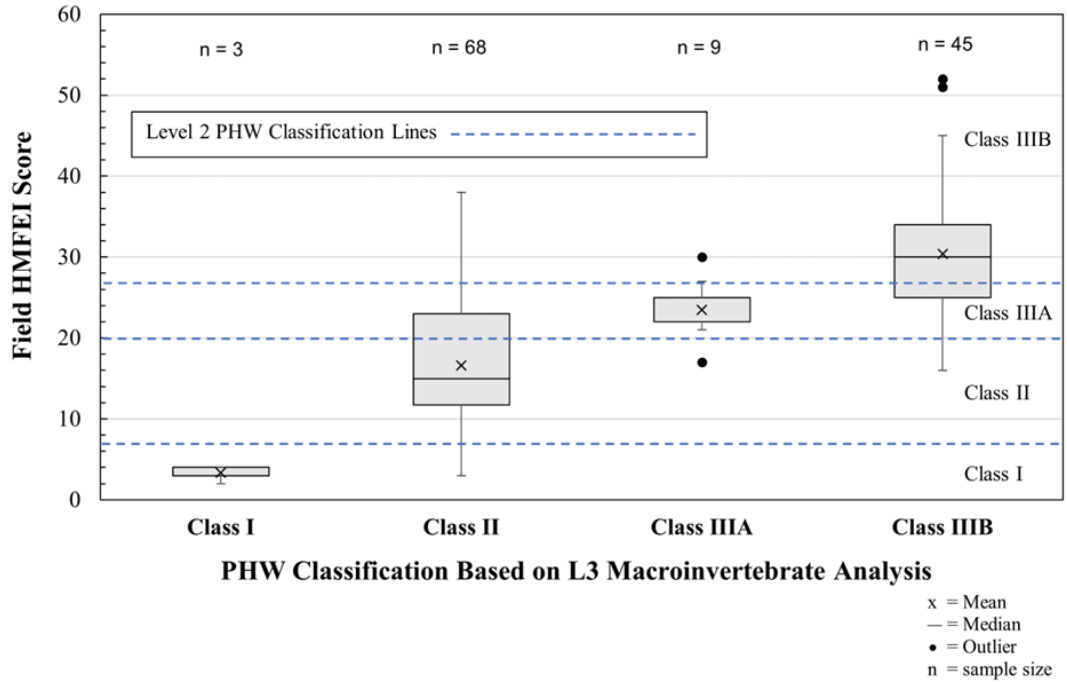


Figure 39. Comparison of Level 2 field HMFEI results to Level 3 macroinvertebrate classification categorization results (note that Class III site data is pooled for this comparison). Dashed lines indicate the Level 2 classification thresholds established by Ohio EPA for the interpretation of HMFEI data.

To test the accuracy of the Level 2 PHW assessment procedures for macroinvertebrates using the HMFEI to Level 3 PHW classifications based upon laboratory identification of macroinvertebrate specimens, a comparison was undertaken like that used earlier in this report to test the Level 1 PHW classifications using HHEI scores. The results are presented in Table 27 and are compared graphically in Figure 39. The purpose of this comparison is to provide insight regarding the use of the rapid HMFEI protocol versus the more resource intensive Ohio EPA Level 3 PHW protocols.

The results presented in Table 27 and Figure 39 indicate that reliance upon HMFEI scores for rapid PHW classification of the macroinvertebrate communities in PHW streams is questionable. The biologists carrying out the sampling for the CUVA headwater stream inventory were competent in the level of taxonomy to complete the assessments. However, the combined frequency of under-classification for all PHW classes was high (23.2% of the sites) and was greater for sites later determined to be Class III PHW based on Level 3 taxonomic assessments (35.2%) than for Class II PHW (14.7%). The overall protective accuracy of the HMFEI conducted in the field (sum of frequencies for correctly identified and over classified sites, was only 76.8% for all stream classes and was less for Class III PHW sites (64.9%).

Table 27. Comparison of Level 2 PHW classification results for inventory sites using the HMFEI to final Level 3 PHW classification results.

Level 3 Macroinvertebrate PHW Class	Correct	Under x 2	Under	Over	Over x 2	Total Sites
Class IIIB	30	3	14	NA	NA	47
Class IIIA	4	0	2	1	NA	7
Class III Total	34	3	16	1	NA	54
Class II	34	NA	10	16	8	68
Class I	3	NA	NA	0	0	3
Totals	71	3	26	17	8	125

The primary difficulty in producing accurate HMFEI scores using the methods described in the current revision of the Ohio EPA PHW manual is the requirement to identify specimens from the Orders Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa) to the Family taxonomic level in the field. Accurate identification of specimens in the field to this level can be time consuming and prone to error, especially at times when early instar larvae are present in the stream. In these situations, taxonomic differences between some Family groups cannot be discerned without microscopic examination.

A potential solution to this problem is the preservation of voucher specimens for evaluation in the laboratory using magnification. To test this approach, HMFEI scores were re-calculated in the laboratory where accurate identification of EPT taxa to the Family level of taxonomy is more certain.

The recalculated HMFEI scores using this method eliminated the under-classification errors completely, but still resulting in a 44.0 % over classification of sites. The over-classification percentage was highly fueled by classification of 85.7% of the Class IIIA sites as Class IIIB PHW. It appears that the small range of HMFEI scores (20 – 26 pts) used as the range for Class IIIA streams using the HMFEI contributes to this result when laboratory examination is used to complete the scoring process.

Macroinvertebrate Taxa Assemblages and Level 3 PHW Classifications

A total of 12,273 aquatic macroinvertebrates from 65 families were collected from the CUVA headwater stream inventory sites throughout the sampling period. Taxonomic evaluations using Ohio EPA protocols for assessment and examination resulted in the identification of 256 qualitative macroinvertebrate taxa among the voucher samples collected during the study. All collected specimens were identified in the laboratory to the lowest practical taxonomic level established by Ohio EPA for the taxon. Detailed data regarding the taxa collected and the numbers within each taxon for each site are provided as part of the electronic data submission package made to NPS for this project.

Macroinvertebrate taxa are categorized in accordance with Ohio EPA methodologies for the interpretation of the data for classification of the streams within the PHW system and the Ohio EPA biological water quality criteria. This includes information regarding taxa that are cold water indicators, taxa from the Orders Ephemeroptera, Plecoptera, Trichoptera (EPT taxa), pollution tolerance categories, including those ranked sensitive taxa (taxa moderately intolerant and intolerant to pollution). Within the 65 macroinvertebrate families collected during the inventory, 185 distinct genera/species were identified. These include 32 cold-water indicator taxa, 56 EPT taxa, and 58 sensitive taxa. Cold water indicator taxa collected during the headwater stream inventory are listed in Table 28.

The macroinvertebrate communities exhibited characteristics of ephemeral (Class I) streams at two sites. These two sites had the lowest numbers of total taxa, Cold-Water taxa, EPT taxa and sensitive taxa. Twenty sites were characterized as Class II, with intermittent and possibly some perennial shallow groundwater flow. Lower species diversity was observed at these Class II locations, with far fewer total taxa and numbers of taxa for defining statistics for taxa characteristics (Cold-Water, EPT, and Sensitive Taxa). A total of 103 perennial (Class III) streams were identified within the CUVA inventory; 51 sites were categorized as Class IIIA sites and 52 met the criteria for the Class IIIB classification. High numbers of EPT and Sensitive Taxa were found at these locations, characteristic of exceptional high quality ecological conditions. The presence of these communities is evidentiary of the predominance of groundwater contributions to the flow regimes in these streams. As stated previously, the primary importance of the macroinvertebrate community assessments was to distinguish between Class IIIA and Class IIIB PHW streams.

The numbers of observations of cold-water indicator taxa, EPT taxa, and sensitive taxa from the evaluation of the macroinvertebrate samples are broken down by taxonomic Order (or Sub-Order) and Family in Tables 28, 29, and 30, respectively. Cold-water indicator taxa were observed from 6 Orders/Sub-Orders and 20 different Families. Taxa collected from the EPT Orders represented 25

Families (8 Ephemeroptera, 5 Plecoptera, and 10 Trichoptera). The composition of sensitive taxa observed within the macroinvertebrate collections was comprised of taxa from 7 Orders and 26 Families. The EPT taxa were the most important component of the macroinvertebrate assemblages with respect to classification of the streams. The EPT comprised 38.5% of families observed within the collections, totaled 52.5% of the Cold-Water Taxa observations and represented 63.4% of the observations for Sensitive Taxa.

Table 28. Cold water indicator macroinvertebrate taxa collected from CUVA headwater steam inventory sites.

Taxonomic Group	Number of Taxa	Taxon Name
Order Diptera	10	• *Diamesa* • *Heleniella sp.* • *Micropsectra sp.* • *Parametriocnemus sp.* • *Polypedilum aviceps* • *Zavrelimyia* • *Dixa sp.* • *Dicranota sp.* • *Limnophila sp.* • *Pedicia sp.*
Order Ephemeroptera	5	• *Ameletus sp.* • *Baetis brunneicolor* • *Baetis tricaudatus* • *Epeorus sp.* • *Habrophlebiodes sp.*
Order Megaloptera:	1	• *Nigronia fasciata*
Order Odonata, Sub-Order Anisoptera:	2	• *Boyeria grafiana* • *Lanthus sp.*
Order Plecoptera:	6	• *Haploperla brevis* • *Sweltsa sp.* • *Leuctra sp.* • *Amphinemura sp.* • *Eccoptura xanthenes* • *Diploperla robusta*
Order Trichoptera:	8	• *Goera sp.* • *Ceratopsyche slossonae* • *Diplectrona modesta* • *Lepidostoma sp.* • *Dolophilodes distinctus* • *Wormaldia moesta* • *Rhyacophila Carolina* • *Rhyacophila invaria* complex

Table 29. Distribution of observations of cold-water indicator taxa among macroinvertebrate Orders/Sub-Orders and Families.

Order/Suborder	Family	Total CW Taxa Observations	Family Percent of Total CW Taxa Obs.	Order/Suborder Percent of Total CW Taxa Obs.
Anisoptera	Aeshnidae	57	12.0%	–
	Gomphidae	1	0.2%	–
Anisoptera Total	–	**58**	–	**12.2%**
Diptera	Chironomidae	98	20.6%	–
	Dixidae	1	0.2%	–
	Tipulidae	25	5.3%	–
Diptera Total	–	**124**	–	**26.1%**
Ephemeroptera	Ameletidae	5	1.1%	–
	Baetidae	16	3.4%	–
	Heptageniidae	7	1.5%	–
	Leptophlebiidae	2	0.4%	–
Ephemeroptera Total	–	**30**	–	**6.3%**
Megaloptera	Corydalidae	16	3.4%	–
Megaloptera Total	–	**16**	–	**3.4%**
Plecoptera	Chloroperlidae	28	5.9%	–
	Leuctridae	67	14.1%	–
	Nemouridae	29	6.1%	–
	Perlidae	3	0.6%	–
	Perlodidae	10	2.1%	–
Plecoptera Total	–	**109**	–	**22.9%**
Trichoptera	Goeridae	2	0.4%	–
	Hydropsychidae	89	18.7%	–
	Lepidostomatidae	1	0.2%	–
	Philopotamidae	15	3.2%	–
	Rhyacophilidae	4	0.8%	–
Trichoptera Total	–	**111**	–	**23.3%**
Total CW Taxa Observations	–	**476**	–	–

Table 30. Distribution of observations of EPT taxa among macroinvertebrate Orders and Families.

Order	Family	Total EPT Taxa Observations	Family Percent of EPT Taxa Obs.	Order Percent of EPT Taxa Obs.
Ephemeroptera	Ameletidae	5	0.5%	–
	Baetidae	159	16.2%	–
	Caenidae	19	1.9%	–
	Ephemerellidae	24	2.4%	–
	Ephemeridae	4	0.4%	–
	Heptageniidae	72	7.3%	–
	Leptophlebiidae	29	2.9%	–
	Siphlonuridae	3	0.3%	–
Ephemeroptera Total	**–**	**315**	**–**	**32.0%**
Plecoptera	Chloroperlidae	52	5.3%	–
	Leuctridae	67	6.8%	–
	Nemouridae	31	3.2%	–
	Perlidae	38	3.9%	–
	Perlodidae	21	2.1%	–
Plecoptera Total	**–**	**209**	**–**	**21.2%**
Trichoptera	Goeridae	2	0.2%	–
	Hydropsychidae	262	26.6%	–
	Hydroptilidae	10	1.0%	–
	Lepidostomatidae	1	0.1%	–
	Leptoceridae	1	0.1%	–
	Limnephilidae	12	1.2%	–
	Philopotamidae	70	7.1%	–
	Phyrganeidae	2	0.2%	–
	Polycentropodidae	59	6.0%	–
	Rhyacophilidae	4	0.4%	–
	Thremmatidae	37	3.8%	–
Trichoptera Total	**–**	**460**	**–**	**46.7%**
Total EPT Taxa Observations	**–**	**984**	**–**	**–**

Table 31. Distribution of observations of pollution sensitive taxa among macroinvertebrate Orders/Sub-Orders and Families.

Order/Suborder	Family	Total Sensitive Taxa Observations	Family Percent of Sensitive Taxa Obs.	Order/Suborder Percent of Sensitive Taxa Obs.
Anisoptera	Aeshnidae	57	7.4%	–
	Gomphidae	12	1.6%	–
Anisoptera Total	–	**69**	–	**9.0%**
Coleoptera	Elmidae	8	1.0%	–
	Psephenidae	56	7.3%	–
Coleoptera Total	–	64	–	**8.3%**
Diptera	Chironomidae	64	8.3%	–
	Tipulidae	68	8.8%	–
Diptera Total	–	**132**	–	**17.1%**
Ephemeroptera	Ameletidae	5	0.6%	–
	Baetidae	46	6.0%	–
	Ephemerellidae	19	2.5%	–
	Ephemeridae	4	0.5%	–
	Heptageniidae	23	3.0%	–
	Leptophlebiidae	5	0.6%	–
Ephemeroptera Total	–	**102**	–	**13.2%**
Megaloptera	Corydalidae	16	–	–
Megaloptera Total	–	**16**	–	**2.2%**
Plecoptera	Chloroperlidae	52	6.8%	–
	Leuctridae	67	8.7%	–
	Nemouridae	31	4.0%	–
	Perlidae	24	3.1%	–
	Perlodidae	21	2.7%	–
Plecoptera Total	–	**195**	–	**25.3%**

Table 31 (continued). Distribution of observations of pollution sensitive taxa among macroinvertebrate Orders/Sub-Orders and Families.

Order/Suborder	Family	Total Sensitive Taxa Observations	Family Percent of Sensitive Taxa Obs.	Order/Suborder Percent of Sensitive Taxa Obs.
Trichoptera	Goeridae	2	0.3%	–
	Hydropsychidae	31	4.0%	–
	Lepidostomatidae	1	0.1%	–
	Limnephilidae	9	1.2%	–
	Philopotamidae	64	8.3%	–
	Polycentropodidae	46	6.0%	–
	Rhyacophilidae	2	0.3%	–
	Thremmatidae	37	4.8%	–
Trichoptera Total	–	**192**	–	**24.9%**
Total Sensitive Taxa Observations	–	**770**	–	–

Comparisons of the total macroinvertebrate taxa for the CUVA Headwater Inventory sites are depicted by HUC12 Watershed in Figure 40 and between site categories and final PHW class in Figure 41. The patterns for sample diversity with respect to the total number of taxa closely resemble those observed for HMFEI scores (Figure 38). The lowest diversity was found in HUC 0404 (median = 12 taxa) and the highest median number of taxa (28) was found in HUC 0503. The highest diversity of organisms, represented by the total number of taxa, was found in the Class IIIB sites (maximum: 57). Similarly, Class IIIB sites had the highest number of Cold-Water taxa (maximum:12), EPT taxa (maximum: 27), and sensitive taxa (maximum: 27). Class I streams, conversely, had the lowest percentages of these attributes: total taxa (maximum: 12), Cold-Water taxa (maximum: 1), EPT taxa (0), and sensitive taxa (maximum: 1). Findings for the Class II and Class IIIA sites, by definition, fell in between Class I and Class IIIB. These findings correlate with the PHW classification scheme (Ohio EPA 2020) based on the native fauna collected within streams, especially focusing on EPT taxa, sensitive taxa, and cold-water macroinvertebrate taxa.

Summary data for the macroinvertebrate communities found at the individual sites within the project area are provided in Appendix E. These summarized data include the results for the L3 analysis of collected macroinvertebrates of the number of total taxa, cold-water taxa, EPT taxa, and sensitive taxa of macroinvertebrates present and Level 3 PHW classifications for each discrete macroinvertebrate sample.

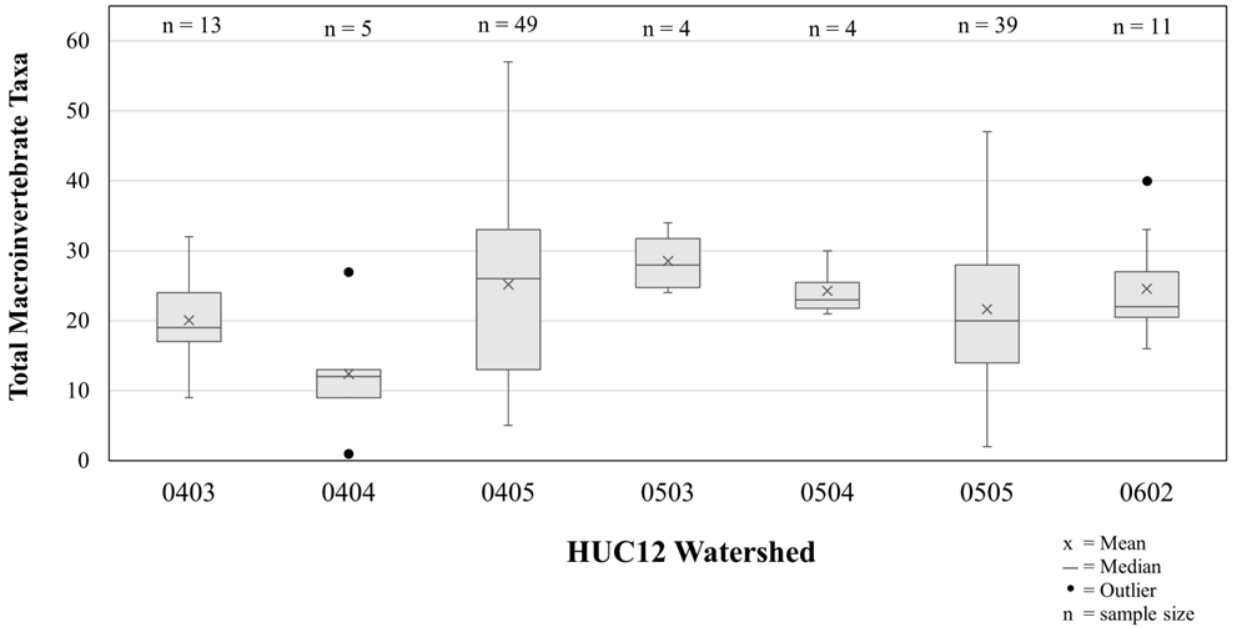


Figure 40. Comparison of the total macroinvertebrate taxa results for sites among HUC12 watersheds.

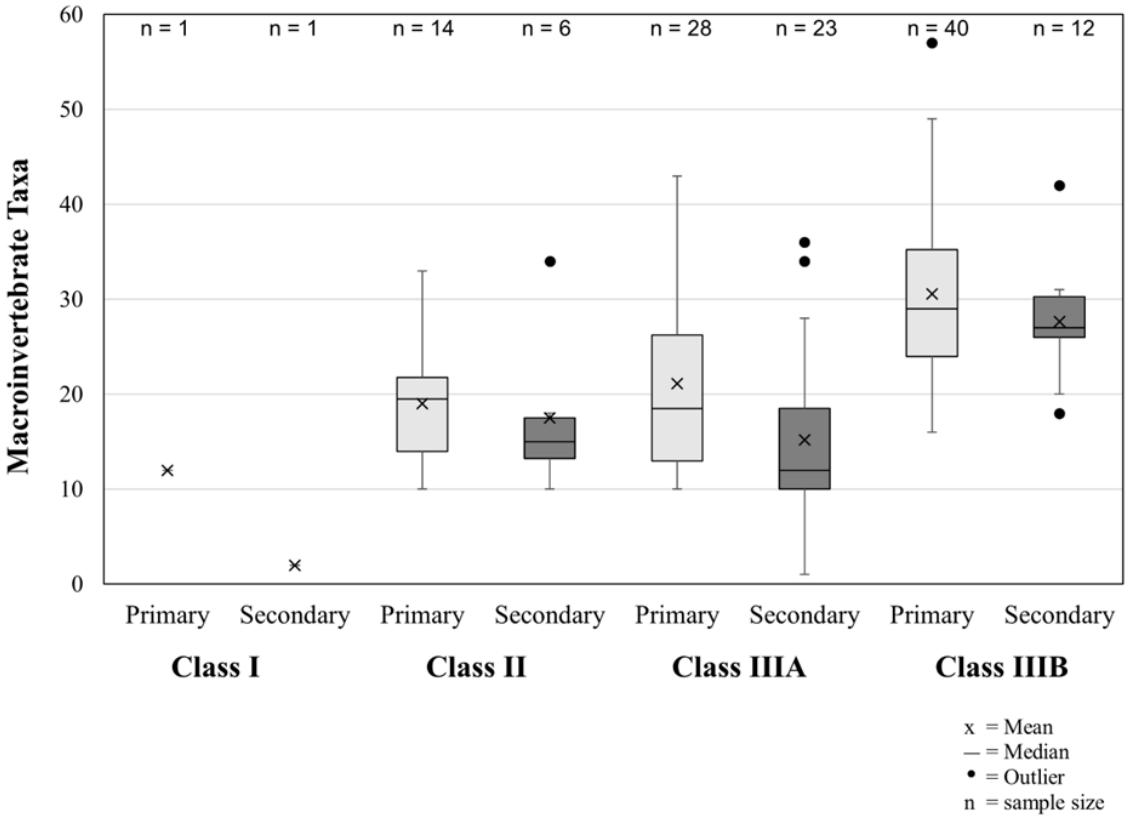


Figure 41. Comparison of the total macroinvertebrate taxa results for sites grouped by site category and PHW class.

Application of Headwater Macroinvertebrate Index to CUVA Headwater Stream Inventory Sites

Headwater stream inventory sites were also scored using the Ohio EPA HWMI using the Level 3 PHW assessment data from the qualitative macroinvertebrate samples. The scoring procedure and use of the HWMI is described in detail in the Methods section of this report. Summary results are depicted in Figure 42 for all inventoried sites by final Level 3 PHW classifications. The boundaries for assignment of narrative rankings for the macroinvertebrate communities based upon HWMI scores are overlaid in the figure. Narrative rankings of Exceptional are assigned to samples meeting the EWH biocriterion for macroinvertebrates, while rankings of Very Good and Good are considered in attainment of the WWH ALU. Values in the Marginally Good range are considered to be within the margin of error for the protocol and are also deemed to be in attainment of the WWH ALU. Rankings of Fair, Poor and Very Poor are considered in non-attainment of the WWH ALU biocriterion. Note that the final Level 3 PHW classifications for the CUVA headwater stream inventory sites encompass all organism groups, including amphibians, fish, and macroinvertebrates (Figure 12). Therefore, assignment of PHW classes to sites subjected to a full Level 3 assessment for macroinvertebrates and vertebrates may not always agree with characterizations using only the macroinvertebrate community composition results.

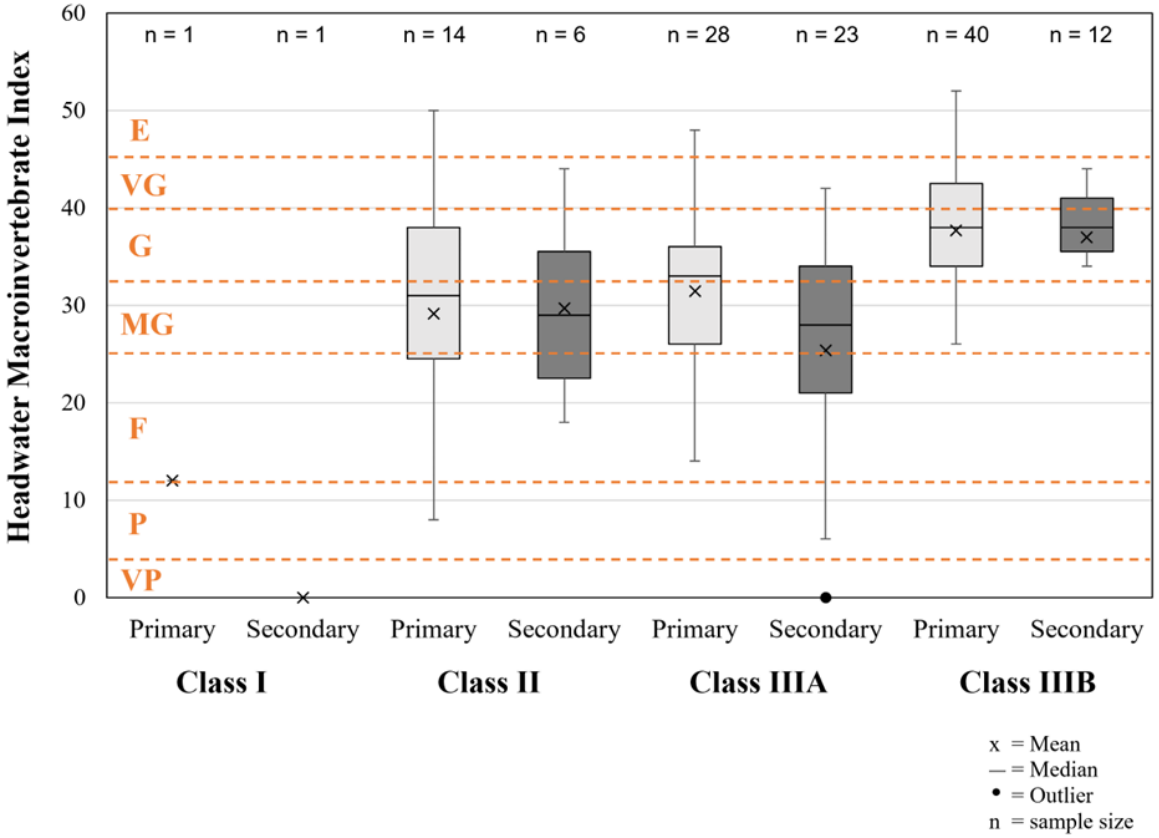


Figure 42. Comparison of Ohio EPA HWMI scores and narrative rankings to final Level 3 PHW classification results. The boundaries for assignment of narrative rankings for the macroinvertebrate communities based upon HWMI scores are overlaid in the figure.

Two older methods developed by Ohio EPA are also used to assign narrative rankings ranging from Exceptional to Very Poor for macroinvertebrate data sets collected using qualitative sampling techniques and laboratory identification of voucher samples to the lowest practicable level. Guidance is provided in Part E.2 of Volume III of the *Biological Criteria for the Protection of Aquatic Life* (Ohio EPA, 2015) for the assignment of narrative scores for qualitative samples relative to the WWH and EWH aquatic life uses based upon the number of EPT taxa collected and separately for the number of Sensitive taxa present in the sample. Both relationships vary by drainage area, with 1.0 mi^2 being the lower limit for the relationship between number of taxa and narrative rank.

Comparisons were made applying each of the three methods (HWMI, EPT taxa by drainage area, and sensitive taxa by drainage area) used by Ohio EPA to assign narrative rankings for qualitative macroinvertebrate samples against results for the sites based upon the Level 3 PHW classifications for the CUVA headwater stream inventory macroinvertebrate data set. The results are summarized in Figure 43. The comparisons revealed marked differences between results for the three methods with respect to distribution of the narrative assignments both within the narrative ranks and between stream classifications using the PHW protocols. Therefore, assignments of narrative scores for the CUVA data sets for purposes of this inventory were assigned using a weight of evidence approach between the Ohio EPA methods. The resulting data distribution for this method of assignment is depicted in Figure 43D. This approach appears to be sufficiently robust and to create an accurate picture of the relative quality of the macroinvertebrate communities among the sites and conforms well to the classifications assigned using the PHW classification protocols (Ohio EPA, 2020). Use of this approach is the basis for the recommendations for assignment of higher ALUs for the sites listed in Table 13 above.

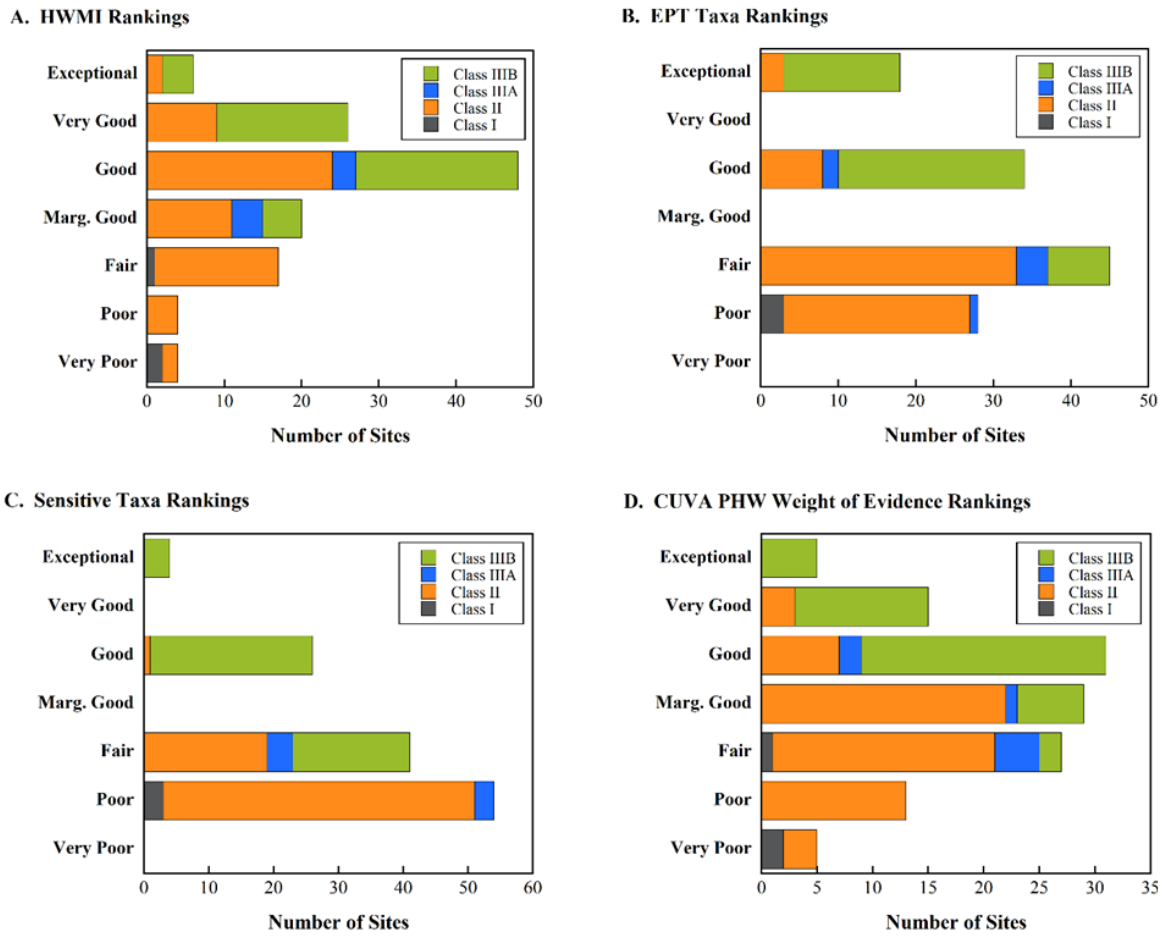


Figure 43 Comparison of Ohio EPA WWH narrative macroinvertebrate community rankings to weight of evidence ranking assignments for CUVA headwater stream inventory sites.

Vertebrates

Assessments to determine the presence and species composition of vertebrates were conducted at each headwater stream inventory site. All vertebrates collected during the inventory were captured and documented in accordance with the approved PSP and IACUC animal research protocol approval for the project. Except for animals suffering mortality during capture and handling, captured vertebrates were handled, identified, photographed, and released live back to the stream habitat in accordance with the PSP. Animals suffering mortality were buried in areas adjacent to the stream in accordance with the PSP. No voucher vertebrate specimens were collected during the inventory, and it was not necessary to use the approved methods for euthanasia for any animals collected during the study.

All vertebrate collection and enumeration data was entered into ArcGIS Survey 1-2-3® application for data entry tailored to the study. Digital voucher photographs were taken in the field to document vertebrate species captured at the 123 sites where target vertebrate species were observed. A total of 325 photographs were collected for fish species and 391 photos were taken of amphibian species. All photographs have been catalogued following NPS guidelines. Digital photographs and accompanying electronic files have been submitted to NPS as part of the project electronic data submission.

Quantitative 10m zones for census of amphibian taxa were assessed at 120 of the 125 CUVA Headwater Inventory sites (Level 3 PHW sampling method). Level 2 qualitative amphibian assessments were conducted at the remaining five sites. The average time spent evaluating each quantitative sampling zone and stream margins for amphibians was 40.75 minutes and ranged from 10 to 95 minutes. Average collection time for sites assessed using qualitative methods was 41 minutes. Amphibians were observed at 111 of the headwater stream inventory sites, and there were no amphibians encountered at the remaining fourteen sites.

Locations where no amphibians were encountered had larger drainage areas than fishless sites. The median drainage area for sites where no amphibians were present was 0.42 mi^2 and only one of these sites had a drainage area less than 0.20 mi^2. Five of the amphibian-free sites were Class IIIB streams, with two classifications resulting from the presence of cold-water indicator fish species and three because of the macroinvertebrate community composition. Eight of the sites were classified as Class II PHW: four based upon both fish and macroinvertebrate community composition and four based solely upon the macroinvertebrate community present. One stream was classified as Class I PHW because of ephemeral conditions and the lack of vertebrates and poor taxa diversity within the macroinvertebrate community.

Fish were collected using backpack electrofishing techniques at 113 inventory sites using the protocols described in in the PSP. At two locations, use of a dip net was deemed sufficient for completion of the fish community assessment because of the limited extent of potential habitat (isolated pools), and at ten locations visual observation of the assessment zone was sufficient to determine that no fish were present. For electrofished sites, the average sampling distance was 196 feet (59.7 meters) of stream channel, the average collection time was 22 minutes, and the average time when active electrical current was discharged was 454 seconds.

There were no fish observed at 27 headwater stream inventory sites (21% of all sites). Fishless sites were equally divided between Primary and Secondary sites (13 and 14 sites, respectively). Commonalities with respect to the identified causes for the lack of fish at these sites included habitat limitations (21 sites), flow conditions (10 sites), substrate embeddedness (3 sites), and barriers to fish passage (7 sites). Multiple causes were identified at 15 sites. The field notes and site data do not identify the cause for the lack of fish at two sites (CUVA-X64 and CUVA-X70), although at Site CUVA-70 it is speculated that a downstream barrier to fish migration may be the issue.

The sources identified as possible causes of fish absence include the following:

- identified habitat limitations included high stream channel gradient (4 sites), dominance of exposed bedrock substrates (4 sites), isolated pools (7 sites) and poor pool depths (14 sites);
- silt and fine-grained substrate aggradation within the stream channel were identified as a source for fish absence at 6 sites;
- low flow conditions observed that contributed to the absence of fish included interstitial flow (6 sites) and intermittent flow (3 sites); and

- fish passage barriers included waterfalls (4 sites), culverts (1 site), high stream channel gradient (4 sites), an historical downstream dam (1 site), log jams and step pools (1 site), and "unknown" barriers (1 site).

The causes and sources associated with fishless sites by the fisheries scientist conducting the assessments for the sites in question are documented within the electronic data package submitted to NPS for the project.

Upstream drainage areas for the fishless sites in the inventory were smaller than those for the overall site list, ranging from 0.10 to 0.96 mi^2 with a median drainage area of 0.20 mi^2. The median drainage area for all inventory sites was 0.40 mi^2, twice that of fishless sites, and was 0.44 mi^2 for all sites where fish presence was documented.

Maximum pool depths were also found to be significantly higher at sites supporting fish than sites without fish (Figure 44). The average maximum pool depth for the 98 sites supporting fish was 38.8 ± 3.9 cm, while the average for the 27 fishless sites was 24.4 ± 3.9 cm. Analysis using a one-way t-test assuming unequal variances found the averages to be significantly different from each other ($p<0.0001$). Only 13 sites supporting fish (13.3%) had maximum pool depths below the median value for streams without fish (22 cm). Therefore, this threshold was used to determine where insufficient pool depths were a contributing factor resulting in the lack of fish in the CUVA inventory streams.

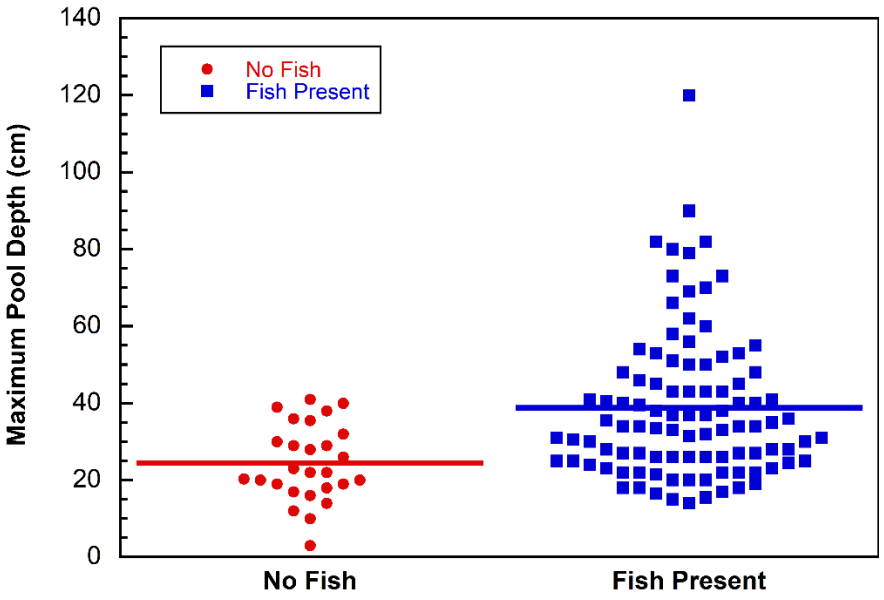


Figure 44. Comparison of maximum pool depths observed at inventory sites with no fish to those measured at sites where fish were encountered. The horizontal lines indicate the median values for the data sets.

Seven of the fishless sites were Class IIIB streams. These classifications all resulted from the diversity of the macroinvertebrate communities present at these locations. Fifteen of the fishless sites

were classified as Class IIIA PHW. Fourteen of these classifications were based upon detection of multiple age classes of the Northern Two-lined Salamander (*E. bislineata*), demonstrating that sustaining reproducing populations of this species are supported by these streams. One of these sites (Site CUVA-X63) supported both a population of *E. bislineata* and a macroinvertebrate community meeting Class IIIA species composition. An additional site (Site CUVA-X50) met the classification criteria for Class IIIA based solely upon the macroinvertebrate community present. Four fishless streams were classified as Class II PHW based solely upon the macroinvertebrate community present (Sites CUVA-19, CUVA-30, CUVA-115, and CUVA-129), and one stream (site CUVA-X26) was classified as Class I PHW because of ephemeral conditions, the lack of vertebrates, and poor taxa diversity within the macroinvertebrate community.

Three of the sites included in the discussion above had neither fish nor amphibians present: sites CUVA-93B, CUVA-115, and CUVA-129. Site CUVA-93B had the smallest drainage area of the sites with no vertebrates (0.10 mi^2) and therefore meets the definition of a rheocrene as defined in the Ohio EPA PHW manual (Ohio EPA, 2020). This site was classified as Class IIIB based solely upon the macroinvertebrate community present which included six cold water indicator taxa, as well as thirteen EPT and nine sensitive taxa. The water temperature of the stream was low (14.2 °C) indicating groundwater contributions to the flow regime for this stream. As discussed by Ohio EPA within the PHW assessment manual, substrates in rheocrene streams are often dominated by fine-grained substrates. Gravel and sand were identified as the two major substrate types for site CUVA-93A and was noted as "aggrading" by the fish biologist. Analysis of current aerial photos of the watershed as well as observations downstream reveal that a significant portion of the length of this direct tributary to the Cuyahoga River is confined to a culvert, effectively prohibiting fish migration upstream.

The results showing the presence or absence of indicator vertebrate communities in this study are consistent with the conceptual basis for the PHW stream classification system (Ohio EPA, 2020). The classification system was devised predicated on the river continuum concept of changes in vertebrate biological communities in headwater stream systems as habitat availability and flow conditions become limiting to the support of fish species. Observations at multiple sites throughout CUVA support the concept that watershed size, groundwater connectivity and flow regime, habitat characteristics, and barriers to upstream migration of fish all contribute to the resulting biological communities that utilize specific stream habitats.

Amphibian Assemblage Results

Salamanders were observed at 107 (85.6%) of the inventoried sites. A total of four salamander and five frog species were encountered throughout the survey. Table 32 lists the amphibian taxa observed and their frequency of encounter with respect to the number and percentage of inventoried sites. Frogs were the only amphibians observed at four sites (3.2% of the total sites), and no amphibians were encountered at 14 sites (11.2%).

The Ohio EPA PHW classification protocol requires evidence of the presence of reproducing populations of indicator salamander species for the assignment of stream classes. It is assumed that the presence of such populations demonstrates continuous habitation of the stream in question.

Reproducing populations are defined by the presence of two or more age classes, (eggs, larvae, juveniles, and/or adults) to make this determination. Salamander species with life histories having multi-year dependency upon flowing water conditions for egg clutch deposition and larval development are assumed to be indicative of perennial flow conditions (Class III PHW). In Ohio, there are eight species from the Family Plethodontidae that fall into this category (Ohio EPA, 2020; Davic, et. al, 2020). Species with life histories having stream-dependent development stages lasting less than twelve months are indicators of intermittent flow conditions (Class II PHW) and consist of three species from the Family Plethodontidae and four taxa from the Family Ambystomatidae. Frog taxa composition is not presently used to classify PHW streams.

Table 32. Amphibian Species Encountered During the CUVA Headwater Stream Inventory

Species	Common Name	Number of Sites	Percent of Sites	PHW Class Indicator
Desmognathus ochrophaeus	Allegheny Mountain Dusky Salamander	16	12.8%	Class II
Desmognathus fuscus	Northern Dusky Salamander	70	56.0%	Class II
Eurycea bislineata	Northern Two-lined Salamander	104	83.2%	Class IIIA
Plethodon cinereus	Red-backed Salamander	9	7.2%	N/A
Lithobates clamitans	Green Frog	2	1.6%	N/A
Lithobates palustris	Pickerel Frog	7	(5.6%)	N/A
Lithobates sylvaticus	Wood Frog	1	(0.8%)	N/A
Lithobates pipiens	Northern Leopard Frog	1	(0.8%)	N/A

Among the salamander species observed during the CUVA Headwater Stream Inventory, the Northern Two-lined Salamander (*Eurycea bislineata*), the Allegheny Mountain Dusky Salamander (*Desmognathus ochrophaeus*), and the Northern Dusky Salamander (*Desmognathus fuscus*) were the only PHW indicator taxa that are used for PHW stream classification. The presence of a reproducing population of *E. bislineata*, defined as the presence of two or more age classes (i.e., eggs, larval year classes differentiated by size, juveniles, and adults) is a Class IIIA indicator species while a similar assemblage of *Desmognathus spp.* is an indicator of a Class II PHW stream. Therefore, the remainder of the discussion regarding amphibians in this report focuses exclusively upon these species.

It should be noted, however, that two other Class III indicator species of salamander are known to inhabit streams within CUVA. Both the Long-tailed Salamander (*Eurycea longicauda*), a Class IIIA indicator, and the Northern Red Salamander (*Pseudotriton ruber ruber*), a Class IIIB indicator species, are known to inhabit springs and ravines within the jurisdictional boundaries of CUVA (Pfingsten, et. al, 2020; Cleveland Metroparks data). These species were not observed at any of the inventory sites sampled for the present study. In addition, the Four-toed Salamander (*Hemidactylium scutatum*), a potential Class II PHW indicator species, has also been historically reported from Summit County (Pfinsgten, et. al, 2020), but was not encountered during the CUVA inventory.

Although reproduction in streams is possible for *H. scutatum*, the habitat preferences for this species do not coincide well with the types of habitats sampled for the present study.

The Class IIIA PHW indicator species *E. bislineata*, was found at 104 (83.2%) of the 125 CUVA Headwater Inventory sites. Reproducing populations were documented at 84 sites (78.9% of the sites with *E. bislineata* present; 65.6% of the total sites), indicating the presence of perennial stream flow at these locations. The Ohio EPA PHW protocols consider *E. bislineata* to be a facultative cool-cold water indicator species that can also tolerate warmer thermal regimes. Therefore, the presence of reproducing populations in the absence of cold water adapted salamander taxa supports evidence of the Class IIIA PHW stream type. The maximum number of life stages observed was four at a total of 18 sites (Figure 45). Overall densities (Individuals per $100m^2$) of *E. bislineata* ranged from 0.4 to 587.6 Individuals per $100m^2$ (Figure 46). Streams in PHW Classes I and II had an average relative density of only 3.2 and 6.4 Individuals per $100m^2$ respectively. Class IIIA sites (n=49) exhibited the highest average density of 48.3 Individuals per $100m^2$ closely followed by Class IIIB sites (n=44) with 40.3 Individuals per $100m^2$.

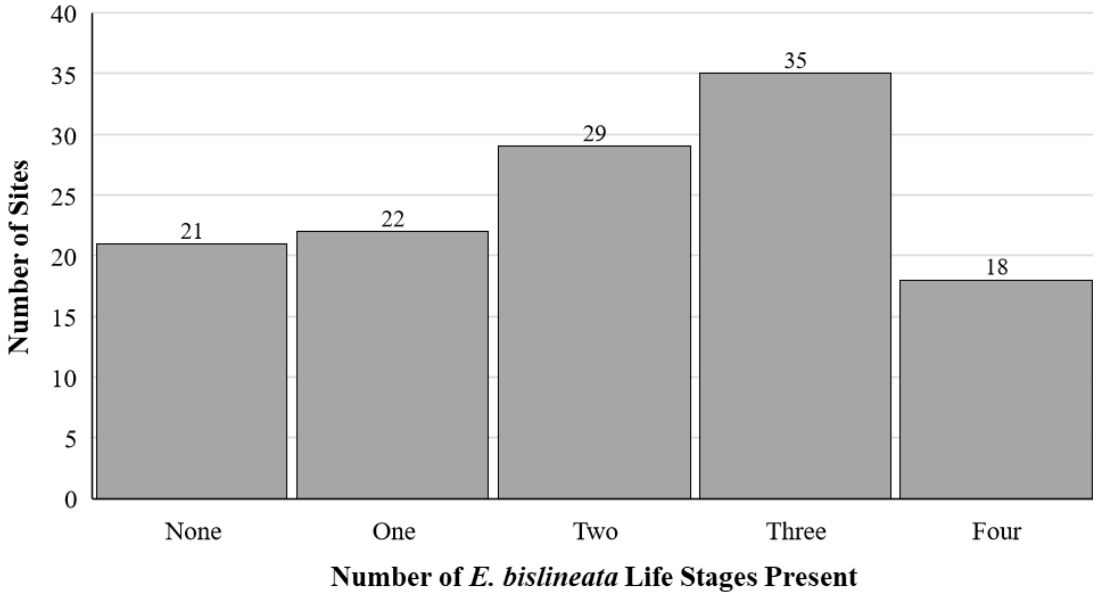


Figure 45. Frequencies for the presence of *Eurycea bislineata* life stages among the CUVA inventory sites.

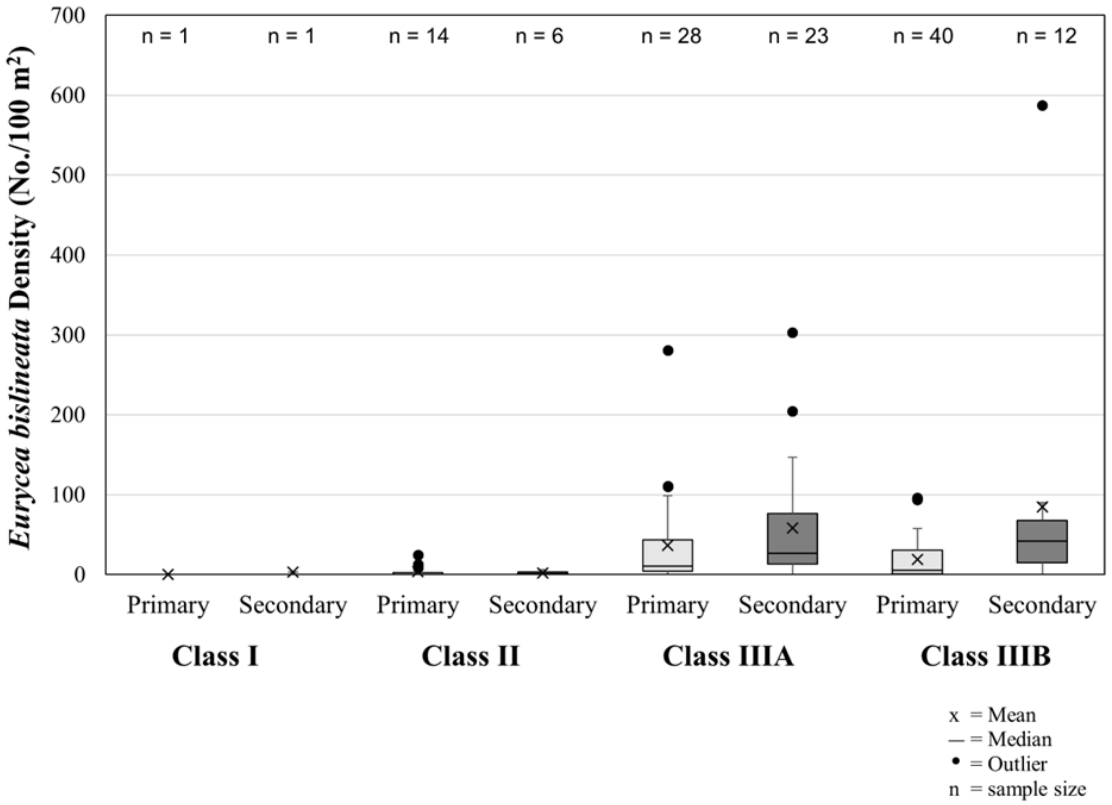


Figure 46. Comparison of *Eurycea bislineata* Densities (No./100 m^2) for Primary and Secondary sites parsed by PHW stream class.

The Class II PHW indicator species *D. ochrophaeus*, was only found at three sites (2.4% of total sites), with densities ranging from 0.5 to 31.25 Individuals per 100m^2. Two of the locations where this species was encountered (Sites 52-B and 52-C) lie within the Brandywine Creek watershed (HUC 0404) and the Stanford Run-Hines Hill HVE management zone, and the third (Site CUVA 17) lies in HUC 0602 within the Northern NZ management area. Multi-year age classes were observed only at Site 52-C for this species. At one location, the presence of both *D. ochrophaeus* and *D. fuscus* were documented, and *D. ochrophaeus* cohabited with populations of *E. bislineata* at all three locations where they were found. Four or more life stages of *E. bislineata* were present at each of these sites. The northern part of CUVA is located at the southwestern fringe of the known range of *D. ochrophaeus* in Ohio and intermingling of populations of this species as well as hybridization with *D. fuscus* has been documented historically (Pfingsten, et. al, 2020).

The Northern Dusky Salamander, *D. fuscus*, had a more extensive range and was encountered more frequently within CUVA than *D. ochrophaeus*, being identified at 25 sites (20% of the total sites). *D. fuscus* was the sole salamander species present at only 2 locations and was co-located with *E. bislineata* at the remaining 23 sites. Multi-year age classes of *D. fuscus* were found at 5 locations, with one site having three age classes present and the remainder having two life stages present. The presence of *Desmognathus* spp. in the census of inventoried locations for this study was indeterminate in the assignment of final PHW classifications because other organisms present at the sites were definitive in the assignment of the overall stream classes.

Qualitative analysis of the data regarding the presence of reproducing populations and the densities of *E. bislineata* as compared with numerous biotic and abiotic variables found that only channel substrates as measured to conduct HHEI scoring and to assess the Rosgen stream channel classification appeared to produce results of interest for further investigation. Other abiotic factors including water chemistry, temperature, stream bank condition (BEHI, NBS, and erosion rates), and stream channel dimensions and gradient did not produce noticeable differences in the presence or abundance of this species.

Abundances of *E. bislineata* were highest (median=25 Individuals per $100m^2$, n=57) at sites where the predominant channel material consisted of cobble substrates (Figure 47). Note that in Figure 47 values of zero (no *E. bislineata* observed) are omitted to enhance clarity of comparisons between the different groups. Abundances of *E. bislineata* exceeded 100 Individuals per $100m^2$ at six cobble dominated sites and was found to be absent at only three sites where cobble predominated (6 percent of the cobble sites). Sites where bedrock dominated the channel substrates exhibited lower abundances of *E. bislineata* (median=13 Individuals per $100m^2$, n=15), and *E. bislineata* were not observed at two of the bedrock dominated sites. Median densities for *E. bislineata* were lower at gravel dominated sites (median=8 Individuals per $100m^2$). Frequencies of sites where no *E. bislineata* were observed were also higher at gravel dominated sites, with no individuals encountered at 27 percent of these locations (13 of 48 sites). Sites dominated by boulder, sand, and silt/clay substrates were rare in the inventory data set (n=2, 1, and 2 sites, respectively). The abundances of *E. bislineata* were 18.2 and 3.2 Individuals per $100m^2$ at the boulder dominated sites and no *E. bislineata* were encountered at either the sand or silt/clay dominated sites.

A statistical comparison of *E. bislineata* densities between sites with bedrock, cobble, and gravel as the dominant channel materials was conducted using the Kruskal-Wallis rank sum test. The results of this test indicate a significant difference between the data sets (p=0.0124). Pairwise comparisons for the three data sets using the Wilcoxon-Mann-Whitney rank sum test found no significant differences in abundances of *E. bislineata* between the data sets for bedrock vs. gravel dominated or for bedrock vs. cobble dominated channels (p=0.2898 and 0.3704, respectively). However, the test between cobble and gravel dominated channels revealed that *E. bislineata* abundances are significantly higher (p=0.0031) at cobble dominated sites. The lower abundances of *E. bislineata* at gravel dominated sites (and by qualitative comparison, sand and silt/clay dominated sites) is likely the combination of several factors relating to the life history of *E. bislineata* including habitat for nesting, foraging, and refuge (Davic et. al, 2020; Pfingsten et. al, 2020; Ohio EPA, 2020).

Please note that the statistical comparisons excluded sites where *E. bislineata* were not encountered. However, calculation of the statistics using the full data sets, including sites with zero *E. bislineata* abundance values did not change the results of the tests other than to negligibly alter the probabilities associated with the results.

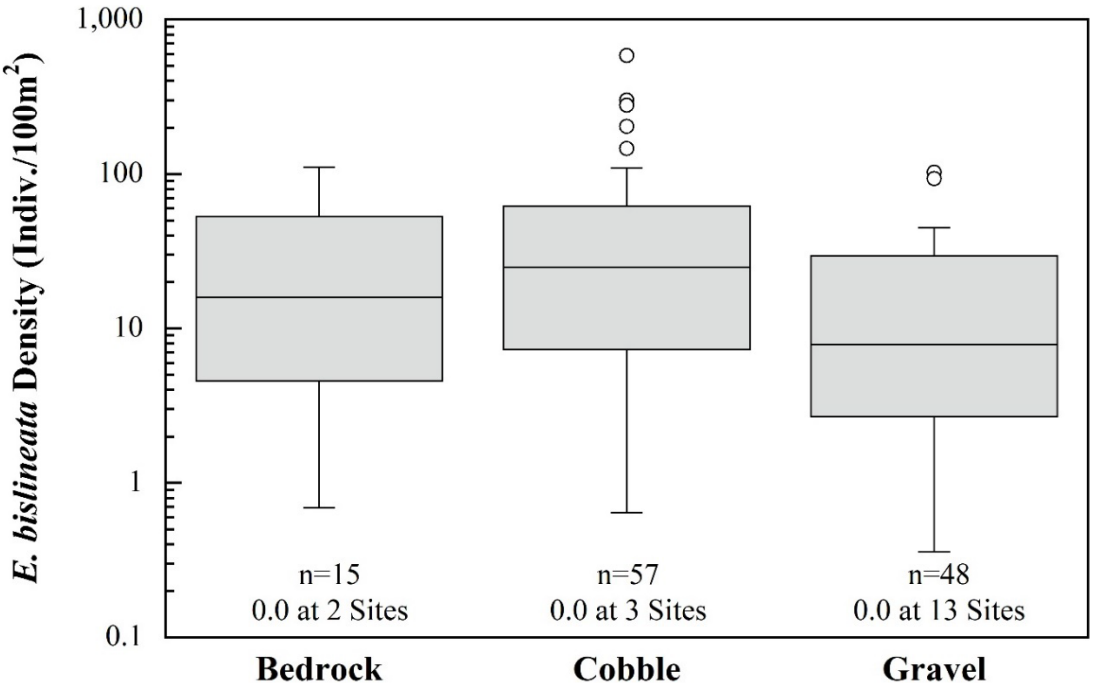


Figure 47. Comparison of the abundances of *Eurycea bislineata* for sites with varying predominant channel materials. Note: sites where *E. bislineata* were absent are excluded for clarity (see text).

Fish Assemblage Results

Visual observations were made at all inventory sites to determine whether fish were present or if sufficient depth of water existed to potentially support fish in the stream. Fish communities were assessed using backpack electrofishing for all sites that exhibited sufficient habitat conditions, fish presence, and flow regimes. A total of 113 sites (90% of the total sites) were sampled using electrofishing. Sites that lacked sufficient water in the channel to successfully sample with the electrofishing equipment, but where fish were either observed or were considered likely to be present were sampled using the macroinvertebrate dip net. Two sites (2% of the total sites) fit this description.

At ten sites (8% of the total), it was determined that no fish were present based upon observation. These sites either lacked suitable habitat, adequate flow conditions, or depth of water to support fish populations. In addition, no fish were encountered during the sampling for macroinvertebrates and amphibians or during the data collection process for other parameters at all these locations, thereby confirming their absence.

Fish were present at a total of 98 sites (78.4% of the total sites). All species captured were positively identified to species in the field by a fisheries biologist. Voucher photographs were taken with sufficient detail to confirm the taxonomic identifications for each species encountered at each inventory site. Therefore, it was not necessary to preserve voucher specimens for any of the fish collected during the inventory. Digital photographic voucher files are cataloged electronically and both the catalog and digital photos have been transferred to NPS according to the project

specifications included in the SOW. A total of 325 fish voucher photos were taken during the inventory.

Fish Species Observed

A total of 6,419 individuals were captured from which 21 total fish species were identified. The fish communities at the CUVA Headwater Inventory sites generally exhibited low diversity with respect to the number of species present (Figure 48). Fish were absent at 27 (21.6%) of the inventory sites and 16 sites (12.8%) were found to support only one fish species. Out of 125 sites only 54 (43.2%) had greater than 2 species present. The average number of fish species observed was 2.6 for all sites and the number of species observed ranged from no fish present to 12 species. Sites where the Class IIIB PHW classification and/or higher ALU fish community criteria were met had the highest diversity with an average of 3.3 species per site. The maximum number of 12 species found during the inventory was documented at two locations.

The relative abundance for the fish species observed throughout the inventory is depicted in Figure 49. *Semotilus atromaculatus* (Creek Chub) and *Rhinichthys atratulus* (Blacknose Dace) were the most abundant fish species observed. These two species co-occurred throughout CUVA, being present together at 79 sites (80.6 percent of the sites with fish) and comprised the entirety of the fish community at 26 sites (28.6 percent of the sites where fish were observed).

Three of the 21 species observed are identified by Ohio EPA as cold-water indicators:

- *Chrosomus erythrogaster* (Southern Redbelly Dace), 10 sites
- *Clinostomus elongatus* (Redside Dace), 8 sites
- *Culaea inconstans* (Brook Stickleback), 2 sites.

Southern Redbelly Dace and Redside Dace co-occurred at 6 locations, and Brook Stickleback co-occurred with Redside Dace at one location. By definition, the Class IIIB PHW classification is applicable for streams supporting cold water indicator fish species. These streams are also candidates for the CWH ALU under Ohio EPA practices if sufficient cold water macroinvertebrate taxa are also present.

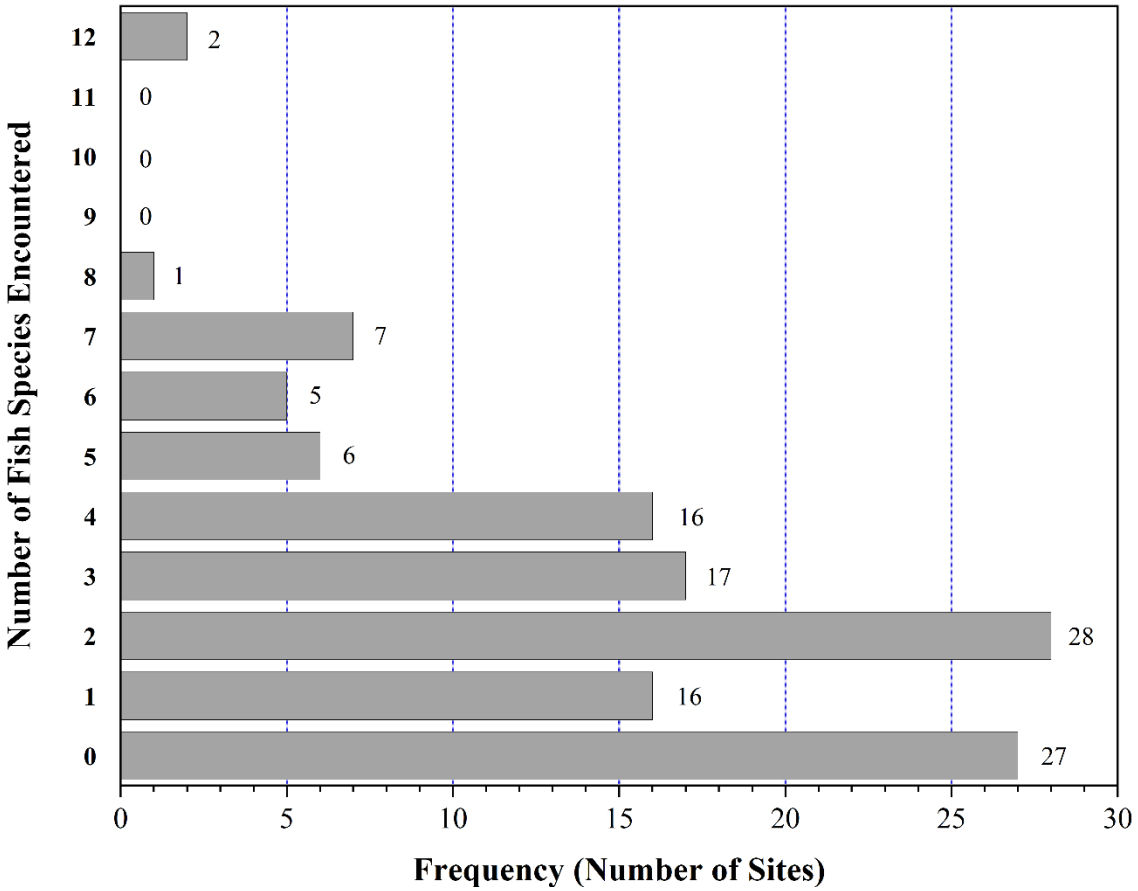


Figure 48. Histogram relating the frequencies of sites with varying numbers of total fish species encountered.

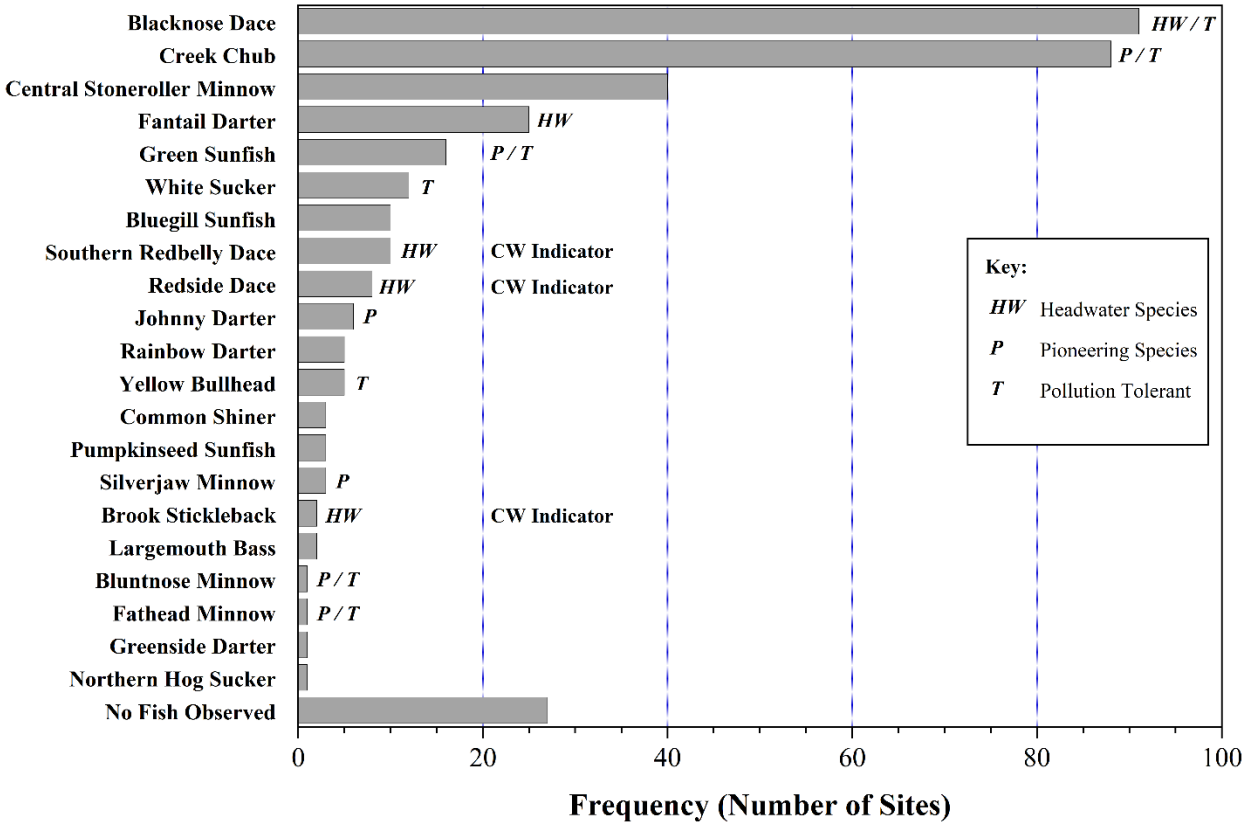


Figure 49. Listing of fish species observed during the inventory assessments and their frequencies of occurrence.

Only 4 species (1.2%) from the assemblage of fish encountered are classified as moderately intolerant or intolerant to pollution ("sensitive species") by Ohio EPA: Northern Hog Sucker (*Hypentelium nigricans*), Redside Dace (*Clinostomus elongatus*), Greenside Darter (*Etheostoma blennioides*) and Rainbow Darter (*Etheostoma caeruleum*). Seven of the fish species collected during the inventory assessments are listed as tolerant to pollution disturbances. These species are indicated in Figure 49. Pollution-tolerant species accounted for 84.19% of fish taxa collected.

The numbers of fish species observed at Primary and Secondary sites are compared by site categories and PHW class in Figure 50. Kruskal-Wallis rank sum analysis (non-parametric equivalent to ANOVA) for Class II, Class IIIA, and Class IIIB pooled results found no significant difference between the stream classes for either number of fish species present or the relative numbers per site ($p=0.149$ and $p=0.170$, respectively). In addition, similar statistical analyses were completed to compare fish relative numbers per site among the HUC 12 watersheds and there was no significant difference at $p=0.079$.

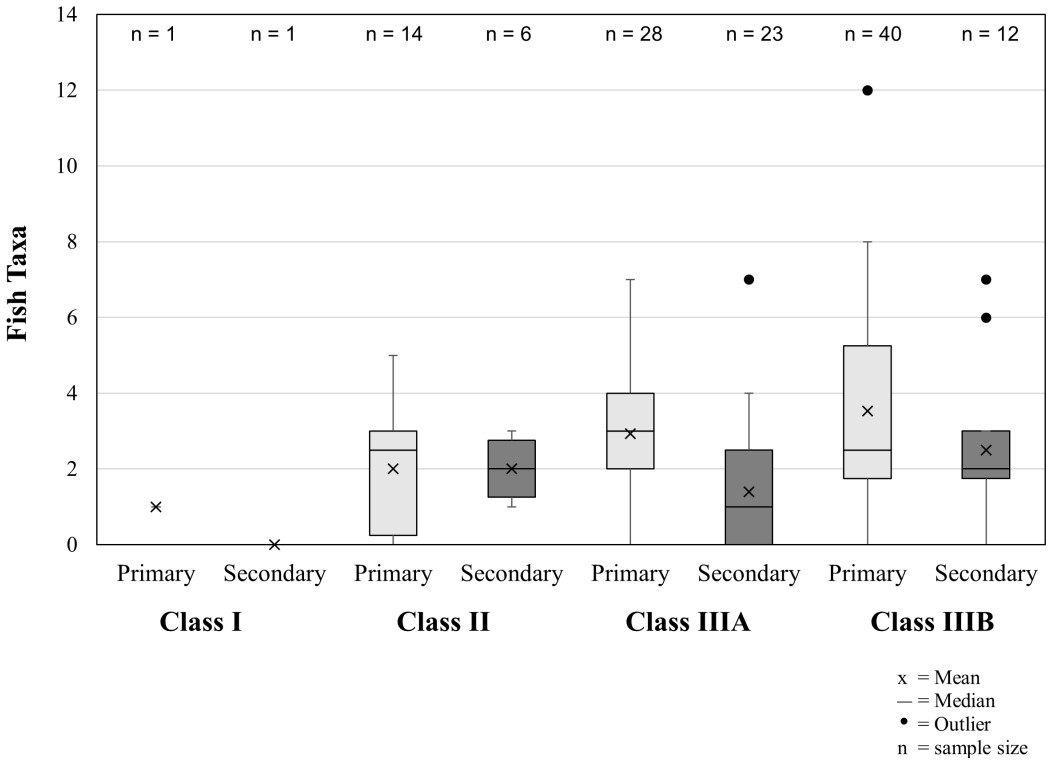


Figure 50. Comparison of the number of fish taxa per site with sites parsed by site category and PHW Class.

Class IIIB and Cold-Water Habitat Fish Communities

Fish community composition analysis to classify PHW streams is based upon the presence or absence of cold-water indicator fish species. The Ohio EPA decision flow chart used to evaluate Level 3 PHW biological assessment results (Figure 12) assigns the Class IIIB II PHW classification to streams where cold-water indicator fish species are found. A total of 13 sites were identified during the inventory that supported populations of cold-water indicator fish species and meet the criteria to be classified as Class IIIB PHW (Table 33).

Table 33. Fish community summary for sites classified as Class IIIB PHW.

HUC12 Watershed	Stream Name	Site Category	Natural Resource Zone	Site Name	CW Fish Species	IBI Score	IBI Narrative	Other ALU (Fish)
041100020405	Boston Run	Primary	A-P North SRZ	CUVA-70	*Clinostomus elongatus*	48	Very Good	CWH (WWH)
041100020505	Unnamed 4	Primary	CMP Brecksville	CUVA-37A	*Clinostomus elongatus, Chrosomus erythrogaster*	50	Exceptional	EWH/CWH
	Unnamed 4	Primary	CMP Brecksville	CUVA-38	*Clinostomus elongatus, Chrosomus erythrogaster*	54	Exceptional	EWH/CWH
	Unnamed 9	Primary	Northern NZ	CUVA-18	*Chrosomus erythrogaster*	34	Fair	CWH
	CMA Creek	Primary	Snowville Woods NZ	CUVA-120	*Clinostomus elongatus, Chrosomus erythrogaster*	56	Exceptional	EWH/CWH
	CMA Creek	Primary	Snowville Woods NZ	CUVA-121	*Clinostomus elongatus, Chrosomus erythrogaster*	52	Exceptional	EWH/CWH
	CMA Creek	Primary	Snowville Woods NZ	CUVA-122	*Clinostomus elongatus, Chrosomus erythrogaster*	44	Good	CWH (WWH)
	CMA Creek	Primary	Snowville Woods NZ	CUVA-39	*Clinostomus elongatus, Culaea inconstans*	56	Exceptional	EWH/CWH
	CMA Creek	Secondary	Snowville Woods NZ	CUVA-X43	*Clinostomus elongatus, Chrosomus erythrogaster*	44	Good	CWH (WWH)
	CMA Creek	Secondary	Snowville Woods NZ	CUVA-X44	*Chrosomus erythrogaster*	30	Fair	CWH
	Unnamed 5	Primary	Snowville Woods NZ	CUVA-123	*Chrosomus erythrogaster*	44	Good	CWH (WWH)
	Unnamed 5	Primary	Snowville Woods NZ	CUVA-46A	*Chrosomus erythrogaster*	36	Marginally Good	CWH (WWH)
041100020602	Unnamed 7	Primary	Northern NZ	CUVA-16	*Culaea inconstans*	30	Fair	CWH

All but two of the 13 sites supporting Class IIIB fish communities are found in HUC 0505. These sites are distributed among the resource management areas as follows:

- Eight Class IIIB fish sites lie within the Snowville Woods NZ resource management area. The watershed called "CMA Creek" by NPS (River Mile 21.70 Tributary to the Cuyahoga River) is found within this management zone and is home to six sites that support Class IIIB fish communities, three of which meet the IBI criteria for the EWH ALU. Five of these sites also support Class IIIB macroinvertebrate communities. Therefore, all five of these sites are listed in Table 13 as candidates for designation as CWH streams in the Ohio WQS.

- One site (CUVA-18) is located within the Northern NZ and is located on the stream named "Unnamed 9" by NPS. This stream supports a population of *Chrosomus erythrogaster* but the number of cold-water indicator macroinvertebrates and sensitive taxa were indicative of Class II PHW biology and no amphibians were observed at this site.

- Two sites (site CUVA-37A and CUVA-38) lie within the Brecksville Reservation (Cleveland Metroparks) and are within the watershed of the River Mile 21.40 Tributary to the Cuyahoga River (NPS stream name of "Unnamed 4"). Both sites support Class IIIB and CWH for both fish and macroinvertebrates and are therefore included in Table 13 as recommended sites for the CWH ALU. The fish IBI scores at both locations also meet the EWH ALU biological criterion. However, the macroinvertebrates at site CUVA-37A were rated as Very Good (within the non-significant departure range for the EWH ALU) while the narrative rank for macroinvertebrates at site CUVA-38 were rated as Good. Therefore, only site CUVA-37A is recommended for the dual CWH/EWH ALU in Table 13 while site CUVA-38 is recommended for the CWH ALU.

The remaining two sites supporting Class IIIB PHW/CWH fish species are sites CUVA-70 located on a tributary to Boston Run in HUC 0405, and site CUVA-16 in HUC 0602. Site CUVA-70 also supported the WWH ALU with a fish community ranking of Very Good based upon IBI score. The macroinvertebrate community was ranked as Fair at this site (Class II PHW community) and did not have enough cold-water indicator taxa to support the Class IIIB or CWH criteria. Site CUVA-16 supports a species of cold-water indicator fish, the Brook Stickleback (*Culaea inconstans*), but the IBI score was within the Fair narrative range (30 points) which does not attain the WWH biocriterion.

The drainage areas for the Class IIIB fish sites ranged from 0.24 to 1.02 mi^2 with a median area of 0.60 mi^2. The watersheds for these sites are heavily forested, with forest cover ranging from 43.1% to 88.2% with a median value of 80.8%. Urbanization and land development are also not prominent in the watersheds for sites with Class IIIB fish communities. The estimated urban land use ranged from 0.7% to 17.5%, but the coverage of impervious surfaces is low, with a median value of 0.8% and a range of 0.01% to 13.5%. The condition of the watersheds with respect to land use likely plays a very important role in the sustainability of the sensitive Class IIIB communities in these streams.

Fish community composition analysis to classify PHW streams is based upon the presence or absence of cold-water indicator fish species. The Ohio EPA decision flow chart used to evaluate Level 3 PHW biological assessment results (Figure 12) assigns the Class II PHW classification to streams where warm water adapted fish species are present. However, the PHW protocols are mute with respect to other factors related to fish including the numbers or types of fish species present and especially IBI scores for the fish community assemblage. In cases where cold-water indicator fish are not present, results for macroinvertebrate and salamander assessments take precedence in assigning PHW classes. This approach is different than that used by Ohio EPA to classify streams for higher ALU assignment and assess attainment of biological WQS under OAC Chapter 3745-1 using the protocols for larger headwater streams. In these situations, the results of fish and macroinvertebrate community results are analyzed in tandem rather than separately, and both must attain the standards for a stream to be considered in attainment of the ALU criteria.

Further complicating this situation is that the presence of cold-water indicator species is not included in the IBI. Therefore, the presence of any cold-water indicator fish species becomes evidence of support of the CWH ALU for fish. However, unless the macroinvertebrate community also supports the CWH ALU, the longstanding Ohio EPA policy is to not assign the use designation to the stream in question. This is also true if the reverse situation occurs (i.e., macroinvertebrates meet CWH, but cold-water indicator fish species are absent). This approach was one of the driving factors for the development of the PHW assessment protocols and classification system (Ohio EPA, 2020).

Index of Biotic Integrity Results

Index of Biotic Integrity scores were calculated for sites where two or more fish species were observed and included 81 out of the 98 sites where fish were observed. Data used in calculating site-specific IBI metric and total IBI scores are included in the electronic data set provided to NPS to fulfill the requirements of the SOW. Initial analysis of this data set found that of the 27 sites where only two species of fish were present, all IBI scores fell within the Fair (8 sites) or Poor (19 sites) narrative ranges. In addition, the species composition for 23 of these sites consisted of Blacknose Dace (*Rhinichthys atratulus*) and Creek Chub (*Semolitus atromaculatus*). Therefore, additional analysis of the IBI results is limited to sites where three or more species were encountered.

As measured by the IBI, community performance and accompanying narratives within the survey for the 54 sites with three or more fish species present ranged from exceptional (IBI=56) to poor (IBI=18), with average conditions characterized as fair (IBI=34.5). Cumulative IBI narrative ranks for streams scored are listed in Table 34. Out of the 54 sites analyzed, 61.1% scored in the Poor and Fair ranges for IBI and did not meet the ecoregional criterion for WWH streams. However, 15 sites (27.8% of the sites) with more than 3 species met the WWH criteria (Marginally Good, Good, and Very Good rankings) for IBI and 9.3% scored within the Exceptional range and met the EWH criterion (IBI scores ≥ 50).

Table 34. Fish Community (IBI) Narrative Rankings Based Upon Ohio Biological Water Quality Criteria for the EOLP Ecoregion

IBI Narrative Rank	Primary Sites	Secondary Sites	Totals
Exceptional	5	0	5
Very Good	1	0	1
Good	6	2	8
Marginally Good	6	1	7
Fair	21	6	27
Poor	5	3	8
PHW (≤ 2 species)*	26	16	42
No Fish	13	14	27
Totals	**83**	**42**	**125**

*Reporting of IBI scores were not deemed appropriate for sites with less than three species of fish.

Results for the IBI for sites with fish communities consisting of three or more species are compared by site category and PHW class in Figure 51. It is interesting to note the positive interrelationship between PHW stream classifications and fish community IBI scores. Streams classified as Class III had higher IBI scores on average, with survey maximum IBIs (IBI=56) and a slightly higher average IBIs (IBI=33.8) overall in Class IIIB communities. Statistical analysis of the data sets for pooled IBI data for the PHW classes using the Kruskal-Wallis rank sum test found that there were significant differences in IBI scores between the groups ($p = 0.00014$). Pairwise comparisons of the data using the Wilcoxon-Mann-Whitney rank sum test detected significant differences for IBI scores between all three PHW classes: Class II vs. Class IIIA, $p = 0.021$; Class II vs. Class IIIB, $p = 0.00028$; and Class IIIA vs. Class III B, $p = 0.0046$. Although this result would appear to be logically obvious based upon the PHW stream classification system, to the knowledge of the authors this comparison has not been made prior to this study.

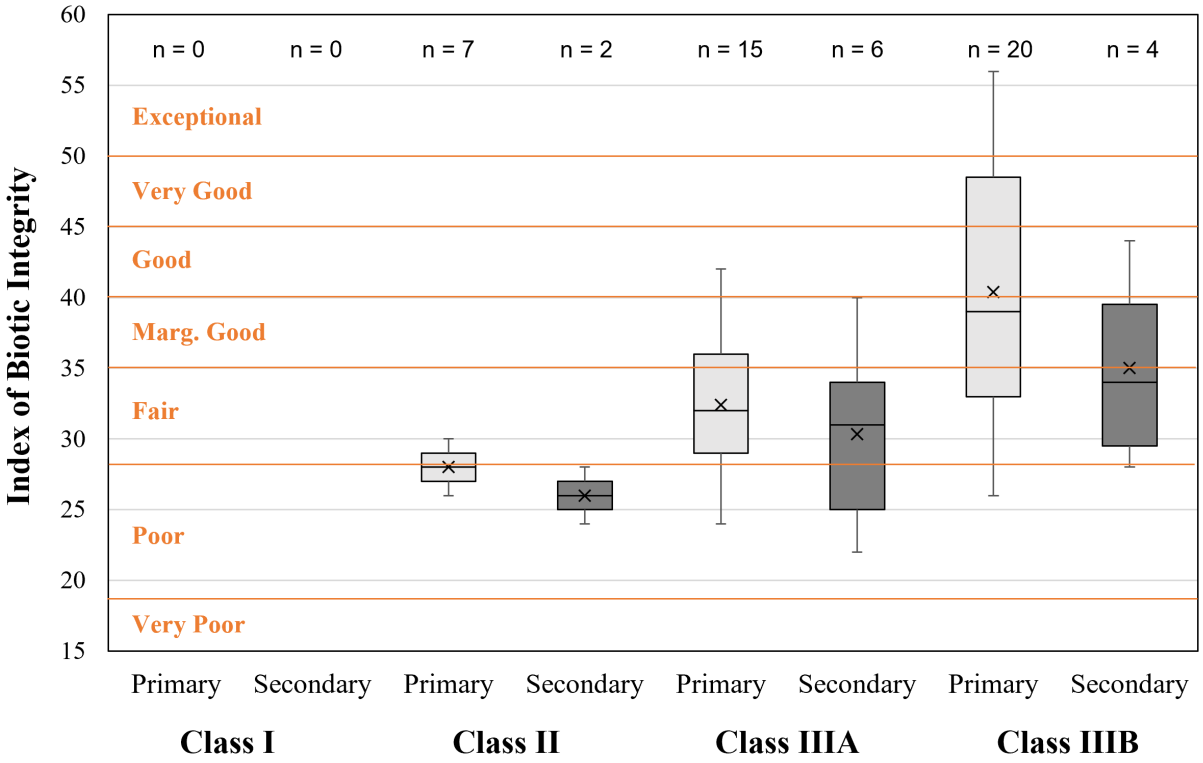


Figure 51. Comparison of IBI Scores for Primary and Secondary sites by stream class for sites with three or more fish species present. Horizontal lines are superimposed at the break points between narrative quality ranking ranges developed by Ohio EPA.

Multivariate Statistical Analysis Results

The factor analysis was performed using variance maximizing factor rotation which resulted in 14 extracted factors explaining 74% of the total variance in the data. Correlation coefficients (factor loadings) were calculated between values of 36 abiotic variables, measured at 125 CUVA stream sites, and the 14 factors. Variables with the highest factor loadings (i.e., correlation coefficients) within each factor were chosen for further analyses. In the case where two or more variables were grouped into one factor, but were not intuitively related to each other, both variables were selected. Also, if the same type of variable was represented by more than one factor, only the variable that had the highest correlation with a factor was retained for further analyses. Variables subsequently used for discriminant function analysis, of groups of sites associated by their PWH class, are shown in bold face in Table 35. Based on the factor loadings, 22 independent variables were selected for inclusion in the DFA as indicated in the table.

Results of the DFA showed significant differentiation among all four groups or PWH classes (Wilk's $\lambda = 0.342$, $F_{42, 285} = 2.96$, $p < 0.0001$). Of the 14 variables included in the forward stepwise model, two variables were significant in differentiating among the classes, Hiram Till Ground Moraine surficial deposit ($F = 6.59$, $p = 0.0004$), and water temperature ($F = 5.06$, $p = 0.003$). All classes were significantly differentiated, with the Mahalanobis distance being greatest between Class I and Class III B, and the lowest between Class II and Class IIIA.

Table 35. Correlation coefficients (factor loadings) between 36 abiotic variables and 14 factors (N = 125).

		Factor													
Factor	**Variable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Factor 1 - Primary and Secondary Substrate	Primary Substrate-Gravel	-0.96	0.02	-0.05	-0.03	0.08	0.02	-0.01	0.12	-0.01	0.12	-0.05	0.01	-0.04	0.01
	Secondary Substrate-Gravel	0.95	-0.05	0.03	-0.03	0.01	-0.07	0.03	-0.08	0.02	0.14	0.00	-0.01	0.04	-0.04
	Secondary Substrate-Cobble	-0.69	0.00	0.03	0.05	-0.10	-0.17	0.03	-0.53	-0.15	0.18	-0.13	-0.08	0.12	-0.10
	Primary Substrate-Sand	0.69	-0.14	-0.11	-0.57	0.03	0.01	-0.06	-0.16	0.03	0.01	-0.07	0.05	-0.04	0.03
Factor 2 - Physical Habitat/Water Chemistry	Percent Imperviousness	-0.09	0.90	0.09	0.01	0.09	-0.07	-0.05	-0.01	0.01	-0.06	-0.12	-0.03	0.02	0.01
	Percent Forest	0.14	-0.82	-0.09	-0.17	-0.05	0.09	0.08	0.06	-0.02	0.08	-0.04	0.00	0.00	-0.09
	Specific Conductance	0.17	0.55	-0.10	-0.02	0.02	0.05	0.34	0.17	-0.08	0.10	-0.39	-0.02	0.07	-0.10
	Slope1085	-0.06	-0.41	-0.32	0.17	0.18	0.03	-0.03	0.07	-0.11	0.27	0.27	-0.14	-0.22	-0.24
	Surficial Deposit-Outwash Lacustrine	0.04	-0.34	0.10	0.26	-0.05	-0.41	-0.22	-0.21	0.31	-0.04	-0.24	0.31	0.10	0.18
	Sinuosity	0.10	-0.32	0.00	-0.26	-0.03	0.01	-0.30	0.17	0.10	0.02	0.16	-0.22	0.21	0.09
Factor 3 - Stream Bank	Bankfull Metric	0.02	0.01	0.89	0.09	0.05	-0.12	-0.02	0.06	0.03	-0.04	0.02	0.07	-0.04	0.01
	Average Bankfull Width	0.01	0.12	0.91	0.07	0.08	-0.01	0.06	-0.01	-0.11	-0.03	-0.06	0.10	-0.04	-0.04
	Average Bankfull Width Depth Ratio	-0.01	0.03	0.63	-0.04	0.00	0.19	0.05	-0.05	0.41	0.08	0.13	-0.16	0.11	-0.16
	Maximum Pool Depth	0.18	0.13	0.32	-0.25	-0.22	-0.13	-0.09	0.20	0.01	0.25	0.17	-0.31	-0.18	0.30

Table 35 (continued). Correlation coefficients (factor loadings) between 36 abiotic variables and 14 factors (N = 125).

		Factor													
Factor	**Variable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Factor 4 - Substrate/ Gradient	Percent Large Substrates	-0.24	0.23	0.20	0.71	0.02	0.05	0.26	-0.29	0.06	-0.01	0.12	0.02	0.13	-0.07
	Primary Substrate-Cobble	0.44	-0.12	0.17	0.68	-0.01	0.01	0.02	0.09	-0.01	0.20	-0.11	-0.15	-0.04	0.04
	Stream Channel Gradient	-0.21	0.00	-0.16	0.68	0.18	0.18	-0.03	-0.14	0.07	-0.17	0.02	0.08	0.02	0.00
Factor 5 - Erosion	Erosion Rate	0.02	0.04	-0.01	0.03	0.92	0.06	0.04	0.02	0.15	-0.01	-0.03	0.09	-0.01	0.02
	Weighted BEHI	-0.04	0.05	0.14	0.03	0.90	0.04	-0.01	-0.09	-0.10	-0.02	0.01	0.00	0.12	-0.04
Factor 6 - Surficial Deposit (Ravines, Silt and Clay)	Surficial Deposit-Ravines	0.00	-0.11	-0.04	0.07	0.13	0.90	-0.07	0.04	-0.07	-0.06	0.03	0.21	0.08	0.02
	Surficial Deposit-Silt and Clay, undifferentiated	0.07	0.38	0.05	-0.22	0.09	-0.54	-0.02	0.03	-0.07	0.21	0.46	0.15	0.14	-0.09
Factor 7 - Number of Substrates/ Entrenchment	Total Number of Substrates	0.02	0.06	0.16	0.26	0.02	0.14	0.64	-0.16	0.04	0.12	-0.04	-0.18	-0.05	0.22
	Percent Open Canopy	-0.01	0.11	0.04	-0.09	-0.05	0.24	-0.62	0.27	-0.07	0.08	-0.15	-0.20	0.07	0.08
	Entrenchment Ratio	-0.06	0.04	-0.12	0.04	-0.01	0.00	-0.52	0.02	-0.49	0.12	0.11	0.02	-0.16	0.06
	Surficial Deposit-Hiram Till, end moraine	-0.06	-0.26	-0.05	0.13	0.06	-0.29	0.49	0.31	-0.27	-0.03	-0.12	0.01	0.13	0.02
Factor 8 - Secondary Substrate Type - Sand	Secondary Substrate-Sand	-0.26	-0.04	0.06	-0.11	-0.11	0.01	-0.10	0.86	0.01	0.03	0.03	0.07	-0.03	-0.01

Table 35 (continued). Correlation coefficients (factor loadings) between 36 abiotic variables and 14 factors (N = 125).

		Factor													
Factor	**Variable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Factor 9 - NBS/Bedrock, Boulder Substrate	Weighted NBS	0.18	0.02	-0.04	0.09	0.09	-0.20	0.01	0.09	0.72	0.10	0.01	-0.18	-0.04	-0.01
	Secondary Substrate-Bedrock/Boulder/ Boulder Slab	-0.11	0.11	-0.20	0.19	0.30	0.31	0.08	-0.02	0.39	0.08	0.18	0.15	-0.34	0.00
Factor 10 - Bedrock and Silt Substrate	Secondary Substrate-Silt	0.00	0.07	0.04	-0.04	0.06	0.10	-0.02	0.02	-0.06	-0.86	-0.01	-0.11	-0.03	0.00
	Primary Substrate-Bedrock	0.20	0.37	0.07	0.25	-0.19	-0.08	0.15	-0.06	0.03	-0.47	0.33	0.05	0.18	-0.14
Factor 11 - Hiram Till Ground Moraine Surficial Deposit	Surficial Deposit-Hiram Till, ground moraine	-0.13	0.31	0.04	-0.08	0.06	-0.08	0.00	-0.09	-0.02	0.07	-0.72	0.03	0.02	-0.07
Factor 12 - Shale Surficial Deposit	Surficial Deposit-Shale, undifferentiated	-0.03	0.00	-0.14	0.05	-0.11	-0.18	0.00	-0.10	0.10	-0.11	-0.02	-0.86	0.02	-0.02
Factor 13 - Alluvium Surficial Deposit	Surficial Deposit-Alluvium	-0.04	-0.05	0.08	-0.21	-0.33	-0.11	0.04	0.04	0.03	0.00	0.03	0.04	-0.70	-0.02
	Water Temperature	0.01	0.40	-0.05	-0.19	-0.11	-0.07	0.30	-0.22	0.12	-0.01	0.15	0.15	0.48	0.11
Factor 14 - Clay, Hardpan Substrate/ Dissolved Oxygen	Secondary Substrate-Clay Hardpan	-0.06	0.06	-0.20	0.00	-0.02	0.15	0.07	0.01	-0.04	0.05	0.08	0.01	0.14	0.73
	Dissolved Oxygen Saturation	0.14	0.03	0.10	-0.08	0.03	-0.34	-0.01	0.06	0.00	-0.08	-0.10	0.05	-0.33	0.53
Explained Variance	–	3.38	2.97	2.56	2.39	2.12	1.93	1.81	1.62	1.40	1.39	1.38	1.33	1.31	1.17
Proportion of Total Variance	–	0.09	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03
Cumulative Proportion of Total Variance	–	0.09	0.18	0.25	0.31	0.37	0.43	0.48	0.52	0.56	0.60	0.64	0.67	0.71	0.74

The canonical plots showed that Classes II, III A and III B were tightly clustered and well separated from Class I. There was, however, a fair bit of overlap among the aforementioned classes (Figures 52 and 53). The first two canonical axes accounted for 87.4% of the variation among the classes. Axis 1, which accounted for 60.5% of the variation, provided strong separation of Class III A from Class III B, whereas Axis 2, accounting for 26.9% of the variation, differentiated Classes I, III A and III B from Class II. The third canonical axis accounted for an additional 12.6% and showed a similar degree of separation among all four classes when plotted against Axis 1. The canonical plot of Axis 2 against Axis 3 showed a great degree of overlap among all four classes with no discernable discrimination among the PWH classes along either axis (Figure 54).

Correlations of all three axes with the abiotic variables indicated that sites belonging to Classes I, II and III A had relatively higher water temperatures and higher percent imperviousness within their watersheds as compared to sites belonging to Class III B (Table 36).

The two sites belonging to Class I and nearly half of the sites belonging to Classes III A and III B were represented by Hiram Till Ground Moraine surficial deposits and gravel substrate as the primary substrate. By contrast, most of the sites belonging to Class II were characterized by clay or hardpan as the secondary substrate (Figure 52). The separation of sites along Axis 3 showed that the two Class 1 sites had relatively lower near bank stress (NBS) and relatively higher water temperatures compared to all other sites (Figure 53). Most sites in Class III A and III B were also characterized by cobble as the secondary substrate prevalent at these sites.

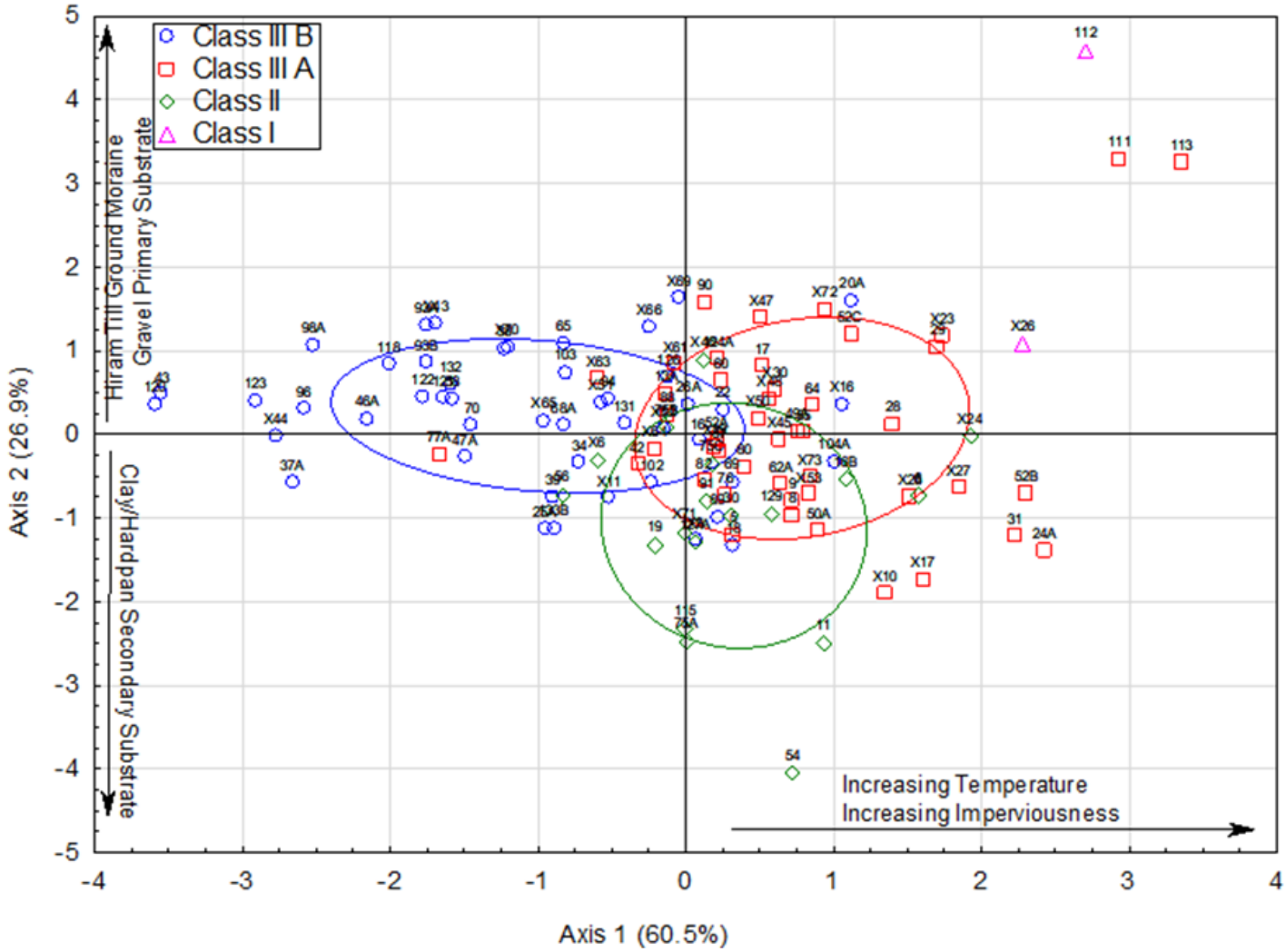


Figure 52. Distribution of canonical scores along Axes 1 and 2 from the discriminant function analysis (125 CUVA stream sites, with 50% ellipsoids about the centroid of each PWH class).

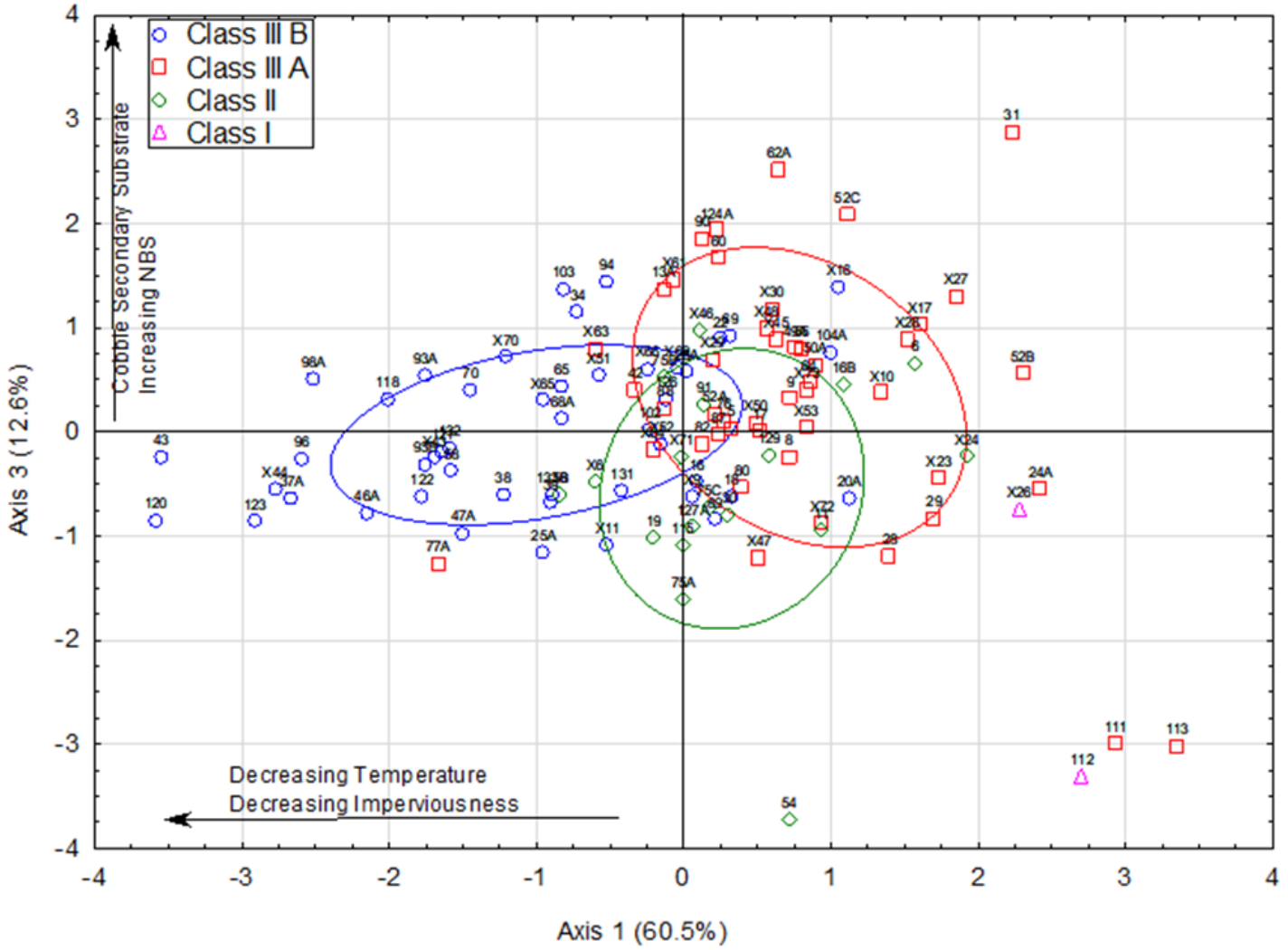


Figure 53. Distribution of canonical scores along Axes 1 and 3 from the discriminant function analysis (125 CUVA stream sites, with 50% ellipsoids about the centroid of each PWH class).

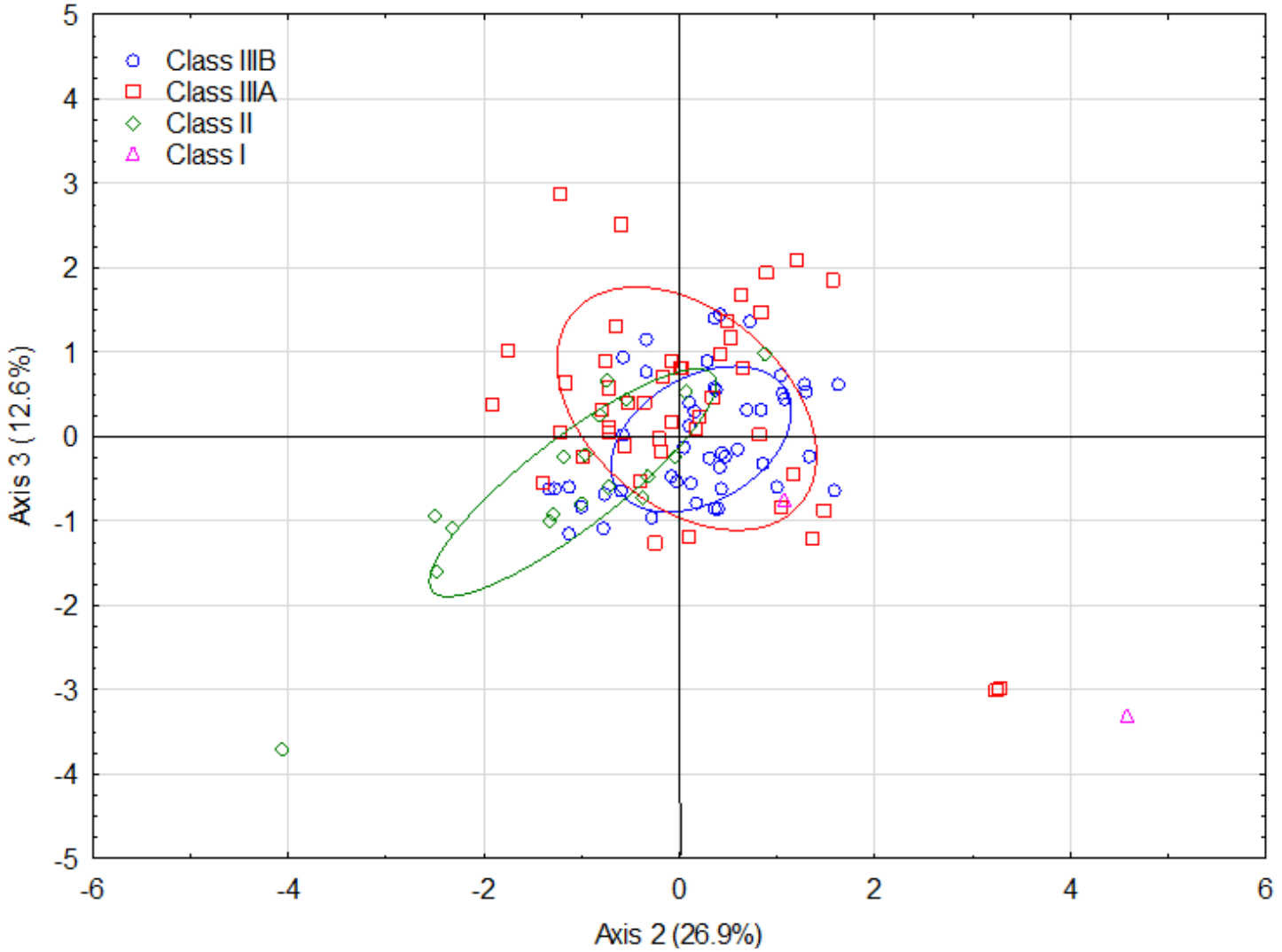


Figure 54. Distribution of canonical scores along Axes 2 and 3 from the discriminant function analysis (125 CUVA stream sites, with 50% ellipsoids about the centroid of each PWH classes.

Table 36. Correlations between 14 abiotic variables from the final DFA model and canonical axes 1, 2 and 3.

Variable	Axis 1	Axis 2	Axis 3
Surficial Deposit – Hiram Till, ground moraine	0.30	0.50	-0.49
Water Temperature	0.40	-0.32	-0.09
Stream Channel Gradient	0.28	0.15	0.27
Surficial Deposit – Ravines	0.22	-0.05	0.27
Total Number of Substrates	-0.03	0.19	0.13
Percent Imperviousness	0.39	-0.08	-0.08
Average Bankfull Width-Depth Ratio	-0.12	-0.26	0.12
Secondary Substrate – Clay Hardpan	0.04	-0.29	-0.31
Secondary Substrate – Sand	-0.28	0.05	-0.07
Secondary Substrate – Cobble	0.18	0.23	0.40
Weighted NBS	-0.06	0.16	0.35
Primary Substrate – Gravel	0.09	0.32	0.14
Surficial Deposit – Shale, undifferentiated	-0.30	0.09	-0.09
Proportion of Total Variance	0.604	0.269	0.126

Using the DFA, between 44 and 85% of the sites were correctly classified back to their *a priori* PWH class (Table 37). Class III A had the highest classification accuracy while Class II sites had the lowest resolution with the same number of sites classified as Class III A as the sites that were correctly classified as Class II.

Table 37. Percentage of sites correctly classified back to their Designated PWH class using discriminant function analysis based upon 14 abiotic variables.

Class	Percent Correct	Class III B	Class III A	Class II	Class I
Class III B	76.60	36	8	3	0
Class III A	84.78	5	39	0	2
Class II	44.44	2	8	8	0
Class I	50.00	0	1	0	1
Total	74.34	43	56	11	3

Visitor Use Impact Assessment Results

Visitor use impacts assessments were successfully completed at all 125 headwater stream inventory sites. No visitor use impacts of any kind were observed at 26 sites (20.8% of all sites). These sites can be generally described as being in relatively remote locations with little to no visitor access that directly impact the streams.

Discerned Visitor Use Impact Summary

Litter and Trash

The presence of litter (or trash) was the predominant indicator of anthropogenic impact found in or adjacent to the headwater stream inventory sites, with trash present at ninety-six (76.8%) of the 125 sites. A frequency chart for the number of sites where various categories of litter were encountered is provided in Figure 55. The most abundant forms of trash encountered in and around the stream channels were plastic materials (observed at 65 sites) and glass (observed at 53 sites). The least encountered types of trash encountered were tires (10 sites) and paper or cardboard (9 sites). Trash included within the "Other" category included an abandoned television tube, rubber balls, mylar balloons, bricks and concrete, a horseshoe, a water heater, various types of lumber, and household items.

Based upon the categories of litter types selected for the VUIA, the number of categories of trash encountered per site where litter was found ranged from zero to five (Figure 56). The average number of trash categories found per site was 1.8 for all locations, and the median number was one type. Only eleven of the inventory sites (8.8%) had four or more litter categories present.

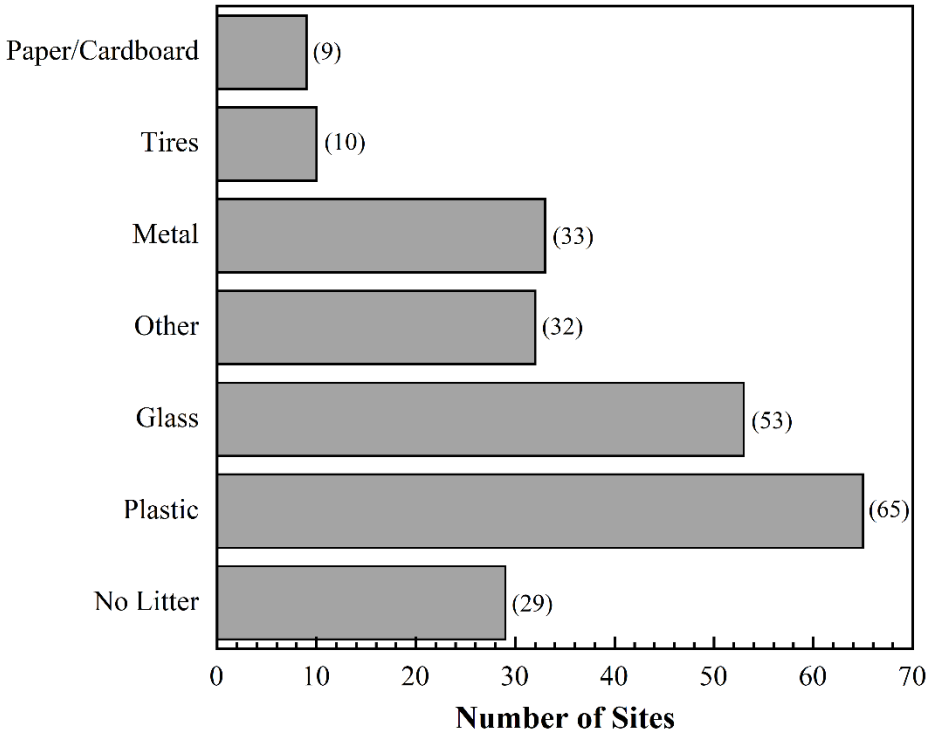


Figure 55. Frequency distribution for litter types observed at CUVA headwater stream inventory sites.

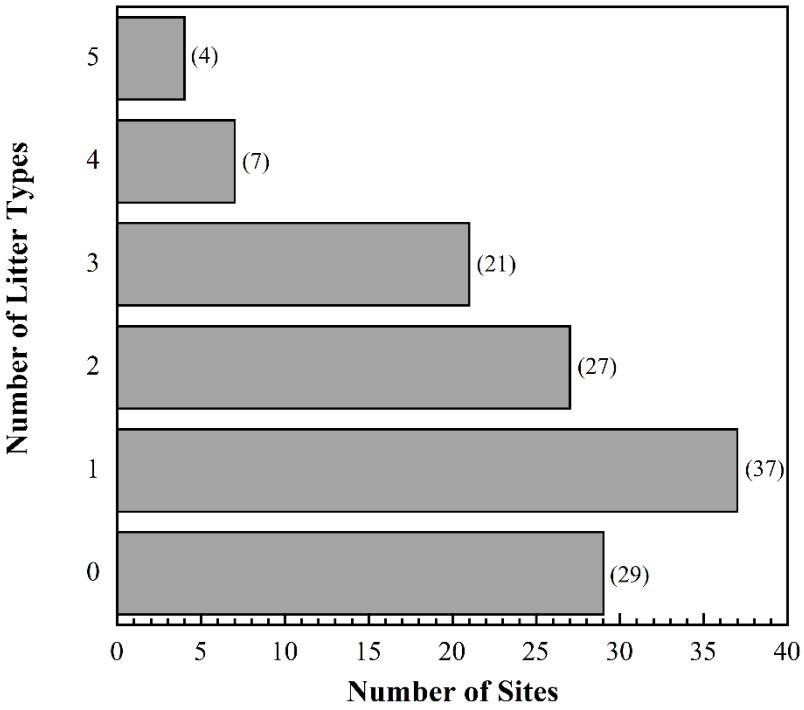


Figure 56. Frequency chart depicting the number sites affected by incremental numbers of litter types.

The number of litter items encountered per site ranged from zero to thirty-five. The median number of litter items encountered was two per site and the average was 3.1 (standard deviation = 4.7). Only one item of litter was encountered at 31 headwater stream inventory sites, which is equivalent to 24.8 percent of all sites and 32.3 percent of sites where litter was observed. Ten or more items of litter or trash were encountered at 10 sites (8% of all sites and 10.4% of sites with litter).

Litter was encountered most frequently within the stream channel itself, being found at 68 sites where trash was observed (70.8% of the 96 sites), and least often within the adjacent riparian areas (42 of 96 sites or 43.8%). Litter was observed in all three VUIA zones (riparian, streambank, and channel/channel margins) at 17 sites (17.7% of sites with litter observed). Only two zones were affected by litter at 30 sites (31.3% of sites with litter), and 49 sites (51.0% of sites with litter) had only one VUIA affected. The channel again had the most instances (26 sites, or 27.1%) when litter was encountered in only one VUIA zone.

The VUIA also included subjective determinations of the age of the litter or trash observed at each site. The litter observed was classified as either “recent”, “weathered”, or both. Weathered material made up most of the litter and trash encountered, being identified as the sole type at 78 sites (81.2% of sites with litter) and in conjunction with recent material at 12 additional sites. Weathered material consisted of both litter items and trash that was apparently a remnant of historical land uses prior to the establishment of CUVA. The sources of the legacy instances of trash within the stream corridors were identified most often as material carried to the assessment location from upstream areas within the watershed (e.g., cans, bottles, and other materials easily carried by stream flow) or through aerial deposition (e.g., mylar balloons). In addition, material present because of past land use was also common among the weathered trash, including trash from past disposal or filling practices (e.g., tires, concrete, bricks, and building materials), former home sites (e.g., household items), and past agricultural activities (e.g., metal materials). Recently derived litter was most often associated with sites with nearby trails (both designated and social) and consisted primarily of waste drink containers and food packaging.

Field crews categorized only nine headwater stream inventory sites (7.2% of all sites) as being impacted by litter or trash with respect to habitat integrity (Figure 57). Of these sites, seven were deemed to be experiencing only localized impacts (less than five percent of functional habitat). The localized impacts were mainly associated with stream access points or trail crossings. Site CUVA-24A, a site within the former Astorhurst Country Club now part of the Cleveland Metroparks Bedford Reservation, was deemed to have moderate impacts upon stream habitat (between five and 10 percent affected) because of legacy disposal activities. The material in question consisted of four litter categories including tires, metal, glass, and plastic. Litter and trash were found within all three VUIA zones. Several of the encountered objects, including mainly tires were partially buried within the alluvium associated with the stream corridor, indicating that the material had been present for a long time.

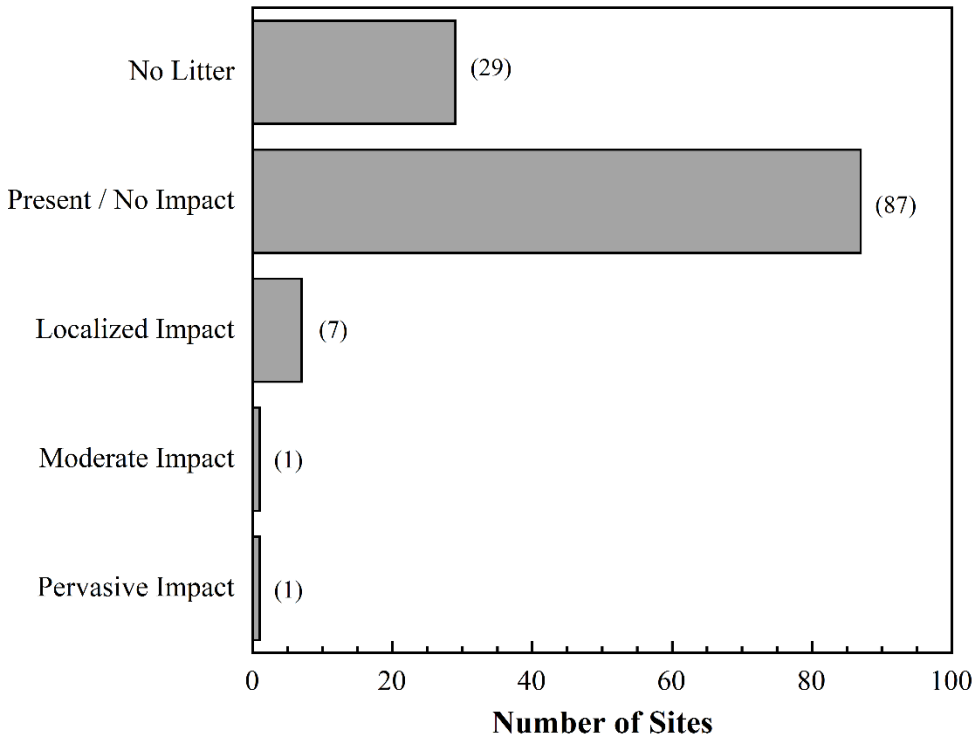


Figure 57. Frequency distribution for impact severity rankings upon habitat for aquatic biota related to litter at CUVA headwater stream inventory sites.

The most impacted site with respect to the effects of litter was site CUVA-111 located within Furnace Run Metro Park, managed by Summit Metro Parks. The upper portion of this site's watershed is heavily urbanized, containing a freeway interchange and commercial development. The litter and trash observed was both weathered and recent and appears to have been transported downstream from the developed areas upstream.

The severity of litter is deemed to be nonexistent for sites with no litter present (29 sites). Litter, though present, was also classified as having no deleterious effects upon stream habitat at an additional eighty-seven sites included in the headwater stream inventory. Therefore, litter was not determined to be a factor affecting the habitat to support aquatic fauna at 92.8 percent of the sites inventoried. These results indicate that the predominant effect of litter upon the CUVA Headwater Inventory sites is related more to aesthetics than upon stream biota except for the exceptions mentioned above.

Non-Litter Visitor Use Impacts

Visitor related stream impacts not including litter or trash were noted at a total of 15 headwater stream inventory sites (12 percent of all sites). Tallies of frequencies of these impacts and severity rankings are presented in Table 38. The impacts are broken down by stream assessment zone including the riparian area, the streambank, and the channel and channel margins.

Table 38. Frequencies for non-litter impacts to VUIA zones observed at CUVA Headwater Inventory sites.

Severity Category	Riparian Zone	Streambank	Channel
No Impacts	112	115	118
Present / No Impact	10	6	5
Localized Impacts	2	2	2
Moderate Impacts	3	1	1
Pervasive Impacts	0	0	0
Total Sites Impacted	**15**	**9**	**8**

Of the 15 sites where non-litter impacts were identified, impacts were observed in all three assessment zones at seven sites, in two of the three zones at three sites, and only in the riparian zone at five sites. Causes and sources attributed to the observed impacts are listed in Table 39 as well as the lengths of trails found affecting the assessment site. Trail impacts assessed during the VUIA included those occurring within the stream channel and margins as well as the streambanks and riparian areas.

Non-litter impacts identified during the inventory were associated with erosion and vegetation damage related to trails and stream access points. Erosion was observed at all 15 sites with non-litter impacts and was the only impact category reported as causing effects upon stream habitat function. Three sites were noted with moderate impacts to stream habitat function, and four sites were reported to have localized impacts related to trails. Hiking was listed as the primary source of the erosion for 11 sites, while bicycling was listed as a cause at three locations. No equestrian trails were present at any of the inventoried stream sites.

No pervasive impacts were noted related to non-litter impacts, but it is interesting to note that site CUVA-111, located within the Brushwood Area of Furnace Run Metro Park was listed with the highest degree of visitor impacts for both litter and non-litter metrics. Site CUVA-113, which is located very near to site CUVA-111 in Furnace Run Metro Park, was also deemed to have moderate impacts to stream habitat as the result of erosion within the riparian zone. Both sites are on tributaries to Rock Creek and are crossed by a heavily used hiking path within the park.

Table 39. Causes and sources of non-litter visitor use impacts and severity rankings for CUVA Headwater Inventory sites.

HUC 12 Watershed	Site Type	Site Name	Stream	PHW Classification	Impact	Source	Designated Trail (ft)	Social Trail (ft)	Severity Rankings*
041100020403	Primary	CUVA-111	Furnace Run	Class IIIA	Erosion	Hiking	50	–	4,4,4
	Primary	CUVA-113	Furnace Run	Class IIIA	Erosion	Hiking / Picnicking	200	–	4,1,1
041100020405	Primary	CUVA-96	Ira Creek	Class IIIB	Erosion / Veg. Damage	Hiking	40	200	4,3,3
	Primary	CUVA-126	Spring Creek	Class IIIB	Veg. Damage	Removal	–	–	2,1,1
	Primary	CUVA-65	Unnamed 11	Class IIIB	Veg. Damage	Trampling	–	–	2,2,1
	Secondary	CUVA-75B	Ritchie Run	Class II	Erosion	Hiking	120	–	2,1,1
	Secondary	CUVA-75C	Ritchie Run	Class II	Erosion	Hiking	100	–	2,2,2
	Secondary	CUVA-X60	Spring Creek	Class IIIB	Erosion	Hiking	–	120	2,2,2
	Secondary	CUVA-X6	Stanford Run	Class II	Erosion	Bicycles	200	–	2,1,1
041100020504	Primary	CUVA-133B	Tinker's Creek	Class IIIB	Erosion	ATV Trail	–	40	2,1,2
	Primary	CUVA-30	Unnamed 9	Class II	Erosion	Hiking	–	200	3,3,2
	Primary	CUVA-31	Unnamed 9	Class IIIA	Erosion	Hiking	–	50	3,2,1
	Primary	CUVA-45	Unnamed 9	Class IIIB	Erosion	Hiking / Bicycles	–	116	2,2,2
041100020602	Primary	CUVA-5	Unnamed 1	Class IIIA	Erosion	Hiking	10	10	2,2,3
	Primary	CUVA-7	Unnamed 2	Class II	Erosion / Veg. Damage	Hiking / Fires	–	–	2,1,1

* Severity rankings are comma delimited in order of Riparian, Streambank, and Channel/Margin rankings using the following key:

1 = Not Present: no impacts observed in assessment zone

2 = Present/No Impacts: noted; but no observed effect on functional habitat

3 = Localized Impacts: noted; localized effects (<5%) on functional habitat

4 = Moderate Impacts: common; moderate loss of functional habitat (5% - 10%)

5 = Pervasive Impacts: significant degradation of functional habitat (>10%)

Other localized erosion impacts were noted at four sites (Table 39). These impacts were all related to access by hikers using both designated and social trails in proximity to the headwater stream. At two locations (CUVA-5 and CUVA-96) these localized effects upon stream habitat were the result of stream crossings via the disruption of in-stream substrates. Site CUVA-96 in particular evidenced heavy localized impacts associated with a crossing of the Buckeye Trail directly through the stream. This location is very close to a trailhead at the intersection of Ira and Martin Rd, where heavy foot traffic is apparent. This location had much more evidence of impact as compared to other more remote crossings associated with the Buckeye Trail that were observed throughout the survey.

Impacts resulting in effects upon vegetation observed during the inventory included vegetation removal, trampling, and physical damage; all were attributed to recreational activities such as picnicking and campfires or were byproducts of access via hiking or bicycling.

Evaluation of Procedure Validity and Recommendations for Future Use

The VUIA field procedure presented no difficulties with respect to staff training or with respect to time efficiency for the field crews to complete. Most of the observations for the VUIA were made within the context of collection of other field assessment data, and results were compiled through discussions and consensus among the field staff. As a stand-alone procedure, compiling the information for the VUIA would require approximately 15 to 20 minutes of effort for a similarly sized area as required to conduct a PHW assessment. The VUIA would complement the procedures for the completion of habitat assessments using the HHEI with minimal extra effort required.

Analysis of the data collected using the VUIA during the CUVA headwater stream inventory appears to have captured important aspects of anthropogenic disturbance well for the sites that were surveyed. This is especially true for sites where the assessment zones were placed near trail crossings or other points of easy stream access. The remoteness of many of the headwater stream inventory sites was reflected in the absence of visitor use impacts at many of the sites apart from issues related to legacy trash disposal or transport of litter via stream flows or from aerial deposition. A more robust approach to using the VUIA through a study design allowing for comparisons of remote sites used as controls to sites associated with trail crossings and other points of public access would allow for a more robust examination of VUIA-derived data and could provide a useful tool for future resource management planning and implementation of protective strategies.

Conclusions and General Recommendations

Cuyahoga Valley National Park primary headwater streams are generally of high quality according to habitat, geomorphology, in situ water chemistry, and biological data collected throughout the 2022 survey. Visitor use impacts were minimal with little human influence observed within the study zones. Water chemistry (in situ) and habitat (HHEI) data were relatively similar for most sites on average, placing most in the Class III PHW category. Biological data was where differentiation between stream classes was observed. The majority (103 sites or 82.4%) of the stream sites in the inventory were found to have Class IIIA or Class IIIB biological communities, indicative of perennial flow conditions. Of these, roughly half of the sites met the characteristics for Class IIIB PHW streams, indicating support of cold water adapted fauna. In most instances macroinvertebrates and salamanders were the primary driving factors for stream classifications. There were very few instances where fish were the driver for overall stream classification, but when cold water taxa were present, the appropriate stream designation became obvious.

Inventoried sites located to the west of the Cuyahoga River, especially within the Willow Lake-Cuyahoga River 12-digit HUC watershed 041100020505 appeared to be of higher quality and in some cases fully meet the Ohio EPA CWH use designation. Specific areas of interest where conservation efforts should be focused within this HUC watershed as all eight of the streams fully meeting CWH (including the EWH/CWH stream) are located in this portion of CUVA.

The stream sub-watersheds of interest include:

- the RM 21.40 Tributary (NPS “Unnamed 4”), home of the EWH/CWH CUVA-37A and CWH CUVA-38 on a tributary to that stream. These streams are located within the CMP Brecksville Reservation.
- the RM 21.70 Tributary (NPS “CMA Creek”) and tributaries including CWH sites CUVA-39, CUVA-120, CUVA-121, CUVA-122, CUVA-X43. This sub-watershed is located within the Snowville Woods Natural Zone.
- the RM 23.40 Tributary (NPS “Unnamed 5”), assessed at site CUVA-123. This sub-watershed is also located in the Snowville Woods Natural Zone.

The results point to the need for special conservation practices to protect these ecologically important streams, especially as they relate to protection of groundwater resources. One of the discerning features of this area is the sites are all located within the region where the Ohio Shale is the topmost bedrock layer. This bedrock unit appears to be the “ground water highway” or the path to the Cuyahoga River in that part of the park. The surficial unit for all the upstream sites in this group is called “Undifferentiated Shale (Bedrock Unit I)” and appears to be an area where groundwater emanates from the valley margins. None of these streams were sampled by Ohio EPA in 2017-2018, but it was noted in their report that multiple other CUVA streams have the potential for CWH use designation encouraging the notion for conservation of these invaluable resources (Ohio EPA, 2023).

In terms of geomorphology, many Cuyahoga Valley PHW streams have reached an equilibrium with respect to vertical and lateral stability. These stream types are typically F or G channels with respect to the Rosgen stream channel classification system, with channel dimensions indicative of entrenchment and high width to depth ratios, particularly for streams classified as F channels (Rosgen, 1996; 2009). Control of the condition of these ravine stream channels is generally derived from contact with the underlying bedrock resulting in stability vertically and from steep valley sides that prevent lateral movement of the channel because of the presence of overlying bedrock layers. Although the potential for bank erosion in these streams is high based upon BEHI scores, the high width to depth ratios observed at these sites produce low NBS values, producing a net result of channel stability, as indicated by examination of the biological communities, particularly the macroinvertebrates and salamander components.

Although the scope of the inventory did not include watershed analysis with respect to changes in stormwater volume or intensity, in instances where the upper watersheds of the inventory sites lie outside of CUVA, increased degrees of urbanization may have an effect on downstream channel stability. Increased peak flows during storm events are likely to stress the stream system outside of equilibrium with respect to vertical stability, especially in situations where the bedrock is erodible. Once vertical stability is affected, the stress upon streambanks increases, resulting in lateral instability.

In situations such as the setting of the lower portions of many PHW streams flowing through CUVA, where the streams become higher in gradient and more confined laterally as they flow in ravine valleys, bank erosion can become severe at the toe of the valley walls, resulting in instability in the valley slopes. The result is the loss of stability for forest trees which then end up in the stream channel, creating logjams which in themselves can exacerbate streambank instability. As these stream channels evolve geomorphometrically over time, a new level of stability can result. However, this process may take many years to complete, and can create significant challenges for protecting downstream infrastructure such as culverts, roadways, the railroad, and utilities. Evidence of direct efforts to “restore” these stream channels within CUVA are many, particularly in areas of impacts upon infrastructure. However, these efforts are likely to produce only temporary results that will require continual long-term maintenance. For these situations, the best long-term management strategy to investigate are partnerships between NPS, other government entities, and the public to explore ways to control stormwater volume and intensity to reduce the downstream stress on these stream ecosystems.

It should be noted that there are also situations where the combination of upstream changes in the watershed and the infrastructure in place on the downstream end of PHW streams has resulted in severe aggradation of material, typically sands and gravels, in the channels. Specific examples include the streams where “mud catchers” were historically installed to protect the Ohio Canal from sedimentation, although other examples exist throughout CUVA where stream channels are confined through culverting to produce similar outcomes. In these cases, long segments of channel incapable of supporting aquatic life may be created since the flows become interstitial. Long-term management

of these systems will require a blending of the importance of the stream ecology, historical preservation, and long-term management of infrastructure.

The VUIA procedure developed for the CUVA headwater stream inventory successfully captured important aspects of anthropogenic disturbance to headwater streams within the park. This was especially true for sites where the assessment zones were placed near trail crossings or other points of easy stream access. There was an absence of visitor use impacts noted for many remotely located sites apart from issues related to legacy trash disposal or transport of litter via stream flows or from aerial deposition. It is recommended that further study of the use of the VUIA within CUVA be considered through comparison of remote sites used as controls to sites associated with trail crossings and other points of public access to determine whether the use of VUIA-derived data developed on a wider scale can become a useful tool for future resource management planning and implementation of protective strategies.

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Appendix A: Primary Assessment Sites and Associated Primary Sites for the CUVA Headwater Stream Inventory

Table 40. Primary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude [a]	Longitude [a]	County
041100020403	Furnace Run S-Oak Hill NZ	CUVA-131	Furnace Run	5/17/2022	0.60	41.21313	-81.59779	Summit
	Furnace Run S-Oak Hill NZ	CUVA-132 [b]	Furnace Run	5/17/2022	0.60	41.21423	-81.59899	Summit
	Furnace Run S-Oak Hill NZ	CUVA-103 [c]	Furnace Run	5/24/2022	0.69	41.22049	-81.59064	Summit
	Furnace Run S-Oak Hill NZ	CUVA-102	Furnace Run	6/13/2022	0.88	41.23118	-81.60734	Summit
	Furnace Run S-Oak Hill NZ	CUVA-104A [c]	Furnace Run	6/13/2022	0.40	41.23883	-81.61559	Summit
	SMP Furnace Run	CUVA-111	Furnace Run	7/11/2022	0.40	41.26984	-81.63738	Summit
	SMP Furnace Run	CUVA-113	Furnace Run	6/22/2022	0.98	41.27506	-81.63946	Summit
	SMP Furnace Run	CUVA-112	Furnace Run	7/11/2022	0.29	41.27649	-81.64311	Summit
041100020404	Stanford Run / Hines Hill HVE	CUVA-54	Brandywine Creek	7/20/2022	0.40	41.26490	-81.53414	Summit
	Stanford Run / Hines Hill HVE	CUVA-55	Brandywine Creek	7/7/2022	0.44	41.26790	-81.53671	Summit
	Stanford Run / Hines Hill HVE	CUVA-52A [e]	Brandywine Creek	7/12/2022	0.22	41.28742	-81.55426	Summit

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

[d] Site relocated to match historical Ohio EPA sampling location.

[e] Desktop resource information inaccurate to match stream channel location.

[f] Site had to be moved to location within park boundary.

Table 40 (continued). Primary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude [a]	Longitude [a]	County
041100020405	Adams Run NZ	CUVA-129	Adams Run	7/21/2022	0.96	41.16769	-81.56159	Summit
	A-P North SRZ	CUVA-70	Boston Run	7/8/2022	0.84	41.23854	-81.52046	Summit
	A-P North SRZ	CUVA-56	Stanford Run	6/28/2022	0.69	41.25497	-81.53596	Summit
	Blossom Woods NZ	CUVA-80	Dickerson Run	7/28/2022	0.55	41.21403	-81.53821	Summit
	Blossom Woods NZ	CUVA-82 [b]	Langes Run	7/19/2022	0.76	41.20138	-81.53870	Summit
	Blossom Woods NZ	CUVA-83	Langes Run	7/19/2022	0.22	41.20154	-81.54076	Summit
	Blossom Woods NZ	CUVA-89	Robinson Run	7/26/2022	0.25	41.20215	-81.55560	Summit
	Blossom Woods NZ	CUVA-88	Robinson Run	7/26/2022	0.46	41.20361	-81.55711	Summit
	Blossom Woods NZ	CUVA-87	Robinson Run	7/26/2022	0.59	41.20456	-81.55403	Summit
	Blossom Woods NZ	CUVA-91	Unnamed 12	6/15/2022	0.44	41.16941	-81.56916	Summit
	Blossom Woods NZ	CUVA-90	Unnamed 12	6/15/2022	0.23	41.19053	-81.57101	Summit
	Botzum NZ	CUVA-94 [c]	Unnamed 15	5/24/2022	0.17	41.15319	-81.57373	Summit
	Botzum NZ	CUVA-93A	Unnamed 15	5/5/2022	0.17	41.15807	-81.57732	Summit
	Botzum NZ	CUVA-93B [c]	Unnamed 15	5/5/2022	0.10	41.15871	-81.57841	Summit
	Columbia SRZ	CUVA-60	Columbia Run	9/1/2022	0.88	41.26803	-81.59327	Summit
	Columbia SRZ	CUVA-58	Columbia Run	5/23/2022	0.18	41.26925	-81.57301	Summit

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

[d] Site relocated to match historical Ohio EPA sampling location.

[e] Desktop resource information inaccurate to match stream channel location.

[f] Site had to be moved to location within park boundary.

Table 40 (continued). Primary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude [a]	Longitude [a]	County
041100020405 (continued)	Everett Cultural HVE	CUVA-96 [b]	Ira Creek	5/9/2022	0.60	41.18114	-81.58613	Summit
	Everett Cultural HVE	CUVA-98A	Unnamed 12	5/11/2022	0.74	41.19526	-81.58404	Summit
	Furnace Run South - Oak Hill NZ	CUVA-68A [c]	Oak Hill Creek	5/11/2022	0.32	41.21791	-81.56347	Summit
	Furnace Run South - Oak Hill NZ	CUVA-64 [d]	Peninsula Creek	8/2/2022	0.40	41.23895	-81.55118	Summit
	Furnace Run South - Oak Hill NZ	CUVA-62A [f]	Slipper Run	8/2/2022	0.39	41.24343	-81.58770	Summit
	Furnace Run South - Oak Hill NZ	CUVA-66	Unnamed 11	5/12/2022	0.66	41.22578	-81.55838	Summit
	Furnace Run South - Oak Hill NZ	CUVA-65	Unnamed 11	5/12/2022	0.43	41.22778	-81.55634	Summit
	Interstate NZ	CUVA-126 [d]	Spring Creek	5/18/2022	0.78	41.25572	-81.57784	Summit
	Snowville Woods NZ	CUVA-47A [c]	Unnamed 10	5/23/2022	0.27	41.27615	-81.57247	Summit
	Stanford Run / Hines Hill HVE	CUVA-124A	Stanford Run	6/21/2022	0.29	41.25553	-81.53340	Summit
	Virginia Kendall HVE	CUVA-69	Boston Run	7/8/2022	0.68	41.23446	-81.51028	Summit
	Virginia Kendall HVE	CUVA-127A	Haskell Run	6/8/2022	0.78	41.23046	-81.51923	Summit
	Virginia Kendall HVE	CUVA-75A	Ritchie Run	6/8/2022	0.70	41.23180	-81.53649	Summit

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

[d] Site relocated to match historical Ohio EPA sampling location.

[e] Desktop resource information inaccurate to match stream channel location.

[f] Site had to be moved to location within park boundary.

Table 40 (continued). Primary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude [a]	Longitude [a]	County
041100020405 (continued)	Virginia Kendall HVE	CUVA-76 [c]	Salt Run	7/28/2022	0.76	41.21365	-81.50863	Summit
	Virginia Kendall HVE	CUVA-77A	Salt Run	7/27/2022	0.44	41.21457	-81.52252	Summit
041100020503	CMP Brecksville Res.	CUVA-118	Chippewa Creek	6/8/2022	0.65	41.31111	-81.60493	Cuyahoga
	CMP Brecksville Res.	CUVA-119	Chippewa Creek	6/8/2022	0.47	41.31266	-81.60649	Cuyahoga
	CMP Brecksville Res.	CUVA-34	Chippewa Creek	6/9/2022	0.60	41.31618	-81.60467	Cuyahoga
	CMP Brecksville Res.	CUVA-35 [c]	Chippewa Creek	6/9/2022	0.43	41.31883	-81.60940	Cuyahoga
041100020504	CMP Bedford Res.	CUVA-25A	Tinker's Creek	7/29/2022	0.27	41.36518	-81.57724	Cuyahoga
	CMP Bedford Res	CUVA-24A	Tinker's Creek	6/27/2022	0.33	41.36561	-81.58290	Cuyahoga
	CMP Bedford Res	CUVA-133B [b]	Tinker's Creek	7/28/2022	1.03	41.36766	-81.58735	Cuyahoga
	CMP Bedford Res	CUVA-115 [b]	Tinker's Creek	7/20/2022	0.96	41.37605	-81.54655	Cuyahoga
041100020505	CMP Brecksville Res.	CUVA-38 [c]	Unnamed 4	6/6/2022	0.58	41.30941	-81.59578	Cuyahoga
	CMP Brecksville Res.	CUVA-37A [c]	Unnamed 4	6/6/2022	0.73	41.30955	-81.59174	Cuyahoga
	Northern NZ	CUVA-19 [c]	Unnamed 3	6/16/2022	0.17	41.34662	-81.60152	Cuyahoga
	Northern NZ	CUVA-18[e]	Unnamed 9	8/5/2022	0.69	41.33578	-81.60565	Cuyahoga
	Old Carriage NZ	CUVA-50A	Unnamed 9	5/25/2022	0.52	41.28966	-81.56091	Summit
	Old Carriage NZ	CUVA-49A	Unnamed 9	5/25/2022	0.32	41.29199	-81.56429	Summit

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

[d] Site relocated to match historical Ohio EPA sampling location.

[e] Desktop resource information inaccurate to match stream channel location.

[f] Site had to be moved to location within park boundary.

Table 40 (continued). Primary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude [a]	Longitude [a]	County
041100020505 (continued)	Old Carriage NZ	CUVA-45	Unnamed 9	5/24/2022	0.43	41.29903	-81.57068	Summit
	Old Carriage NZ	CUVA-42	Unnamed 9	5/24/2022	0.55	41.30182	-81.57138	Summit
	Old Carriage NZ	CUVA-31	Unnamed 9	6/23/2022	0.40	41.31686	-81.58316	Summit
	Pinery Narrows / Twin Sisters SRZ	CUVA-30 [c]	Unnamed 9	6/30/2022	0.59	41.32330	-81.58127	Summit
	Pinery Narrows / Twin Sisters SRZ	CUVA-29 [c]	Unnamed 9	6/30/2022	0.19	41.33099	-81.58785	Summit
	Pinery Narrows / Twin Sisters SRZ	CUVA-28	Unnamed 9	6/29/2022	0.81	41.33311	-81.58793	Summit
	Pinery Narrows / Twin Sisters SRZ	CUVA-27	Unnamed 9	6/29/2022	0.50	41.33868	-81.58621	Summit
	Snowville Woods NZ	CUVA-120	CMA Creek	5/25/2022	0.60	41.29385	-81.58357	Cuyahoga
	Snowville Woods NZ	CUVA-122	CMA Creek	6/3/2022	0.29	41.29556	-81.59088	Cuyahoga
	Snowville Woods NZ	CUVA-43	CMA Creek	5/25/2022	0.30	41.29625	-81.58491	Cuyahoga
	Snowville Woods NZ	CUVA-121	CMA Creek	6/3/2022	1.02	41.29687	-81.59392	Cuyahoga
	Snowville Woods NZ	CUVA-39	CMA Creek	6/1/2022	0.60	41.30730	-81.58771	Cuyahoga
	Snowville Woods NZ	CUVA-46A	Unnamed 5	5/19/2022	0.42	41.28391	-81.57538	Cuyahoga
	Snowville Woods NZ	CUVA-123	Unnamed 5	5/19/2022	0.39	41.28539	-81.57878	Cuyahoga

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

[d] Site relocated to match historical Ohio EPA sampling location.

[e] Desktop resource information inaccurate to match stream channel location.

[f] Site had to be moved to location within park boundary.

Table 40 (continued). Primary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude [a]	Longitude [a]	County
041100020505 (continued)	Twin Sisters-Mudcatcher SRZ	CUVA-26A	Sagamore Creek	6/1/2022	0.40	41.35074	-81.58825	Summit
	Twin Sisters-Mudcatcher SRZ	CUVA-22	Sagamore Creek	6/16/2022	0.12	41.35212	-81.58364	Cuyahoga
	Twin Sisters-Mudcatcher SRZ	CUVA-20A	Unnamed 9	5/31/2022	0.43	41.34815	-81.58891	Summit
041100020602	Northern NZ	CUVA-13A [b]	Brookside Creek	6/14/2022	0.85	41.35705	-81.61443	Cuyahoga
	Northern NZ	CUVA-17	Stone Road Creek	8/4/2022	0.47	41.37649	-81.63480	Cuyahoga
	Northern NZ	CUVA-5	Unnamed 1	8/1/2022	0.29	41.38788	-81.62985	Cuyahoga
	Northern NZ	CUVA-11	Unnamed 2	6/14/2022	0.34	41.36992	-81.61817	Cuyahoga
	Northern NZ	CUVA-9	Unnamed 2	6/17/2022	0.61	41.37029	-81.61925	Cuyahoga
	Northern NZ	CUVA-8	Unnamed 2	6/17/2022	0.44	41.37138	-81.62011	Cuyahoga
	Northern NZ	CUVA-7 [c]	Unnamed 2	7/1/2022	0.27	41.37169	-81.62414	Cuyahoga
	Northern NZ	CUVA-6	Unnamed 2	7/25/2022	0.23	41.37249	-81.62341	Cuyahoga
	Northern NZ	CUVA-16B	Unnamed 7	7/25/2022	0.51	41.37293	-81.62255	Cuyahoga
	Northern NZ	CUVA-16	Unnamed 7	8/1/2022	0.67	41.37995	-81.62056	Cuyahoga

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

[d] Site relocated to match historical Ohio EPA sampling location.

[e] Desktop resource information inaccurate to match stream channel location.

[f] Site had to be moved to location within park boundary.

Appendix B: Secondary Assessment Sites and Associated Primary Sites for the CUVA Headwater Stream Inventory

Table 41. Secondary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude [a]	Longitude [a]	County	Assoc. Site
041100020403	Everett Cultural HVE	CUVA-X74	Perkins Run	9/20/2022	1.14	41.19449	-81.60359	Summit	None
	Everett Cultural HVE	CUVA-X73 [c]	Perkins Run	8/31/2022	0.19	41.20167	-81.60062	Summit	None
	Furnace Run S-Oak Hill NZ	CUVA-X45 [b]	Furnace Run	8/31/2022	0.42	41.20655	-81.60067	Summit	CUVA-131
	Furnace Run S-Oak Hill NZ	CUVA-X47 [c]	Furnace Run	9/8/2022	0.27	41.21532	-81.60382	Summit	CUVA-132
	Furnace Run S-Oak Hill NZ	CUVA-X46	Furnace Run	9/8/2022	0.26	41.21633	-81.60322	Summit	CUVA-132
041100020404	Boston-Brandywine HVE	CUVA-52C [c]	Brandywine Creek	9/16/2022	0.11	41.28727	-81.55180	Summit	None
	Boston-Brandywine HVE	CUVA-52B [c]	Brandywine Creek	8/17/2022	0.20	41.28905	-81.55189	Summit	CUVA-52A
041100020405	Blue Hen Falls NZ	CUVA-X9	Spring Creek	8/12/2022	1.28	41.25805	-81.57423	Summit	CUVA-X61
	Blue Hen Falls NZ	CUVA-X61 [c]	Spring Creek	9/15/2022	1.34	41.25916	-81.57170	Summit	CUVA-X60
	Blue Hen Falls NZ	CUVA-X63	Spring Creek	9/2/2022	0.12	41.26041	-81.56461	Summit	None

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

Table 41 (continued). Secondary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude[a]	Longitude[a]	County	Assoc. Site
041100020405 (continued)	Blue Hen Falls NZ	CUVA-X60 [c]	Spring Creek	9/15/2022	1.43	41.26304	-81.56675	Summit	CUVA-X61
	Columbia SRZ	CUVA-X54	Columbia Run	9/1/2022	0.16	41.26436	-81.59191	Summit	None
	Columbia SRZ	CUVA-X53	Columbia Run	9/1/2022	0.15	41.26599	-81.59232	Summit	None
	Columbia SRZ	CUVA-X52 [c]	Columbia Run	8/23/2022	0.14	41.27161	-81.56980	Summit	None
	Columbia SRZ	CUVA-X51	Spring Creek	8/25/2022	0.22	41.25718	-81.57432	Summit	CUVA-126
	Everett Cultural HVE	CUVA-X11	Ira Creek	8/15/2022	0.16	41.17838	-81.58975	Summit	CUVA-96
	Everett Cultural HVE	CUVA-X10	Ira Creek	8/15/2022	0.40	41.17952	-81.59015	Summit	CUVA-96
	Everett Cultural HVE	CUVA-X72	Unnamed 12	9/2/2022	0.16	41.19218	-81.59847	Summit	None
	Furnace Run S-Oak Hill NZ	CUVA-X17 [c]	Unnamed 11	8/8/2022	0.31	41.22495	-81.56134	Summit	CUVA-66
	Furnace Run S-Oak Hill NZ	CUVA-X16	Unnamed 11	8/8/2022	0.32	41.22570	-81.56067	Summit	CUVA-66
	Interstate NZ	CUVA-X64	Grannys Run	9/20/2022	0.44	41.25615	-81.56127	Summit	None
	Stanford Run-Hines Hill HVE	CUVA-X6 [c]	Stanford Run	8/29/2022	0.21	41.26130	-81.53822	Summit	None
	Stanford Run-Hines Hill HVE	CUVA-X50	26.65 Trib Cuy R	8/12/2022	0.11	41.26318	-81.55172	Summit	None

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

Table 41 (continued). Secondary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude[a]	Longitude[a]	County	Assoc. Site
041100020405 (continued)	Virginia Kendall HVE	CUVA-75B[c]	Ritchie Run	9/14/2022	0.17	41.22279	-81.52473	Summit	CUVA-75A
	Virginia Kendall HVE	CUVA-75C	Ritchie Run	9/14/2022	0.17	41.22503	-81.52215	Summit	CUVA-75A
041100020505	Old Carriage NZ	CUVA-X49	Unnamed 9	8/10/2022	0.19	41.29320	-81.56249	Summit	CUVA-49A
	Old Carriage NZ	CUVA-X48	Unnamed 9	8/10/2022	0.11	41.29329	-81.56272	Summit	CUVA-49A
	Old Carriage NZ	CUVA-X30	Unnamed 9	8/24/2022	0.20	41.29760	-81.56561	Summit	CUVA-45
	Old Carriage NZ	CUVA-X29	Unnamed 9	8/24/2022	0.18	41.29804	-81.56591	Summit	CUVA-29
	Old Carriage NZ	CUVA-X28[c]	Unnamed 9	8/26/2022	0.14	41.30125	-81.56685	Summit	CUVA-42
	Old Carriage NZ	CUVA-X27	Unnamed 9	8/26/2022	0.35	41.30183	-81.56735	Summit	CUVA-42
	Snowville Woods NZ	CUVA-X44	CMA Creek	9/7/2022	0.24	41.28970	-81.58585	Cuyahoga	CUVA-120
	Snowville Woods NZ	CUVA-X43	CMA Creek	9/7/2022	0.27	41.29016	-81.58683	Cuyahoga	CUVA-120
	Snowville Woods NZ	CUVA-X70	Unnamed 5	9/12/2022	0.11	41.27722	-81.57994	Summit	CUVA-46A
	Snowville Woods NZ	CUVA-X69	Unnamed 5	9/12/2022	0.32	41.27757	-81.58029	Summit	CUVA-46A
	Snowville Woods NZ	CUVA-X65[c]	Unnamed 5	8/31/2022	0.14	41.28249	-81.58194	Cuyahoga	CUVA-123

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

Table 41 (continued). Secondary assessment sites and associated primary sites for the CUVA Headwater Stream Inventory.

HUC12 Watershed	CUVA Mgmt. Zone	Site Name	Sub-Watershed	Survey Date	Drainage Area (mi^2)	Latitude[a]	Longitude[a]	County	Assoc. Site
041100020505 (continued)	Snowville Woods NZ	CUVA-X66	Unnamed 5	8/31/2022	0.22	41.28262	-81.58063	Cuyahoga	CUVA-123
	Twin Sisters-Mudcatcher SRZ	CUVA-X25	Unnamed 9	8/25/2022	0.66	41.33165	-81.58419	Summit	CUVA-28
	Twin Sisters-Mudcatcher SRZ	CUVA-X26	Unnamed 9	8/25/2022	0.12	41.33217	-81.58346	Summit	CUVA-28
	Twin Sisters-Mudcatcher SRZ	CUVA-X24	Unnamed 9	8/24/2022	0.27	41.33620	-81.58298	Summit	CUVA-27
	Twin Sisters-Mudcatcher SRZ	CUVA-X23	Unnamed 9	8/24/2022	0.19	41.33716	-81.58222	Summit	CUVA-27
041100020602	Terra Vista	CUVA-X71	15.11 Trib Cuy R	9/21/2022	1.01	41.37778	-81.60175	Cuyahoga	None

[a] Coordinate System: decimal degrees, ellipsoid=GRS80, datum=NAD83

[b] Site relocated because PSP location either impractical or unsafe.

[c] Site relocated to meet project DQOs.

Appendix C: Supplementary Maps

Figures 58 through 67 are maps of land cover, surficial geology, bedrock geology, and inventory sites.

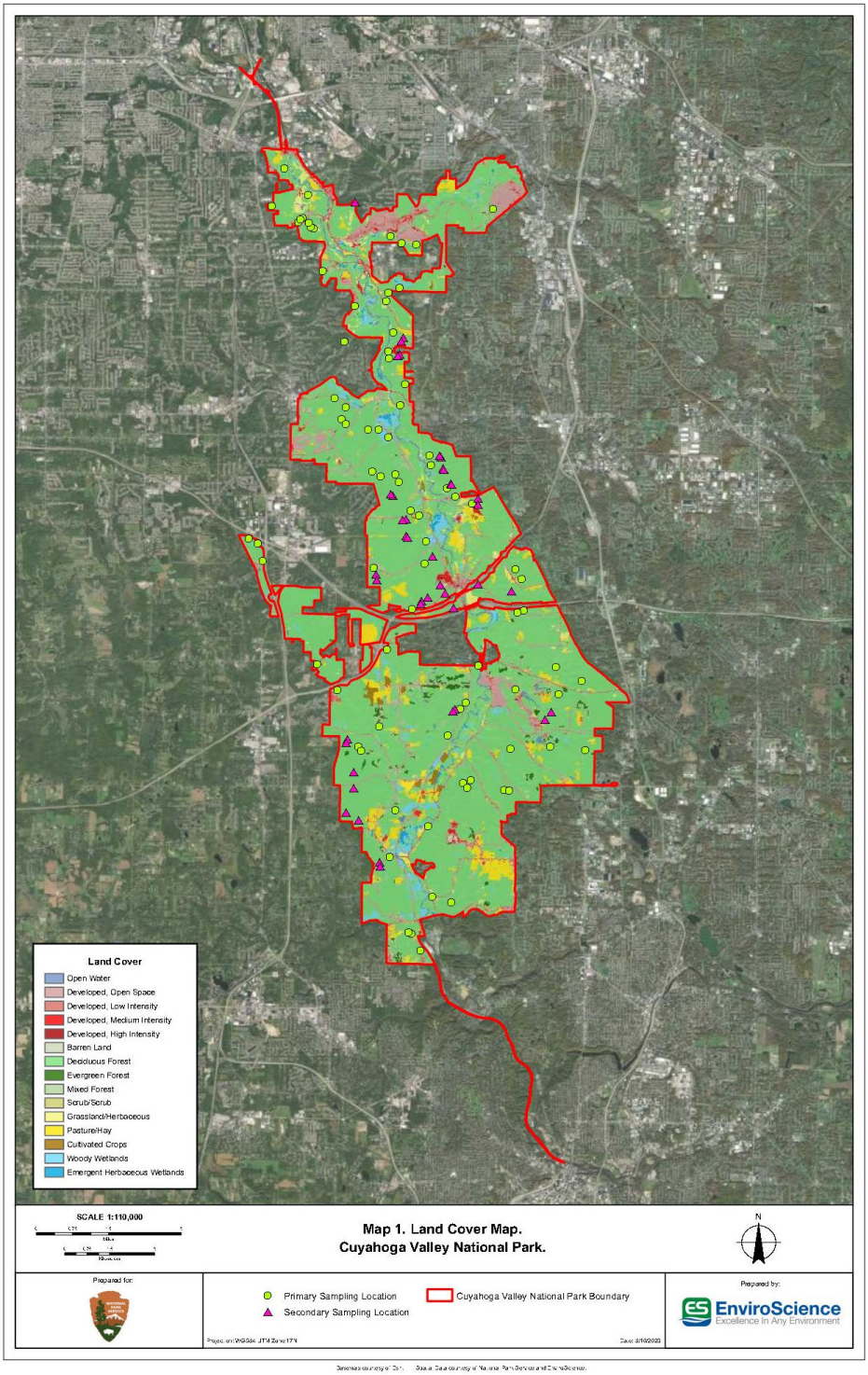


Figure 58. Map of Cuyahoga Valley National Park land cover.

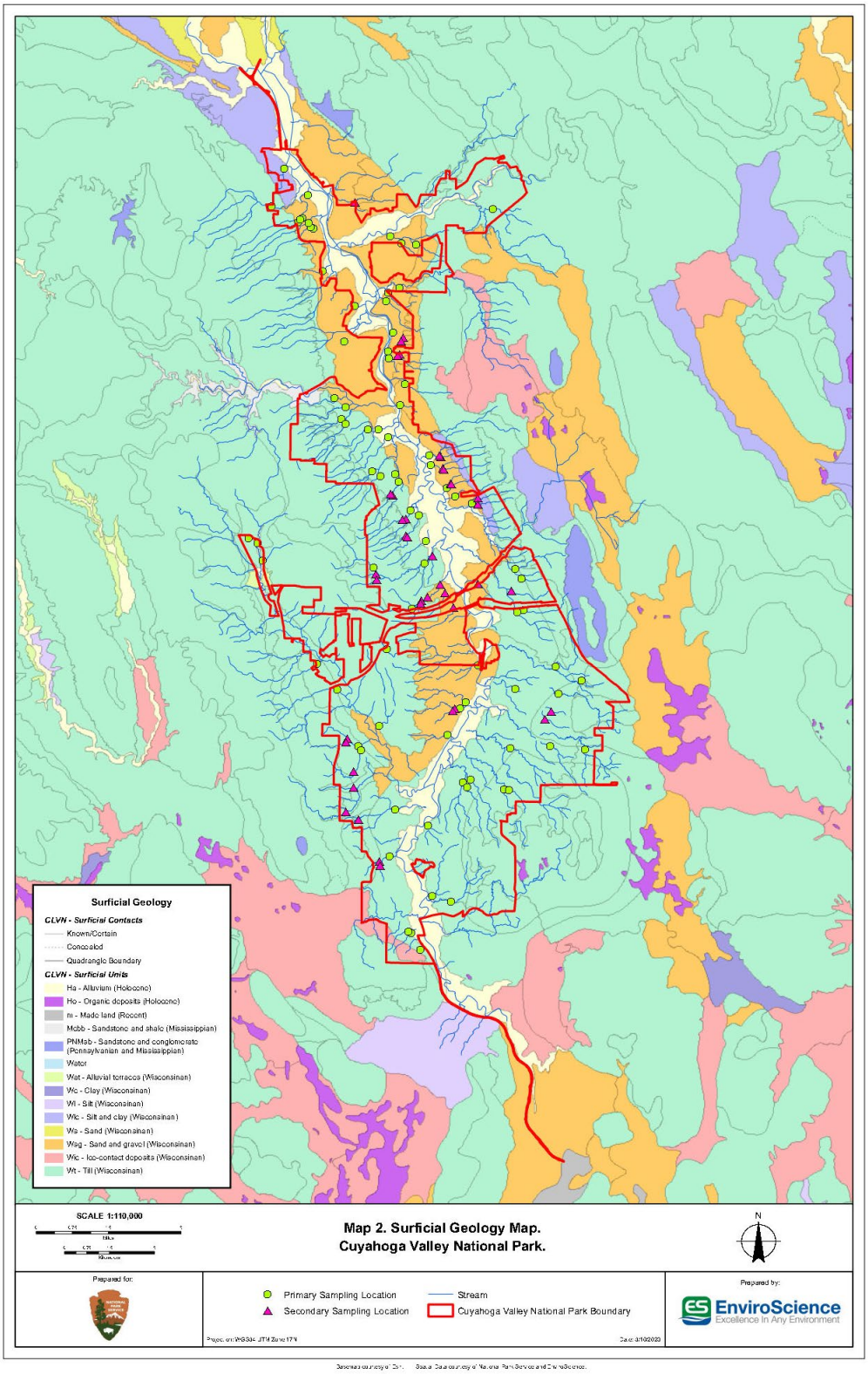


Figure 59. Map of Cuyahoga Valley National Park surficial geology.

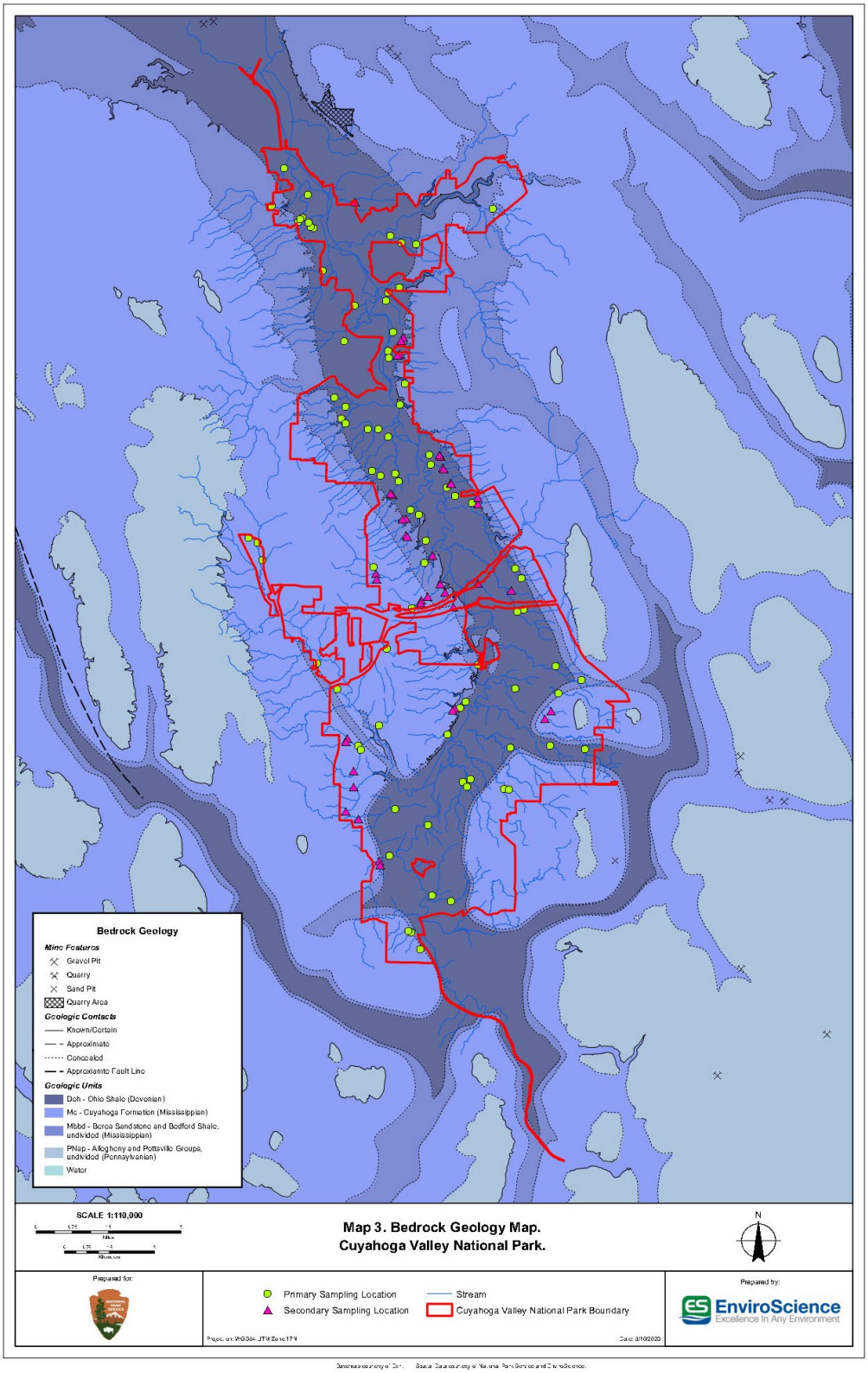


Figure 60. Map of Cuyahoga Valley National Park bedrock geology.

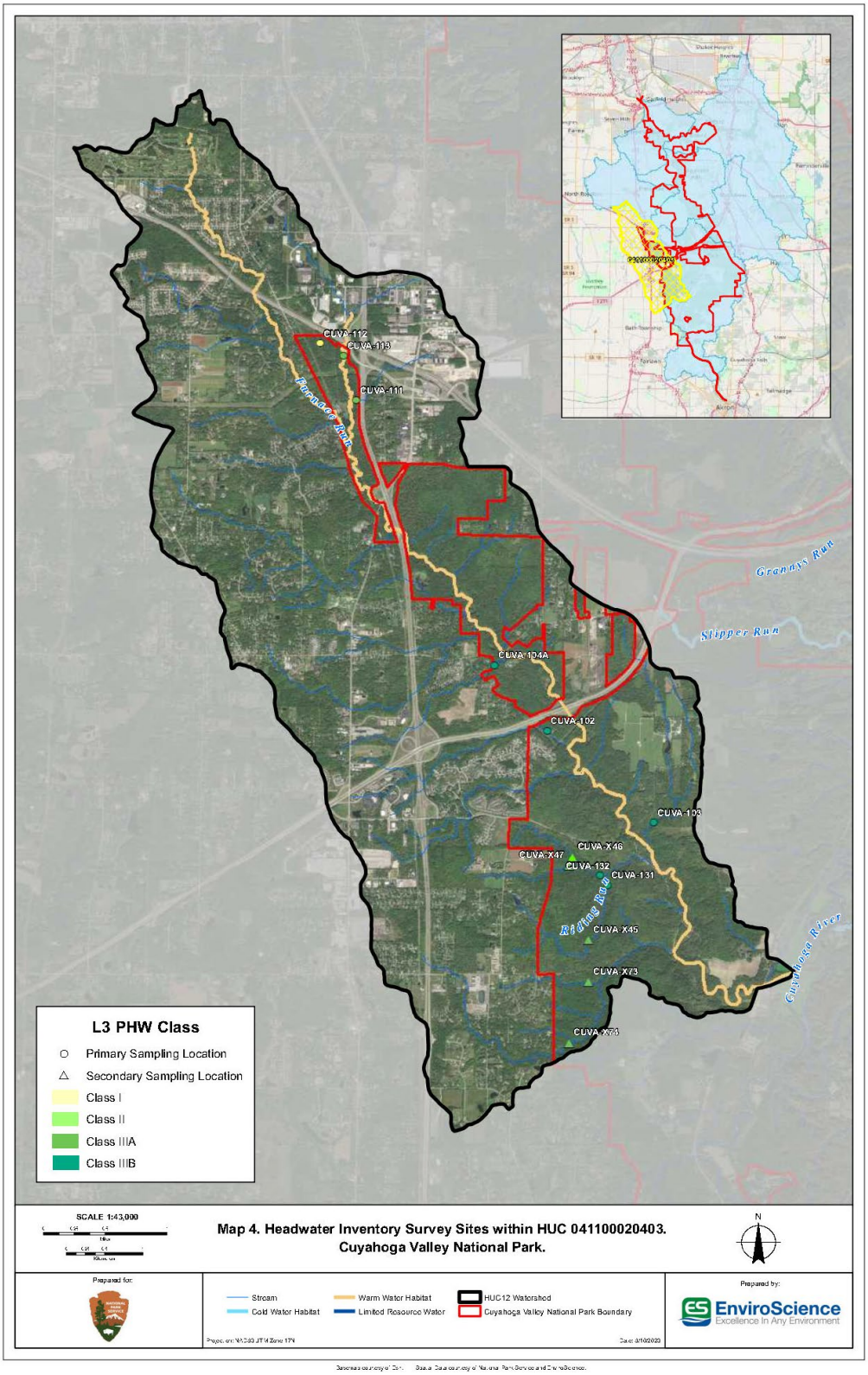


Figure 61. Map of Cuyahoga Valley National Park Headwater Inventory survey sites within HUC 041100020403.

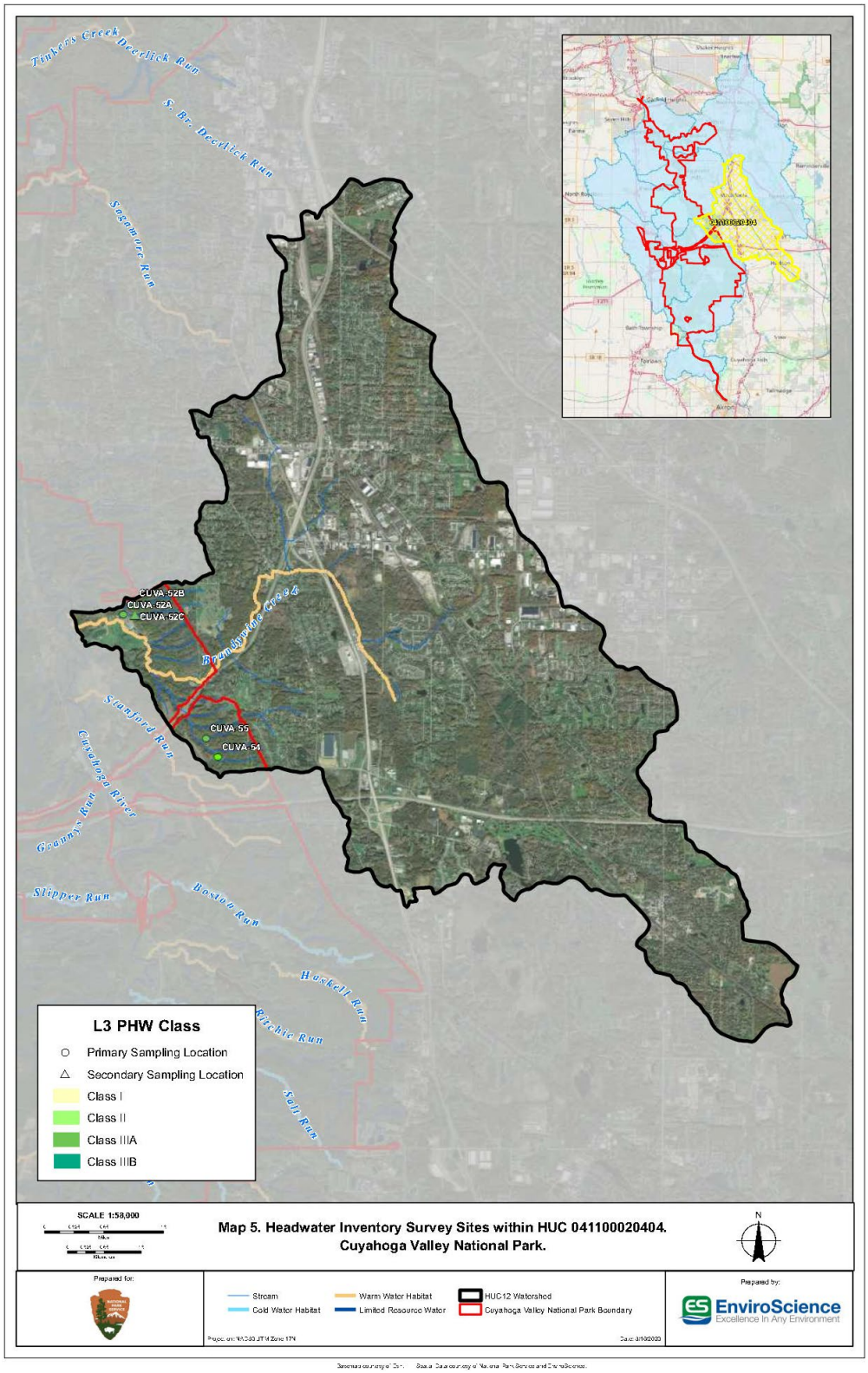


Figure 62. Map of Cuyahoga Valley National Park Headwater Inventory survey sites within HUC 041100020404.

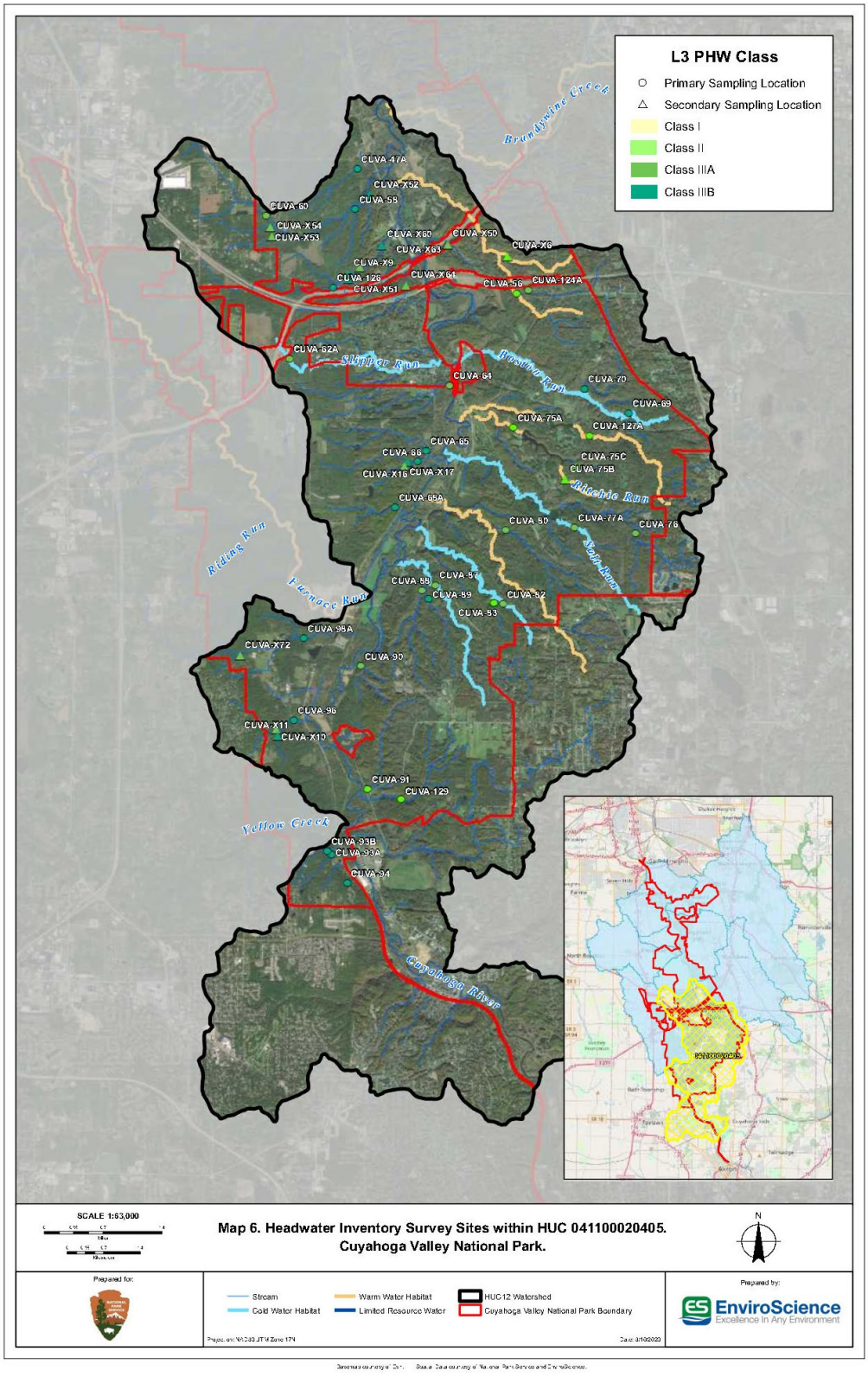


Figure 63. Map of Cuyahoga Valley National Park Headwater Inventory survey sites within HUC 041100020405.

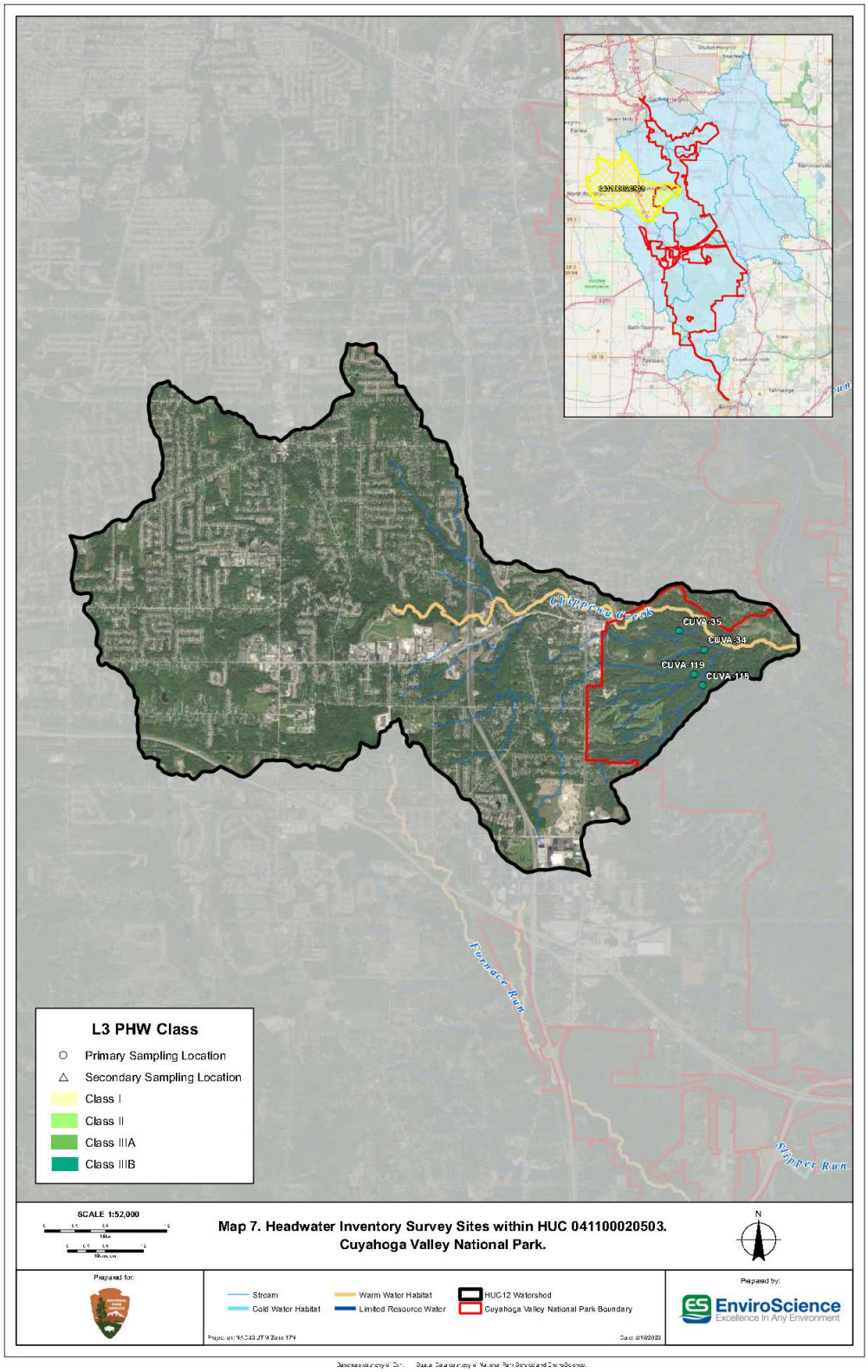


Figure 64. Map of Cuyahoga Valley National Park Headwater Inventory survey sites within HUC 041100020503.

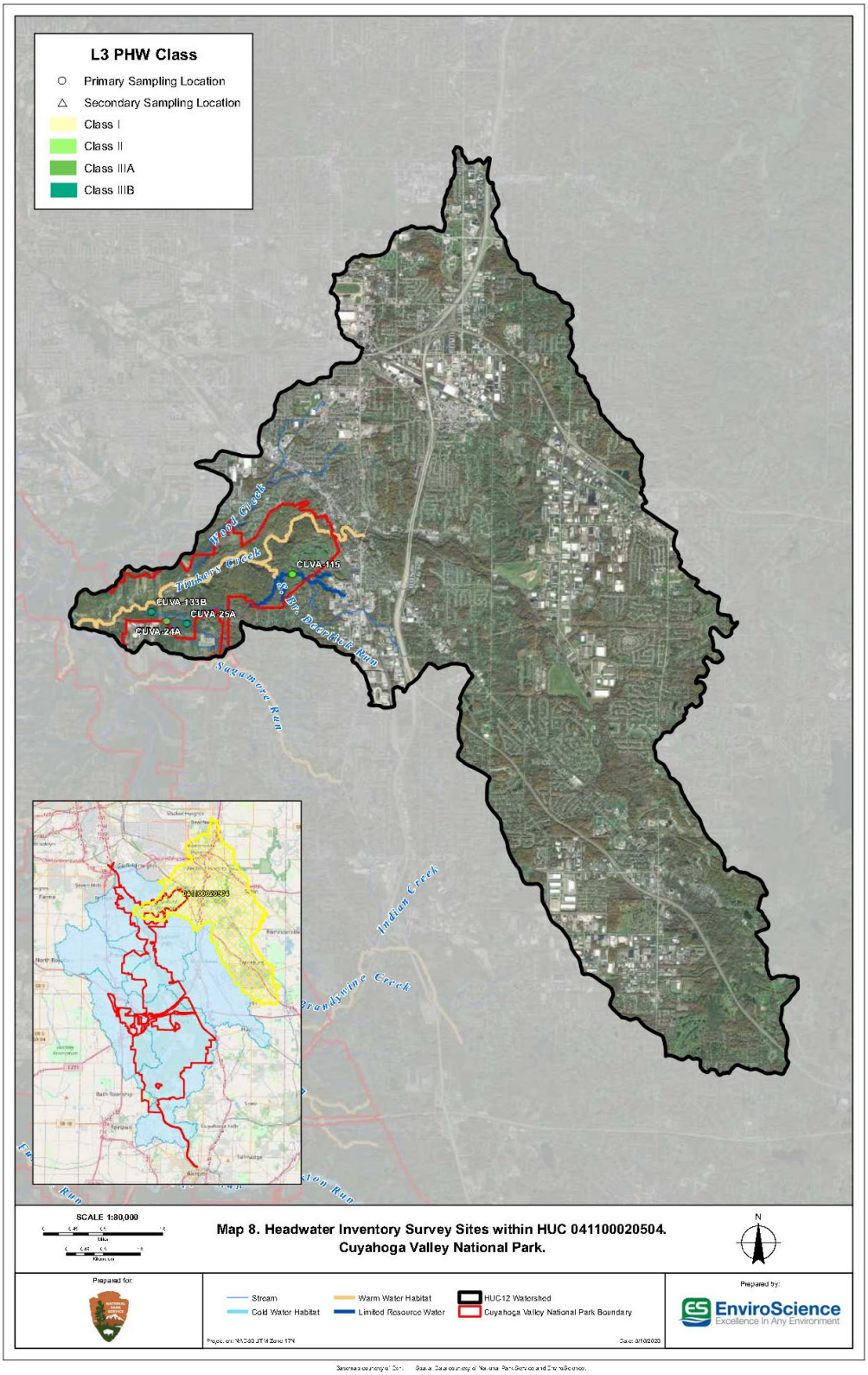


Figure 65. Map of Cuyahoga Valley National Park Headwater Inventory survey sites within HUC 041100020504.

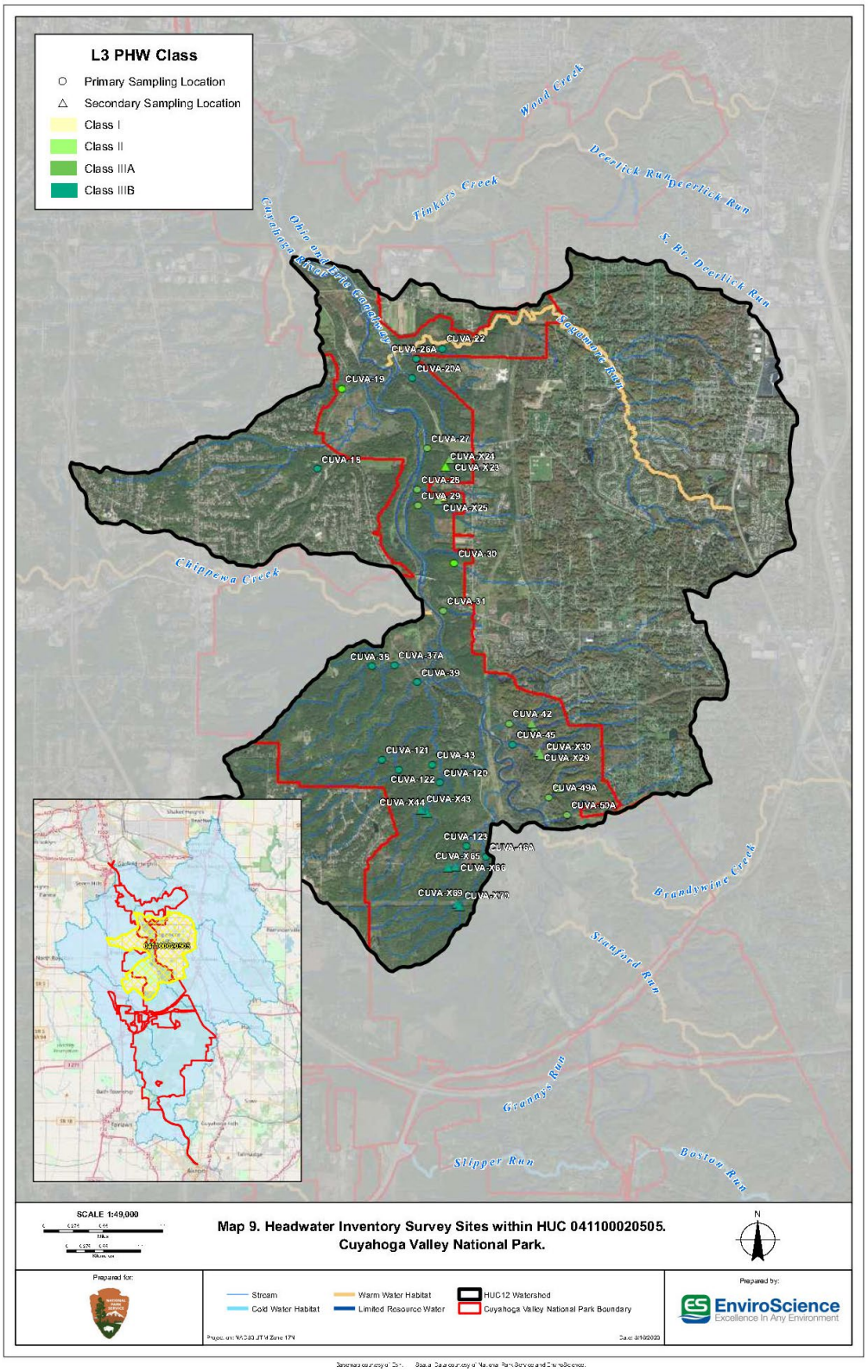


Figure 66. Map of Cuyahoga Valley National Park Headwater Inventory survey sites within HUC 041100020505.

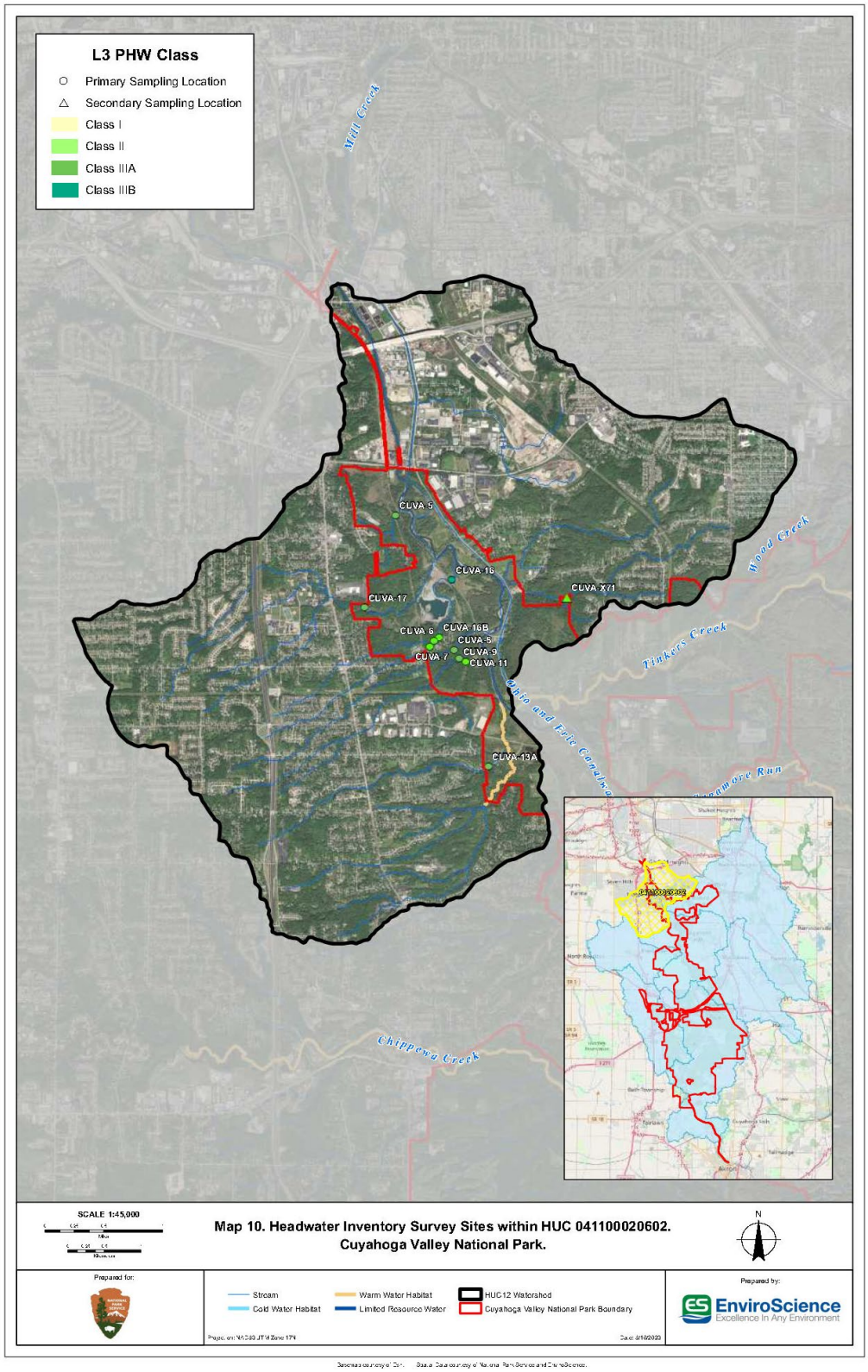


Figure 67. Map of Cuyahoga Valley National Park Headwater Inventory survey sites within HUC 041100020602.

Appendix D: Example Site Photos

Figures 68 through 81 are site photos demonstrating primary headwater stream class characteristics and Rosgen stream channel types.



Figure 68. Photo of site CUVA-X27: Class I PHW; Rosgen stream channel type F2b (source: ENVIROSCIENCE).



Figure 69. Photo of site CUVA-X112: Class I PHW; Rosgen stream channel type B3c (source: ENVIROSCIENCE).



Figure 70. Photo of site CUVA-83: Class II PHW; Rosgen stream channel type B4c (source: ENVIROSCIENCE).



Figure 71. Photo of site CUVA-77A: Class IIIA PHW; Rosgen stream channel type B4c (source: ENVIROSCIENCE).



Figure 72. Photo of site CUVA-47A: Class IIIB PHW; Rosgen stream channel type B4c (source: ENVIROSCIENCE).



Figure 73. Photo of site CUVA-X30: Class IIIA PHW; Rosgen stream channel type B3c (source: ENVIROSCIENCE).



Figure 74. Photo of site CUVA-77A: Class IIIB PHW; Rosgen stream channel type (source: ENVIROSCIENCE).



Figure 75. Photo of site CUVA-75C: Class II PHW; Rosgen stream channel type C4 (source: ENVIROSCIENCE).



Figure 76. Photo of site CUVA-93A: Class IIIB PHW; Rosgen stream channel type C4 (source: ENVIROSCIENCE).



Figure 77. Photo of site CUVA-X71: Class II PHW; Rosgen stream channel type F4 (source: ENVIROSCIENCE).



Figure 78. Photo of site CUVA-88: Class IIIA PHW; Rosgen stream channel type F4 (source: ENVIROSCIENCE).



Figure 79. Photo of site CUVA-37A: Class IIIA PHW; Rosgen stream channel type F4 (source: ENVIROSCIENCE).



Figure 80. Photo of site CUVA-64: Class IIIA PHW; Rosgen stream channel type G3 (source: ENVIROSCIENCE).



Figure 81. Photo of site CUVA-X69: Class IIIB PHW; Rosgen stream channel type G3 (source: ENVIROSCIENCE).

Appendix E: Macroinvertebrate Community L3 Analyses and Classification Results

Table 42. Summary of macroinvertebrate community L3 analyses and classification results for CUVA headwater inventory sites.

HUC12	Site Category	Site Name	Total Taxa	Cold Water Taxa	EPT Taxa	Sensitive Taxa	PHW Class (Macroinv.)
041100020403	Primary	CUVA-102	28	9	12	12	Class IIIB
	Primary	CUVA-103	21	6	11	12	Class IIIB
	Primary	CUVA-104A	32	6	10	10	Class IIIB
	Primary	CUVA-111	24	2	7	4	Class II
	Primary	CUVA-112	12	1	0	1	Class I
	Primary	CUVA-113	19	1	3	2	Class II
	Primary	CUVA-131	31	8	16	12	Class IIIB
	Primary	CUVA-132	22	5	9	6	Class IIIB
	Secondary	CUVA-X45	18	2	6	6	Class II
	Secondary	CUVA-X46	18	3	7	4	Class II
	Secondary	CUVA-X47	10	1	3	1	Class II
	Secondary	CUVA-X73	9	2	3	2	Class II
	Secondary	CUVA-X74	17	1	7	3	Class II
041100020404	Primary	CUVA-52A	13	3	5	3	Class II
	Primary	CUVA-54	12	1	5	2	Class II
	Primary	CUVA-55	27	3	8	4	Class II
	Secondary	CUVA-52B	9	0	1	1	Class II
	Secondary	CUVA-52C	1	0	0	0	Class I
041100020405	Primary	CUVA-124A	10	1	3	1	Class II
	Primary	CUVA-126	39	9	12	14	Class IIIB
	Primary	CUVA-127A	32	3	11	5	Class II
	Primary	CUVA-129	14	2	8	5	Class II
	Primary	CUVA-29	12	2	5	2	Class II
	Primary	CUVA-30	15	1	0	0	Class II
	Primary	CUVA-31	12	2	4	2	Class II
	Primary	CUVA-47A	29	9	12	13	Class IIIB

Table 42 (continued). Summary of macroinvertebrate community L3 analyses and classification results for CUVA headwater inventory sites.

HUC12	Site Category	Site Name	Total Taxa	Cold Water Taxa	EPT Taxa	Sensitive Taxa	PHW Class (Macroinv.)
041100020405 (continued)	Primary	CUVA-56	12	0	2	0	Class II
	Primary	CUVA-58	57	12	27	27	Class IIIB
	Primary	CUVA-60	15	2	6	5	Class II
	Primary	CUVA-62A	10	2	1	3	Class II
	Primary	CUVA-64	13	2	6	5	Class II
	Primary	CUVA-65	49	12	25	24	Class IIIB
	Primary	CUVA-66	43	11	25	24	Class IIIB
	Primary	CUVA-68A	25	10	12	11	Class IIIB
	Primary	CUVA-69	33	4	7	11	Class IIIB
	Primary	CUVA-70	40	3	9	6	Class II
	Primary	CUVA-75A	14	0	2	0	Class II
	Primary	CUVA-76	43	2	13	8	Class II
	Primary	CUVA-77A	18	3	11	8	Class II
	Primary	CUVA-80	34	3	14	7	Class II
	Primary	CUVA-82	22	3	7	5	Class II
	Primary	CUVA-83	33	2	9	7	Class II
	Primary	CUVA-87	41	3	13	10	Class II
	Primary	CUVA-88	26	4	9	5	Class IIIA
	Primary	CUVA-89	33	5	11	7	Class IIIB
	Primary	CUVA-90	11	4	4	3	Class IIIA
	Primary	CUVA-91	10	3	2	2	Class II
	Primary	CUVA-93A	36	6	14	13	Class IIIB
	Primary	CUVA-93B	28	6	13	9	Class IIIB
	Primary	CUVA-94	25	7	10	7	Class IIIB
	Primary	CUVA-96	24	8	12	11	Class IIIB
	Primary	CUVA-98A	32	6	9	6	Class IIIB
	Secondary	CUVA-75B	10	0	2	1	Class II
	Secondary	CUVA-75C	13	0	2	1	Class II
	Secondary	CUVA-X10	28	3	9	6	Class II

Table 42 (continued). Summary of macroinvertebrate community L3 analyses and classification results for CUVA headwater inventory sites.

HUC12	Site Category	Site Name	Total Taxa	Cold Water Taxa	EPT Taxa	Sensitive Taxa	PHW Class (Macroinv.)
041100020405 (continued)	Secondary	CUVA-X11	31	7	9	10	Class IIIB
	Secondary	CUVA-X16	31	5	13	11	Class IIIB
	Secondary	CUVA-X17	11	2	6	5	Class II
	Secondary	CUVA-X50	36	4	7	2	Class IIIA
	Secondary	CUVA-X51	42	6	13	10	Class IIIB
	Secondary	CUVA-X52	27	7	16	17	Class IIIB
	Secondary	CUVA-X53	12	2	5	4	Class II
	Secondary	CUVA-X54	5	0	1	0	Class II
	Secondary	CUVA-X6	34	2	7	8	Class II
	Secondary	CUVA-X60	18	4	9	9	Class IIIB
	Secondary	CUVA-X61	14	3	7	7	Class II
	Secondary	CUVA-X63	20	4	6	6	Class IIIA
	Secondary	CUVA-X64	12	3	5	3	Class II
	Secondary	CUVA-X72	12	2	4	4	Class II
	Secondary	CUVA-X9	27	5	12	10	Class IIIB
041100020503	Primary	CUVA-118	34	6	10	8	Class IIIB
	Primary	CUVA-119	25	7	10	10	Class IIIB
	Primary	CUVA-34	24	4	7	5	Class IIIB
	Primary	CUVA-35	31	6	11	6	Class IIIB
	Primary	CUVA-115	21	2	6	3	Class II
	Primary	CUVA-133B	24	7	9	5	Class IIIB
	Primary	CUVA-24A	22	3	5	2	Class II
	Primary	CUVA-25A	30	7	5	8	Class IIIB
041100020505	Primary	CUVA-120	44	7	13	11	Class IIIB
	Primary	CUVA-121	24	5	8	9	Class IIIB
	Primary	CUVA-122	29	6	7	10	Class IIIB
	Primary	CUVA-123	29	8	13	12	Class IIIB
	Primary	CUVA-18	22	2	7	3	Class II
	Primary	CUVA-19	20	2	0	2	Class II

Table 42 (continued). Summary of macroinvertebrate community L3 analyses and classification results for CUVA headwater inventory sites.

HUC12	Site Category	Site Name	Total Taxa	Cold Water Taxa	EPT Taxa	Sensitive Taxa	PHW Class (Macroinv.)
041100020505 (continued)	Primary	CUVA-20A	20	7	7	6	Class IIIB
	Primary	CUVA-22	21	8	5	10	Class IIIB
	Primary	CUVA-26A	35	8	10	11	Class IIIB
	Primary	CUVA-27	15	1	3	1	Class II
	Primary	CUVA-28	14	2	6	3	Class II
	Primary	CUVA-37A	40	7	13	13	Class IIIB
	Primary	CUVA-38	36	6	13	10	Class IIIB
	Primary	CUVA-39	47	7	13	12	Class IIIB
	Primary	CUVA-42	12	3	3	1	Class II
	Primary	CUVA-43	23	6	7	9	Class IIIB
	Primary	CUVA-45	21	5	10	7	Class IIIB
	Primary	CUVA-46A	16	3	9	8	Class II
	Primary	CUVA-49A	15	3	7	5	Class II
	Primary	CUVA-50A	14	1	2	1	Class II
	Secondary	CUVA-X23	10	2	5	2	Class II
	Secondary	CUVA-X24	14	3	8	2	Class II
	Secondary	CUVA-X25	13	0	3	1	Class II
	Secondary	CUVA-X26	2	1	0	0	Class I
	Secondary	CUVA-X27	9	0	4	2	Class II
	Secondary	CUVA-X28	18	3	7	4	Class II
	Secondary	CUVA-X29	21	3	8	8	Class II
	Secondary	CUVA-X30	19	4	5	4	Class IIIA
	Secondary	CUVA-X43	30	4	13	10	Class IIIB
	Secondary	CUVA-X44	23	0	5	0	Class II
	Secondary	CUVA-X48	12	1	3	4	Class II
	Secondary	CUVA-X49	34	2	7	6	Class II
	Secondary	CUVA-X65	29	4	11	8	Class IIIB
	Secondary	CUVA-X66	27	6	12	14	Class IIIB
	Secondary	CUVA-X69	20	5	9	10	Class IIIB

Table 42 (continued). Summary of macroinvertebrate community L3 analyses and classification results for CUVA headwater inventory sites.

HUC12	Site Category	Site Name	Total Taxa	Cold Water Taxa	EPT Taxa	Sensitive Taxa	PHW Class (Macroinv.)
041100020505 (continued)	Secondary	CUVA-X70	27	6	9	9	Class IIIB
041100020602	Primary	CUVA-11	22	3	9	2	Class II
	Primary	CUVA-13A	33	3	11	3	Class II
	Primary	CUVA-16	21	0	4	1	Class II
	Primary	CUVA-16B	22	3	7	3	Class II
	Primary	CUVA-17	26	2	7	2	Class II
	Primary	CUVA-5	23	3	8	3	Class II
	Primary	CUVA-6	19	2	7	5	Class II
	Primary	CUVA-7	20	3	6	2	Class II
	Primary	CUVA-8	28	4	8	5	Class IIIA
	Primary	CUVA-9	40	4	11	5	Class IIIA
	Secondary	CUVA-X71	16	1	4	1	Class II

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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