User Manual & Scientific Support for the Ohio Stream Assessment Method (OSAM)

Division of Surface Water
401, Isolated Wetland Permitting, and Mitigation Section

Version 3.0 - March 2024

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Acknowledgements

The Ohio Stream Assessment Method (OSAM) 3.0 is adapted from earlier Stream Quantification Tools (SQT) all developed from concepts established by Stream Mechanics and Ecosystem Planning and Restoration. Special attention was paid to other US EPA Region 5 tools developed for Minnesota, Wisconsin, and Michigan. Most instrumental to the development of OSAM 3.0 was the Georgia SQT, which is refined to encompass fewer metrics and was used as a starting template. OSAM was developed with input and feedback from stakeholders during the Ohio's stream rulemaking process. OSAM also includes valuable input from our partners at the Buffalo, Huntington, and Pittsburgh Corps Districts, as well as USEPA, Region 5. We look forward to working with these groups moving forward to develop the best tool possible for Ohio.

Glossary of Terms

Alluvial Valley - Valley formed by the deposition of sediment from fluvial processes.

Catchment - Portion of the project watershed that drains to the uppermost extent of the assessment reach. The catchment is the total drainage area contributing to the assessment reach.

Colluvial Valley - Valley formed by the deposition of sediment from hillslope erosion processes, typically confined by terraces or hillslopes.

Condition Score - A value between 0.00 and 1.00 that expresses whether the associated parameter, functional category, or overall assessment reach is functioning, functioning-at- risk, or not functioning compared to a reference condition.

- ECS = Existing Condition Score
- PCS = Proposed Condition Score

Credit - A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the accrual or attainment of aquatic functions at a compensatory mitigation site. The measure of aquatic functions is based on the resources restored, established, enhanced, or preserved (33 CFR 332.2; 40 CFR 230.922).

Debit – A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the loss of aquatic functions at an impact or project site. The measure of aquatic functions is based on the resources impacted by the authorized activity (33 CFR 332.2; 40 CFR 230.92).

Flow Regime –

Ephemeral- These streams are normally dry and only flow during and after precipitation runoff (episodic flow). These streams normally have a dry stream channel with no evidence of isolated pools of water.

Intermittent- These streams have flow for extended periods of time seasonally, but gradually reach a state where there are either isolated pools of water that are not hydraulically connected by sub-surface flow, or a dry channel. Biology may be present in wet hyporheic subsurface substrate.

Perennial- Water that flows permanently in a stream channel.

Functional Capacity - The degree to which an area of aquatic resource performs a specific function (33 CFR 332.2; 40 CFR 230.92).

Functional Category - The levels of the Stream Functions Pyramid Framework: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. Each category is defined by a functional statement.

Functional Foot Score (FFS) - The product of a condition score and stream length.

- Existing FFS = Existing Functional Foot Score. Calculated by measuring the existing stream length and multiplying it by the ECS.
- Proposed FFS = Proposed Functional Foot Score. Calculated by measuring the proposed stream length and multiplying it by the PCS.

Function-Based Parameter – A structural measure or function (e.g., expressed as a rate) that both represents and supports the ecosystem functions expressed as functional statements for each functional category.

Functions - The physical, chemical, and biological processes that occur in ecosystems (33 CFR 332.2; 40 CFR 230.92).

Performance Standard - Observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine if a compensatory mitigation project meets its objectives (33 CFR 332.2; 40 CFR 230.92). OSAM uses reference curves that convert measured field data values (i.e., measurement methods) to an index value of between 0.0 and 1.0.

Reference Conditions - Conditions incorporating the whole range of variability exhibited by a regional class of aquatic resource as a result of both natural processes and anthropogenic disturbances (33 CFR 332.1; 40 CFR 230.92).

Reference Standard Condition - A stream condition that is considered fully functioning for the parameter being assessed.

Restoration - Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource (33 CFR 332.2; 40 CFR 230.92).

Riparian Buffer (a.k.a. stream buffer or buffer) - Zone or area extending outwards from top of bank on either side of the channel that is comprised of natural vegetation. In Ohio, natural riparian buffer vegetation should typically include a mixed assemblage of trees, saplings, shrubs, vines, and ground cover vegetation.

Stream Functions Pyramid Framework (SFPF) - The Stream Functions Pyramid is comprised of five functional categories (see above) stratified based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate.

1. Introduction and Purpose

Substitute House Bill 175 (HB 175), passed by the 134th Ohio General Assembly and signed into law by Governor DeWine on April 20, 2022, directed the Ohio Environmental Protection Agency (Ohio EPA/the Agency) to adopt substantive mitigation standards into rule by July 2024. As a part of the Agency's effort to develop stream mitigation rules in accordance with the requirements of HB 175, Ohio EPA began evaluating existing stream mitigation frameworks currently or historically utilized within Ohio and in other states. As a result, the Ohio Stream Assessment Method (OSAM) was developed as a debit/credit functional tool and is based on the Georgia Stream Quantification Tool (SQT) using the Stream Functional Pyramid. Although the OSAM is based on Georgia's tool, it was modified and adapted for use in Ohio.

During pre-early stakeholder outreach, Ohio EPA presented several paths toward rule making, including promulgation of the current 2016 Guidelines and further evaluation and adoption of a debit/credit functional assessment framework based upon the SQT (specifically Georgia's SQT developed by the Savannah Corps District (Somerville et al., 2021)). During subsequent discussions with interested parties, a stakeholder developed and proposed the Ohio Stream Assessment Method ("OSAM") tool, which is based on the Georgia SQT/Stream Functional Pyramid (Figure 1) but modified and adapted for use in Ohio. Ohio EPA has evaluated OSAM and determined it has merit as a debit/credit functional assessment framework for use by the Section 401 and 404 Clean Water Act programs in Ohio. Ohio plans to further develop this tool through updating regional curves for Ohio and through the collection of data to verify and establish reference curves based on data collected in Ohio. This version of OSAM should be considered interim, as additional data will be collected to better inform the tool.

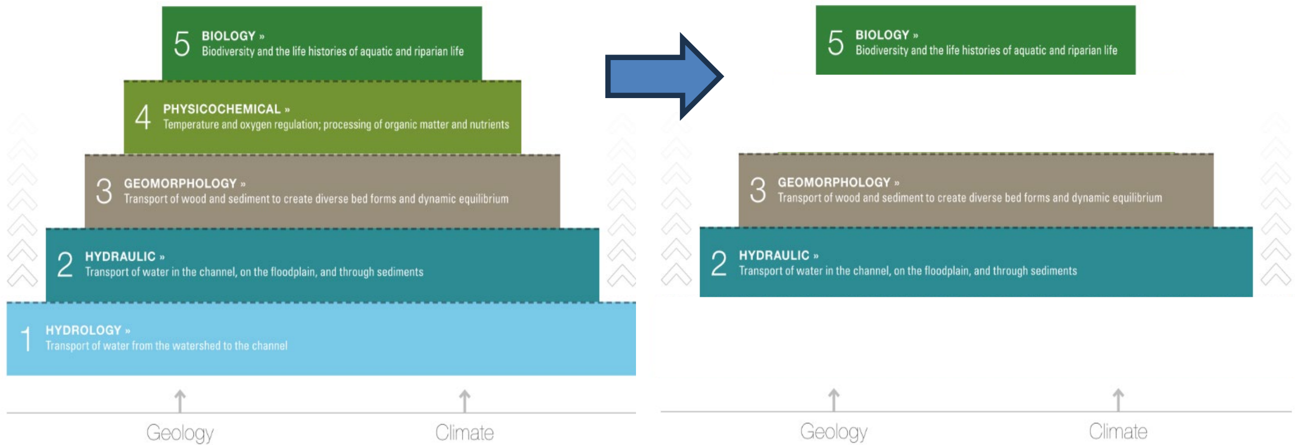


Figure 1. SQT is based upon the Stream Functional Pyramid (Harman et al. 2012). Continued iterative development of SQTs for various states and Corps Districts has led to refinement of function-based parameters that have become incorporated in various SQTs. "SQT Lite" in Georgia dropped the hydrology and physiochemical function-based parameters to focus on hydraulics, geomorphology, and biology; this is continued in the OSAM for the majority of cases.

Overview of Ohio Stream Assessment Method (OSAM)

The OSAM is a multi-metric, objective, quantitative evaluation of several stream parameters associated with hydraulics, geomorphology, and biology (or physiochemical characteristics in lieu of biology for mitigation projects proposing to address stream impairments due to acid mine drainage [AMD]). The tool evaluates stream parameters that impact functions and provides a method to directly measure functional loss associated with an impact site to determine debits, or functional lift associated with a mitigation project to assign credits. While the Hydrology and Physiochemical steps of the pyramid are clearly important functions, they were not included to streamline the tool. Hydrology can be influenced by site selection and should be considered at that step. Additionally, data in Ohio has shown that chemical impacts to streams are not a large source of impairment, stream quality is more largely affected by human modifications and development. OSAM attempts to focus on the functions that are most responsive to restoration efforts.

OSAM calculates credits and debits based on the length of stream affected by the project. It should be noted, OSAM is not a design tool. The function-based parameters, metrics, and index values are not intended to be used as the basis for design criteria. OSAM measures the existing functions and measures the predicted or actual response or outcome to a project design at a reach scale.

The purpose of this User Manual is to introduce the (OSAM) and provide both background and instruction on its use to calculate functional lift and determine the amount of stream mitigation credits awarded and owed for projects undertaken in accordance with the Clean Water Act

(CWA), Section 404 and 401 regulatory programs in Ohio. This manual includes descriptions of how to collect and calculate field values for each assessment metric in the stream reach condition assessments and describes how those field values are converted to index values within the OSAM. Few measurements are unique to the OSAM, and procedures are often detailed in other instruction manuals or literature. Where appropriate, this document will reference other data collection manuals and make clear any differences in data collection or calculation methods needed for the OSAM. This manual will refer to stream restoration in accordance with the definition used by the Final Mitigation Rule (33 CFR 332; 40 CFR 230):

Restoration means the manipulation of the physical, chemical, or biological characteristics of a *site with the goal of returning natural/historic functions to* a *former or degraded aquatic resource.*

This definition encompasses all activities aimed to improve stream functions undertaken for compensatory mitigation or other purposes. Fischenich (2006) described 15 key stream and riparian zone functions aggregated into five categories including system dynamics, hydrologic balance, sediment processes and character, biological support, and chemical processes and pathways. This work informed the development of the Stream Functions Pyramid Framework (SFPF; Harman et al., 2012) and the North Carolina SQT (Harman and Jones, 2017). The functional pyramid provides an organizational framework around which stream restoration practitioners and project reviewers can develop and identify clear goals, inform better site selection and focus on a suite of measurements for assessing applicable functions in an objective manner. This document and the OSAM worksheet assume the reader has a firm knowledge of stream processes and the SFPF. Therefore, it does not provide extensive definitions of geomorphic terms such as bankfull, thalweg, riffle, etc.

Collection and analysis of the watershed-scale and stream reach-scale data necessary to evaluate a stream restoration project, or even selecting a potential stream restoration site, is not limited to the assessment metrics and methods included in the OSAM. The OSAM incorporates only some of the necessary assessment metrics that all stream restoration practitioners collect to assess and document as part of project siting and planning. Thus, the OSAM is not a stand-alone method or protocol for monitoring or planning stream restoration projects.

OSAM takes the form of a macro-enabled Excel spreadsheet. Once general site information has been completed, field values for various assessments evaluating existing condition (for impact and mitigation sites) and proposed condition (for mitigation sites) are entered. Linear feet of impact or linear feet of mitigation is adjusted based upon a stream's existing condition score and proposed condition score to determine functional loss or gain, and thus debits and credits. Several assessment methods and scoring ranges are based upon Rosgen stream type, drainage area, or channel slope – the tool automatically selects and calculates the appropriate metric based upon those criteria. The various metrics and assessment methodologies utilized within OSAM have scoring ranges that have been adjusted to Ohio's stream systems using data published by Ohio EPA or by other authorities (e.g., Rosgen 1994).

The OSAM Microsoft Excel Workbook and User Manual can be downloaded from Ohio EPA's website at: https://epa.ohio.gov/divisions-and-offices/surface-water/permitting/wetland-and-stream-mitigation

The OSAM and accompanying documents will be updated periodically as additional data are gathered and reference standards and assessment metrics are refined. Users are encouraged to periodically review the documents posted to this directory in case updates have been made since their last use of the OSAM.

2. Getting Started with the OSAM

The OSAM is used to determine mitigation credit allocations for stream mitigation projects undertaken pursuant to the CWA 404 and 401 regulatory programs. The assessment metrics, measurement methods, and associated performance standards utilized in the OSAM will not necessarily be the only field variables necessary to be monitored, nor will they be the only field variables for which performance standards will be assigned.

The OSAM uses three functional categories from the SFPF: Hydraulics, Geomorphology and Biology (or physiochemical characteristics in lieu of biology for mitigation projects proposing to address stream impairments due to acid mine drainage (AMD)). The tool evaluates stream parameters that impact functions and provides a method to directly measure functional loss associated with an impact site to determine debits, or functional lift associated with a mitigation project to assign credits. All OSAM functional categories, parameters, and assessment metrics used to assess existing (baseline) conditions must also be used to assess post-construction conditions throughout the monitoring period.

As previously mentioned, OSAM takes the form of a macro-enabled Excel spreadsheet. Users are directed to enter information associated with a project site (e.g., watershed, county, latitude/longitude, project type, etc.). Once general site information has been completed, field values for various assessments evaluating existing condition (for impact and mitigation sites) and proposed condition (for mitigation sites) are entered. *Please note that two spreadsheets will need completed for each stream – one for the impact site and one for the mitigation site.*

Debits are calculated based on the length of impact to the stream and the existing condition score to determine the functional loss. Credits generated are determined considering the existing and proposed conditions to generate a functional foot score (FFS) which is applied to the stream mitigation length provided to calculate a functional gain. Measurement methods and applicable reference curves are based upon Rosgen stream type, drainage area, ecoregion and channel slope – the spreadsheet automatically selects the appropriate parameter and measurement method based upon those criteria. The various metrics utilized within OSAM have scoring ranges that have been adjusted to Ohio's stream systems using data published by Ohio EPA, provided by the development of the GA SQT, other SQT development, or by other authorities (e.g. Rosgen 1994). References to assessment manuals or technical reports, including citations and weblinks, are provided within the spreadsheet.

2.1 Site Information

The Site Information section of the OSAM Excel spreadsheet includes general site information and other project-specific information necessary to determine which reference curves are applied for calculating index values. The values selected or entered into these fields establish links between the OSAM spreadsheet and the applicable reference curves. It is therefore important for the user to input accurate site information.

Some fields in this section include drop-down menus from which the user selects the appropriate value, while others require information to be entered manually. The blue fields are those where you can select from a drop-down menu. The gray fields are those in which you will need to manually enter the information.

2.2 Existing and Proposed Condition Assessment Field Values

Once the Site Information section has been completed, the user may input data into the field value column of the Existing and Proposed Condition Assessment tables.

The Existing Condition Assessment field values are derived from measurements collected in the field during baseline condition assessment of the project site before any work is undertaken. The Proposed Condition Assessment field values are estimated during the development of the mitigation plan, and informed by design studies/calculations, reports, and best available science. Proposed Condition field values are subsequently validated or refined by measurements in the field during the post-construction monitoring phase. Realized functional gain is calculated based on field measurements taken during the monitoring period and entered into the Proposed Condition field values. The Existing Condition Assessment is the baseline.

2.3 Scoring Functional Gain

Scoring occurs automatically as field values for each assessment metric are entered into the Existing Condition Assessment or Proposed Condition Assessment tables. A field value will reflect an index value ranging from 0.0 to 1.0 for that assessment metric, based on the reference curves provided in the Reference Curves worksheet. Parameter scores within each functional category are equally weighted and averaged to calculate functional category scores for Hydraulics and Geomorphology. For Habitat and Biology (or Chemistry) weighting is determined by the drainage area of the stream when measuring biology. For AMD projects, when chemistry is used instead of biology, habitat and chemistry are equally weighted. Functional category scores are weighted to reflect a foundational approach to establishing improving stream functions and averaged to calculate an overall condition score. The Hydraulics functional category is worth 40% of the score, Geomorphology is worth 35% of the score and Biology is worth 25% of the overall condition score. This weighting reflects the stream functional pyramid, recognizing the importance of getting the lower layers functioning in order to support functional gain at the higher levels.

The OSAM spreadsheet summarizes the scoring at the top of the sheet in the Function Based Parameters Summary table, below the Site Information table. There are three summary tables:

Mitigation Site – Functional Gain (Credits), Function Based Parameters Summary, and Functional Category Report Card.

The Mitigation Site – Functional Gain (Credits) table provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections. This table illustrates the overall condition scores, functional change occurring at the project site, and incorporates the length of stream in the project to calculate the overall Functional Foot Score (FFS). The change in functional condition of the project stream is the difference between the proposed condition score (PCS) and the existing condition score (ECS). An FFS is the product of a condition score and the stream length. The table includes the existing and proposed stream lengths to calculate and display both existing and proposed FFS. Since the condition score must be 1.0 or less, an FFS is always less than or equal to the actual stream length.

$$\textit{Existing FFS} = \textit{ECS} \times \textit{Existing Stream Length}$$
$$\textit{Proposed FFS} = \textit{PCS} \times \textit{Proposed Stream length}$$

The difference between the Proposed FFS and the Existing FFS is the amount of functional gain (or loss) resulting from the project related activities and will inform the calculation of mitigation credits.

The Proposed FFS - Existing FFS score is also reported in the Mitigation Site – Functional Gain (Credits) table. If this value is a positive number, functional lift is occurring at the project site. A negative number represents a functional loss. To evaluate projects that consist of multiple reaches, the rater will need to complete one spreadsheet for each reach.

The Function Based Parameters Summary table provides a summary of the existing and proposed scores for each assessed parameter (e.g., floodplain connectivity, riparian vegetation, bed form characterization, habitat, and biology). Each of these parameter scores is calculated through the assessment of specific sets of equally weighted measurement methods (e.g., bank height ratio, entrenchment ratio, etc.). The parameter scores also play an important role in the roll up scoring of the Existing and Proposed Condition Assessments sections, as they support the calculation of functional change between the PCS and ECS.

The Functional Category Report Card table summarizes the functional change between PCS and ECS at the individual functional category level (e.g., Hydraulics, Geomorphology, Biology). The mean functional change of these functional categories is the Change in Functional Condition score outlined in the Mitigation Site – Functional Gain (Credits) table.

3. Assessment Metric Field Values

The OSAM includes Condition Assessments on the spreadsheet. Data collection and analysis procedures for existing condition assessments and post-construction monitoring events should follow the procedures outlined in this section of the User Manual. During the project design and review period, the proposed condition assessment table is filled out with data collected to inform the project design and the anticipated project outcome. Following project construction, actual measured field values collected during each monitoring event are entered in the monitoring data worksheets. Therefore, additional work or corrective actions may be necessary, based on the actual field values that are measured after project construction.

The field methods used to collect and/or calculate measured field values for each assessment metric are summarized below. Most field methods will be familiar to stream restoration practitioners, as they are based on common stream measurements or procedures that have been utilized regularly for designing and monitoring stream restoration projects. The only assessment metric with which practitioners may be unfamiliar is the Headwater Summary Macroinvertebrate Index (HWMI), for evaluating macroinvertebrates in smaller drainage areas. The HWMI is discussed further in Section 3.3 of this manual.

3.1 Hydraulics

The OSAM currently contains one function-based parameter to describe the transport of water in the channel, on the floodplain, and through sediments: floodplain connectivity. Two assessment metrics are used to quantify floodplain connectivity: bank height ratio (BHR) and entrenchment ratio (ER). This parameter is 40% of the total score and both assessment metrics (each 20% of the total score) should be used for all stream mitigation projects. Note that the reference curves are stratified by Rosgen (1996) stream type to account for differences between streams within alluvial valleys relative to colluvial valleys. Both BHR and ER should be assessed for a stream length that is 20x the bankfull width or the entire assessment reach length, using whichever is shorter (Harrelson et al., 1994). Note however that the minimum assessment reach length for the OSAM is 100 meters (328 feet). The selected reach should not be within close proximity to a structure, such as a culvert or bridge.

3.1.1 Bank Height Ratio (BHR)

Bank height ratio (BHR) is a measure of channel incision and therefore representative of the potential for a stream to inundate its floodplain; the closer the ratio is to 1.0, the greater the likelihood for bankfull flows to inundate the floodplain. Higher ratios indicate the inability of a channel to engage its floodplain except at increasingly larger storm events. The most common calculation for BHR is the low bank height divided by the maximum bankfull riffle depth (Dmax). The low bank height is the lower of the left and right streambanks (measured at a riffle), indicating the minimum water depth necessary to inundate the floodplain:

$$BHR = Low\ Bank\ Height/Dmax \qquad \text{Equation (1)}$$

To improve consistency, the OSAM requires BHR to be measured at every riffle within the assessment reach. The BHR should be measured at the midpoint of the riffle, halfway between the head of the riffle and the head of the run, or pool if there is not a run. Using this dataset, a weighted BHR is calculated using Equation (2) and illustrated in Table 1.

$$BHR_{(weighted)} = \sum_{i=1}^{n} (BHR_i * RL_i) / \sum_{i=1}^{n} RL_i \qquad \text{Equation (2)}$$

where, RL_i is the length of the riffle where BHR_i was measured.

Table 1. Example calculation of weighted bank height ratio (BHR).

Riffle ID	Length (RL)	BHR	BHR * RL
R1	25	1.0	25
R2	50	1.5	75
R3	5	1.1	5.5
R4	30	1.7	51
Total	**110 ft.**	**Total**	**156.5**
Weighted BHR = 156.5/110 = 1.4			

The reference curve for BHR is based on categories of risk provided by Rosgen (2014), where very low and low risk banks are functioning (i.e., BHR ≤1.2); high, very high, and extreme risk banks are not functioning (i.e., BHR ≥ 1.6); and moderate risk banks are functioning-at-risk (i.e., 1.2 <BHR<1.6). This approach was used by Georgia and is similar to other Midwest states researched including Michigan and Wisconsin. For the OSAM, BHR can be calculated for each riffle within the assessment reach using either detailed or rapid field methods. While rapid field methods may be suitable for preliminary site assessments, detailed methods must be used for more formal assessment of baseline conditions, design, and post-construction monitoring.

Detailed Method:
For the OSAM, the BHR is measured at riffle features from the longitudinal profile. Harrelson et al. (1994) provides field instructions for surveying a longitudinal profile, and examples of BHR calculations made at riffles along the longitudinal profile are provided in Rosgen (2014). This method is objective and reproducible, as it is measured directly from the surveyed longitudinal profile and easily verified in the office.

Rapid Method:
The rapid method for measuring BHR is undertaken in the field using a stadia rod and a hand level and does not require a longitudinal profile survey. A line level can be used instead of a

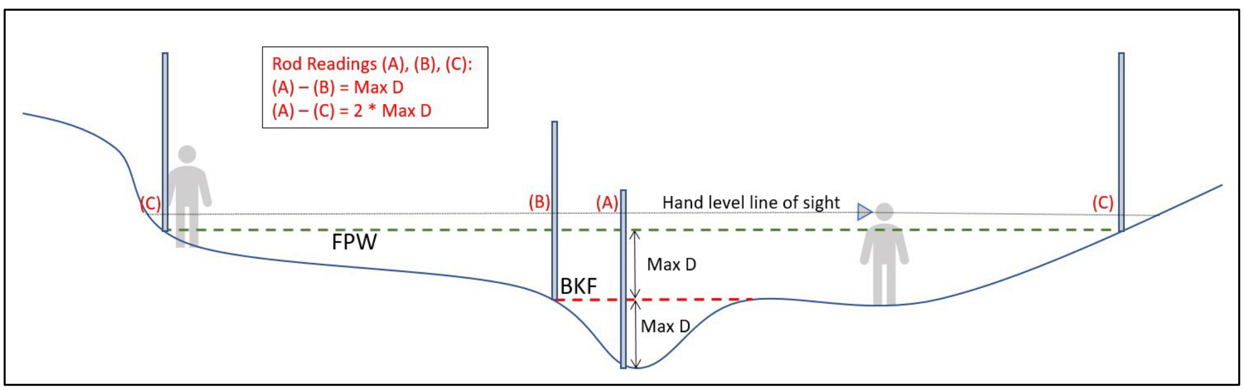
hand level for small streams.

1. Identify the middle of the riffle feature and the lower of the two streambanks.
2. Measure the difference in stadia rod readings from the thalweg to the top of the low streambank. This result is the Low Bank Height in Equation (1).
3. Measure the difference in stadia rod readings from the thalweg to the bankfull indicator and enter this value in the denominator of Equation (1).
4. Measure the length of the riffle.
5. Repeat these measurements for every riffle to enter values into Equation (2).

3.1.2 Entrenchment Ratio (ER)

Entrenchment ratio (ER) is used to describe the vertical containment of a channel. It is a measure of approximately how far the 2-percent-annual-chance (50-year) discharge will laterally inundate the floodplain (Rosgen, 1996). ER is calculated by dividing the flood prone width by the bankfull width of a channel, measured at a riffle cross section (Equation (3)). The flood prone width (FPW on Figure 2) is measured as the cross- section width at an elevation two times the bankfull max depth.

$$ER = Flood\ Prone\ Width/Bankfull\ Width \qquad \text{Equation (3)}$$



Source: TDEC (2017)

Figure 2. Surveying entrenchment ratio using rapid methods.

Unlike the BHR, the ER does not have to be measured at every riffle if the valley width is fairly consistent. For valleys that have a variable width, or for channels that have BHR's that range from 1.8 to 2.2, it is recommended that the ER be measured at each riffle and calculate a weighted ER using Equation (4) and as illustrated in Table 2.

$$ER_{(weighted)} = \sum^{n}{}_{i=1}(ER_i * RL_i) / \sum^{n}{}_{i=1} RL_i \qquad \text{Equation (4)}$$

where, RL_i is the length of the riffle where ER_i was measured.

Table 2. Example calculation of weighted entrenchment ratio (ER).

Riffle ID	Length (RL)	ER	ER * RL
R1	25	1.2	30
R2	50	2.1	105
R3	5	1.6	8
R4	30	1.8	54
Total	**110 ft.**	**Total**	**197**
Weighted ER = 197/110 = 1.8			

There are two reference curves for ER, one for C, E, and F type streams that are typically in alluvial valleys, and one for A, B, and G type streams that typically occur in higher gradient systems with confined valleys. While F and G have been included for impacts sites, it would be unusual for a restoration project to target these stream types. Note that the reference curves utilized in the OSAM for restoration projects are based on the proposed stream type, not the existing stream type. For example, if the existing stream type is a Ge and the proposed stream type (which should be the appropriate stream type for the given valley morphology) is a C, the OSAM will use reference curves for a C type channel. It should also be noted that ER is ignored for D type streams, since these are braided channels. The reference conditions for this assessment metric are based on the classification criteria for stream type. This is the approach Georgia used and is similar to other Midwest states researched. For the OSAM, ER can be calculated using either detailed or rapid field methods. While rapid field methods may be suitable for preliminary site assessments, detailed methods must be used for more formal assessment of baseline conditions, design, and post-construction monitoring.

Detailed Method:
Measure ER at riffle features from surveyed cross sections. Harrelson et al. (1994) provides field instructions for surveying a cross section, and example ER calculations are provided in Rosgen (2014). This method is objective and reproducible, as it is measured directly from the surveyed cross sections and is easily verified in the office.

Rapid Method:
The rapid method for measuring ER is undertaken in the field using a stadia rod and a hand level and does not require surveyed cross sections. A line level can be used instead of a hand level for small streams. The rapid method measures the ER using bankfull and entrenchment widths measured from a riffle cross section.

1. Identify the middle of the riffle feature.
2. Measure the width between bankfull indicators on both banks and enter this value in the denominator of Equation (4).
3. Measure the difference in stadia rod readings from the thalweg to the bankfull indicator.

4. Locate and flag the point along the cross section in the floodplain where the difference in stadia rod readings between the thalweg and that point is twice that of the difference measured in the previous step.
5. Repeat step 4 on the other bank.
6. Measure the distance between the flags and enter this value as the numerator of Equation (3).
7. Measure the length of the riffle and repeat these measurements for every riffle to enter values into Equation (4), if needed.

3.2 Geomorphology

The OSAM contains two function-based parameters to describe and measure the way streams influence the landscape through the movement of and interaction with debris (trees and branches) and sediment (dirt, sand, gravel, and boulders). These processes create habitat, diverse bed forms and maintain dynamic equilibrium. The two function-based parameters are: Riparian Vegetation and Bed Form Characterization. One assessment metric is used to represent riparian vegetation and three metrics are used to characterize bed forms. Geomorphology makes up 35% of the overall score.

3.2.1 Riparian Vegetation

Riparian vegetation is a critical component of a healthy stream ecosystem. While riparian vegetation is itself a biological component of stream environments that supports other biological components of the stream ecosystem and could therefore be included in the biology functional category, it also directly affects channel stability (geomorphology) and supports the nitrogen cycle and other water quality functions. The assessment metric used in the OSAM is the width of the vegetated riparian buffer measured laterally on both the left and right sides of the channel. The width of the riparian buffer plays an important role in the capacity of the channel to adjust in response to long-term climatic trends and commensurate changes in sediment load and/or discharge. Therefore, riparian vegetation is placed within the Geomorphology functional category of the OSAM. Riparian width makes up half of the total Geomorphology score, resulting in a 17.5% contribution to the overall condition score.

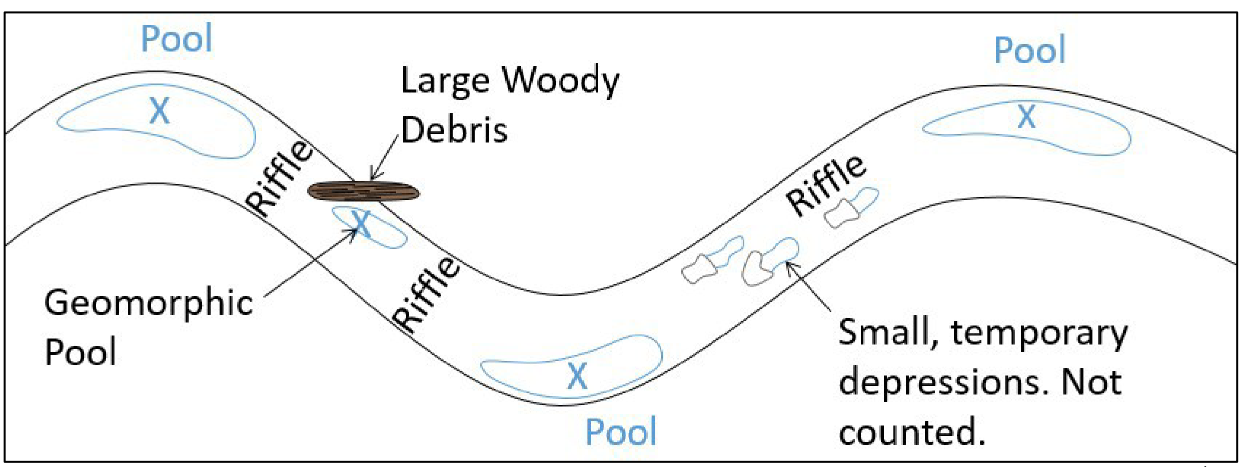
The riparian buffer width is measured horizontally from the top of the stream bank to the outer limit of the natural vegetative buffer or the proposed forested conservation easement boundary. Buffer width is measured perpendicular to the fall-line of the valley on the left and right sides of the channel. This measurement excludes the channel width itself. Measurements should be taken every 50-100 feet along the centerline of the channel (not the thalweg) and can be performed using recent aerial-imagery. However, remote sensing measurements must be verified with sufficient measurements collected in the field. An average buffer width is then calculated individually for the right and left side of the assessment reach of the channel.

3.2.2 Bed Form Characterization

Bed forms include riffles, runs, pools, and glides. Together, these bed features create important habitats for aquatic life and help dissipate the energy of flowing water. The location, stability, and depth of these bed features are indicative of sediment transport processes acting against the channel boundary conditions. Therefore, if the bed forms are representative of reference standards, it is assumed that the sediment transport processes are functioning normally and in equilibrium. Bed Form Characterization is half of the Geomorphology score, therefore each of the three metrics each comprise 5.8% of the overall condition score.

There are three assessment metrics for this parameter: pool spacing ratio, percent riffle, and large woody debris frequency. Pool spacing ratio and percent riffle should be assessed over a channel length that is at least 20x the bankfull width (two meander wavelengths for meandering streams is preferable) or the entire assessment reach length, whichever is shorter (Harrelson et al., 1994). Large woody debris should be assessed over a channel length of 100 meters. Note that the minimum assessment reach length for the OSAM is 100 meters.

Pools are only measured if they are geomorphically significant and relatively permanent. In reference standard alluvial systems, these include pools located along the outside of meander bends and pools downstream of large, relatively stable flow obstructions such as steps formed by large trees, boulders, or bedrock outcrops (Figure 3). Large pools providing energy dissipation are included, but small pools providing only habitat are not. For example, small, temporary depressions within riffles are not included as pools in the OSAM. Pools should be noticeably deeper than riffle features, and the water surface slope of the pool should be lower than the riffle water surface slope at low flow.

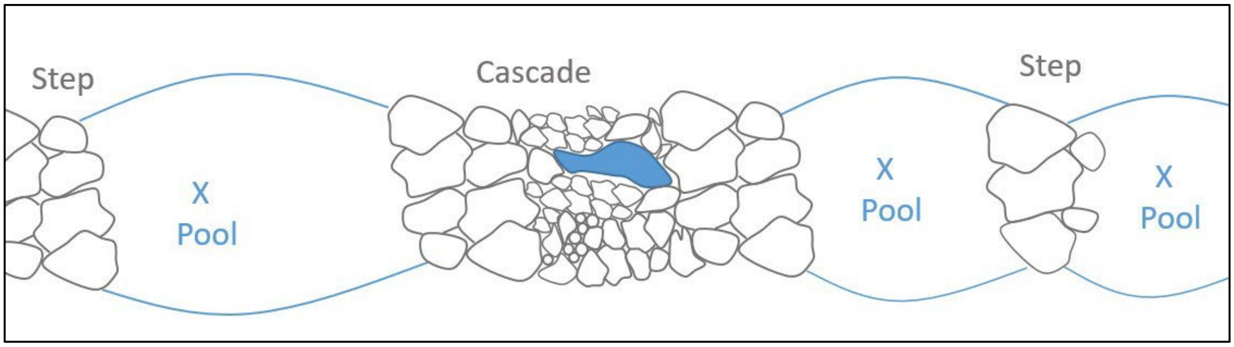


Source: TDEC (2017)

Figure 3. Pool spacing in alluvial valley streams (X marks the D_{max} location of pools counted for pool spacing).

Compound pools that are not separated by a riffle within the same meander bend are treated as a single pool. The deepest of such compound pools is used for measuring pool spacing. Compound bends with two pools separated by a riffle are treated as two pools. These scenarios are illustrated in Rosgen (2014).

Pools in colluvial valleys should only be included in measurements of pool spacing for the OSAM if they are downstream of a riffle. Small, temporary pools within a riffle or cascade are not counted (Figure 4).



Source: TDEC (2017)

Figure 4. Pool spacing in colluvial valleys (X marks the D_{max} location of pools counted for pool spacing).

3.2.2.1 Pool Spacing Ratio

The pool spacing ratio is the calculation of the distance between successive geomorphically relevant pools divided by the mean bankfull riffle width (Equation 5). The mean bankfull riffle width is measured from each of the riffle cross sections within the assessment reach. Dimensions from these riffles are used in this ratio to quantify the departure from a stable condition.

Equation (5):

$$\text{Pool spacing Ratio} = \frac{\text{Distance between sequential pools}}{\text{Mean bankfull width}}$$

The pool spacing ratio is calculated for each pair of sequential pools in the assessment reach. While the range of pool spacing ratios observed at a site should be assessed and reported, the field value entered in the OSAM is the median value based on at least five consecutive pool spacing measurements. In a meandering stream, a moderate ratio is preferred over a very low or very high ratio. In other words, having too many pools or too many riffles can be detrimental to channel stability. In steeper gradient systems, the frequency of pools often increases with slope, and concerns about channel stability increase with higher pool spacing ratios.

Reference curves for pool spacing ratio in the OSAM are adopted from the GA SQT which were based on field data collected from 23 high-quality, stable reference streams in South Carolina and Tennessee (Somerville et al., 2021). Data will be collected from several high quality, stable reference streams in Ohio to provide adjustments to the current reference data as necessary.

Detailed Method:
For the detailed method, pool-to-pool spacing is measured from the longitudinal profile as the distance between the deepest points of two successive pools.

Rapid Method:
For the rapid measurement of pool spacing, a tape measure is laid along the stream centerline or bank and the stations for the deepest point of each pool within the assessment reach are recorded in the field and used to calculate the pool-to-pool spacing. A stable riffle is selected from within the assessment reach and the bankfull width of this stable riffle is measured with a tape measure and recorded to calculate the pool-to-pool spacing ratio for each pair of pools using Equation (5). While rapid field methods may be suitable for preliminary site assessments, detailed methods must be used for more formal assessment of baseline conditions, design, and post-construction monitoring.

3.2.2.2 Percent Riffle

The percent riffle is the total length of riffles within the assessment reach divided by the total assessment reach length. Riffle length is measured from the head (beginning) of the riffle downstream to the head of the pool. Thus, run features are included with the riffle length. Calculating the percent pool in the assessment reach is optional, and reference conditions for percent pool are not provided. However, if practitioners choose to calculate percent pool, the glide features should be included with the pools in the percent pool calculation.

Reference curves for percent riffle in the OSAM are adopted from the GA SQT which were based on field data collected from 23 high-quality, stable reference streams in Alabama, South Carolina and Tennessee (Somerville et al., 2021). Data will be collected from several high quality, stable reference streams in Ohio to provide adjustments to the current reference data as necessary.

Detailed Method:
For the detailed assessment method, the percent riffle is measured from a longitudinal profile of the stream thalweg. Instructions for surveying a longitudinal profile are provided by Harrelson et al. (1994).

Rapid Method:
For the rapid assessment, a tape measure is laid along the stream centerline or bank and the stations at the beginning of each riffle and end of each run within the assessment reach is recorded in the field and used to calculate the individual riffle lengths. These lengths are then summed and divided by the total assessment reach length. While rapid field methods may be suitable for preliminary site assessments, detailed methods must be used for more formal

assessment of baseline conditions, design, and post-construction monitoring.

3.2.2.3 Large Woody Debris

Large woody debris (LWD) is defined as dead wood, standing or fallen, over 3.28 ft (1 M) in length and at least 3.94 inches (10 cm) in diameter at the largest end. The wood must be within the bankfull channel or spanning the bankfull channel. LWD that lies in the floodplain, but is not at least partially in the active channel, is not counted. OSAM uses frequency to assess LWD which is the count of the number of LWD pieces within a 100-meter section of stream.

A sample reach of 100 meters is required and must be within the assessment reach or sub-reach limits as the other geomorphology assessments. Additionally, the 100-meter stream reach from which the LWD frequency is calculated should represent the 100-meter segment of the larger assessment reach that will yield the highest LWDI score. The highest score, rather than an average score, is selected to reduce subjectivity in identifying an average condition.

Reference curves for LWD in the OSAM are adopted from the Wisconsin SQT beta version which were based on field data collected in Michigan for the development of the SQT used in Michigan. (Michigan EGLE, 2020). Data will be collected from several high quality, stable reference streams in Ohio to provide adjustments to the current reference data as necessary.

3.3 Habitat and Biology

The OSAM contains two function-based parameters to evaluate the biodiversity and ecological integrity of streams as well as the habitat that supports aquatic life. These function-based parameters have been calibrated to the ecoregions occurring in Ohio and to the whole state. The function-based parameters are Habitat and Biology. One assessment metric is used to represent Habitat, with two possible measurement methods available based on the drainage area of the stream and one assessment metric is used to evaluate Biology with three possible measurement methods available which are also selected based on drainage area. For Acid Mine Drainage projects, biology is replaced with Water Chemistry as the Function-Based parameter. This functional category makes up 25% of the overall score. The breakdown of this quarter of the overall score is dependent on drainage area and project type as detailed below:

For streams under 1 sq mile drainage area:
Habitat (20% (5% of total))
Biology (80% (20% of total))
For streams over 1 sq mile drainage area:
Habitat (40% (10% of total))
Biology (60% (15% of total))
For AMD treatment (all drainage areas):
Habitat (50% (12.5% of total))
Chemistry (50% (12.5% of total)

3.3.1 Habitat

Stream habitat quality is assessed using one of two rapid assessment methodologies for streams and primary headwater habitats developed by Ohio EPA. These include the Headwater Habitat Evaluation Index (HHEI) for streams that drain less than 1.0 square mile of surface area and the Qualitative Habitat Evaluation Index (QHEI) for those streams that drain more than 1.0 square mile of area. Both of these methodologies measure a number of stream metrics including substrate composition, channel morphology, and riparian quality. To use these methodologies, the user will need to perform a desktop review to determine the size of the area being drained by the stream in question and then select the appropriate methodology.

3.3.1.1 Headwater Habitat Evaluation Index

If it is determined that the stream being assessed drains an area that is less than 1.0 square mile, then HHEI should be used to collect data about the stream's habitat potential. These smaller streams are also known as Primary Headwater (PHW) streams and are often referred to as "Unnamed Tributary" with the waterbody name or river mile location into which it flows. Although headwaters can be defined as streams with drainage areas up to 20 square miles in area, the HHEI should only be used for streams that occupy the uppermost reaches of a given watershed. As noted above, these streams are characterized by having a drainage area of 1.0 square mile or less. Once the user has determined that they are evaluating a PHW they will use the HHEI to collect data to be input into the OSAM. It is important to note that Ohio's Primary Headwater Manual has three levels of assessments that measure both physical and biological aspects of a given stream. For the purposes of the measurement of the Habitat function-based parameter, users will only use the Level 1 Assessment Methodology which is the HHEI.

The reference curve for HHEI is based on classifications developed in the Primary Headwater Habitat Manual (Ohio EPA, 2020). The reference conditions for this assessment metric are based on sampling performed at 292 streams in 4 different eco-regions of Ohio between 1999-2001 as part of the development of the Primary Headwater Habitat Manual.

The HHEI manual can be found at the following location or on the primary headwaters section of the Division of Surface Water page on Ohio EPA's website:

[Ohio EPA PHWH Manual]

3.3.1.2 Qualitative Habitat Evaluation Index

If it is determined that the stream being assessed drains an area that is greater than 1.0 square mile, then the assessor will need to use the QHEI to collect data about the stream's habitat potential. Streams assessed using the QHEI are generally named streams found on USGS maps of the region. Once the reviewer has determined the drainage area of the stream being assessed is greater than 1.0 square mile then they will use the QHEI to collect data to be input into the OSAM. Unlike the HHEI, there are no assessment levels associated with the QHEI.

Two reference curves for QHEI are used based on drainage area, either above or below 20 square miles. The curves are based on narrative ranges established in the QHEI Manual (Ohio EPA, 1989). The reference conditions for this assessment metric are based on sampling performed at hundreds of streams throughout the state of Ohio in the 1980's as part of the development of the QHEI and the beneficial use designations and biological criteria in Ohio.

The QHEI manual can be found at the following location, or on the Biological Criteria for Aquatic Life section of the Ohio EPA's website:

Ohio EPA QHEI Manual

3.3.2 Biology

The OSAM contains two potential function-based parameters to evaluate the biodiversity and ecological integrity of aquatic life: macroinvertebrate community structure and fish community structure. Three possible measurement methods are used and are selected based on the drainage area of the stream in question. The Headwater Macroinvertebrate Field Evaluation Index (HMFEI) has been calibrated to reference conditions for streams draining under 1.0 square mile; for streams draining 1-20 square miles the Headwater Macroinvertebrate Index (HWMI) will be used, and for streams draining over 20 square miles, the Fish Index of Biotic Integrity (IBI) is the appropriate tool.

Detailed procedures for collecting and analyzing stream benthic macroinvertebrate and fish data for the OSAM are provided in these manuals: Field Methods for Evaluating Primary Headwater Streams in Ohio (HMFEI) and the Biological Criteria for the Protection of Aquatic Life (Fish IBI and HWMI) which is further refined by the Headwater Summary Macroinvertebrate Index Based on Presence/Absence technical bulletin (HWMI). Ohio EPA recommends approved Qualified Data Collectors are used to collect biological data.

For designated streams there is an option to forgo biological sampling and use the designated Aquatic Life Use for impact sites. If a stream is designated, select yes, to use existing Aquatic Life Use for impact site and choose the correct designation. If biological data is not collected for an impact site, then the user should assume the highest index score for this metric. This option should not be used for restoration sites. Aquatic Life Uses are designated for streams that have been sampled and their biological communities are known. Reference values are established as such (EWH/CWH = 100, WWH = 70, MWH = 30, LRW = 0).

3.3.2.1 HMFEI

The HMFEI is a rapid bio-assessment field sampling method that has been documented to be a good predictor of the various classes of primary headwater streams in Ohio. It uses field level identification at the Family or Order level of taxonomy to classify different assemblages of benthic macroinvertebrates found in primary headwater streams. Three scoring categories are used for benthic macroinvertebrate taxa to derive the HMFEI score. Scoring values are assigned to the macroinvertebrate categories based upon the correlation of each taxa group to Class III biological communities. The final HMFEI is calculated as follows: for Taxa Groups 1 and 2, each taxa group present at the site is multiplied by the appropriate scoring value; for Taxa Group 3, the scoring protocol is identical except for the EPT taxa, where each field-recognizable family belonging to these groups is multiplied by the scoring value of three points.

The reference curve for HMFEI is based on classifications developed in the Primary Headwater Habitat Manual (Ohio EPA, 2020). The reference conditions for this assessment metric are based on sampling performed at 292 streams in 4 different eco-regions of Ohio between 1999-2001 as part of the development of the Primary Headwater Habitat Manual.

The HHEI manual can be found at the following location or on the primary headwaters section of the Division of Surface Water page on Ohio EPA's website:

Ohio EPA PHWH Manual

3.3.2.2 HWMI

For streams with drainage areas between 1 and 20 square miles the Headwater Macroinvertebrate Index (HWMI) is the appropriate measurement for the biology function-based parameter. The HWMI is calculated from a qualitative sampling of the macroinvertebrate community at the sampling site as described in the Biocriteria Manual Volume III. Because artificial substrates are rarely employed at drainage areas less than 20 square miles, most macroinvertebrate condition assessments are narrative ratings based on qualitative samples. Although the narrative ratings are reliable indicators of condition, categorical ratings lack the advantages inherent in a continuously scaled index. The HWMI, a summary numeric index based on qualitative data, was constructed by assembling candidate metrics based on either class counts or as percentages of total taxa found at a given site.

The reference curve for HWMI is based on the analysis of qualitative sampling of macroinvertebrate communities performed in accordance with the biocriteria manual vol. III described in the Headwater Summary Macroinvertebrate Index Based on Presence/Absence Technical Bulletin (Ohio EPA, 2023). The reference conditions for this assessment metric are based on extensive sampling conducted throughout the state of Ohio on hundreds of streams in all eco-regions of Ohio in the 1980's as part of the development of the beneficial use designations and biological criteria in Ohio.

The Ohio Biocriteria manual also known as the Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities can be found at the following location or on the Biological Criteria for Aquatic Life section of the Ohio EPA's website:

Ohio Biocriteria Vol III

3.3.2.3 Fish IBI

The IBI incorporates 12 fish community metrics. The value of each metric is compared to the value expected at a reference site located in a similar geographic region where human influence has been minimal. Ratings of 5, 3, or 1 are assigned to each metric according to whether its value approximates (5), deviates somewhat from (3), or strongly deviates (1) from the value expected at a reference site. The maximum IBI score is 60 and the minimum is 12. The individual IBI metrics assess fish community attributes that are correlate with biotic integrity. All of the IBI metrics combined include the redundancy that is needed to accomplish a consistent and sensitive measure of biotic integrity.

The reference curve for the fish IBI is based on established Aquatic Life Use designation ranges outlined in OAC 3745-1-07 and established originally in the Ohio EPA Biological Criteria Vol II (Ohio EPA, 1987). The reference conditions for this assessment metric are based on extensive sampling conducted throughout the state of Ohio on hundreds of streams in all eco-regions of Ohio in the 1980's as part of the development of the beneficial use designations and biological criteria in Ohio.

The Ohio Biocriteria manual, also known as the Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities, can be found at the following location or on the Biological Criteria for Aquatic Life section of the Ohio EPA's website:

Ohio Biocriteria Vol III

3.3.3 Physiochemical

The physiochemical metric is utilized in lieu of the biology metric for mitigation projects proposing to remediate AMD. The physiochemical metric measures six water quality parameters, including pH, dissolved oxygen, specific conductivity, iron, aluminum, and manganese. These parameters are often impaired by AMD, resulting in channels that are devoid of aquatic life. Thus, they are measured instead of biology to quantify functional lift associated with water quality improvements.

A channel's pH is lowered in AMD affected streams by the oxidation of sulfide minerals, which are commonly found in coal or ore bearing rocks. When exposed to air and water, sulfide minerals react with oxygen to form sulfuric acid, which reduces stream pH. Reductions in pH can have numerous impacts on stream ecology, such as lowering a stream's dissolved oxygen level by reducing the growth and survival of primary producers (e.g., algae, plants). It can also affect the solubility of oxygen within acidic water and impact bacterial communities that can contribute to oxygen depletion through the breakdown of organic matter. AMD also affects the concentrations of various ions within streams, including sulfate ($SO4^{2-}$), iron (Fe^{2+} and Fe^{3+}), aluminum (Al^{3+}), and manganese (Mn^{2+}) and other heavy metals. Changes in water chemistry associated with increased ion and metal concentrations can directly stress or kill aquatic life, which rely on osmoregulation to balance their internal body chemistry and physiological processes.

The reference curves for these chemical parameters are based on based on natural background levels in Ohio streams. The reference conditions are based on extensive sampling conducted throughout the state of Ohio on every watershed in Ohio. Sampling occurs every year in different parts of the state and the dataset has been updated regularly since the 1980's.

The Surface Water Field Manual is updated regularly by the Ohio EPA's Division of Surface Water and can be found at the following location or on the Biological and Water Quality Monitoring and Assessment section of the Ohio EPA's website:

Surface Water Field Sampling Manual

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