Monitoring Abandoned Mine Drainage: Techniques and Protocols

5th West Branch Susquehanna Restoration Symposium

Field Training

May 7, 2010

Why This Training and Manual?

Reclamation of the West Branch Susquehanna watershed from abandoned mine drainage has become a priority for a gamut of federal, state, and non-profit entities including Trout Unlimited (TU) and the West Branch Susquehanna Restoration Coalition (WBSRC). To date, millions of dollars have been utilized for abandoned mine drainage remedies and initiatives. One significant component of the watershed restoration effort has been the *West Branch Susquehanna Subbasin AMD Remediation Strategy* which focused on the current water quality status of the watershed and targeted opportunities to improve existing conditions.

As part of the Strategy, more than 100,000 data records collected between 1990 and 2007 by agencies and volunteers were obtained for use in an integrated database and model designed to determine existing water quality conditions and simulate water quality changes. *Astoundingly, only 30% of the 100,000 data records met the analytical criteria required for use in the model. The three most common shortfalls of the data were determined to be the lack of 1) geo-referencing, 2) flow measurements, and 3) AMD-specific chemical parameters. Subsequently three of the nine summary recommendations of the Strategy pertained to the need for additional and credible data collection.*

In an effort to increase the amount of data collected throughout the watershed that meet the model criteria, TU and the WBSRC incorporated a field-day training into their 5th West Branch Susquehanna Restoration Symposium. The training, conducted by state, federal, and volunteer organizations has been designed to provide participants with both demonstration and hands-on-learning of proper field collection techniques.

In concert with the field day training, the following manual documenting state protocols has been compiled. What follows is the Department of Environmental Protection's protocols for the collection of field data tailored to acid mine drainage circumstances. These protocols have been extracted directly from *Standardized Biological Field Collection and Laboratory Methods* and the *Instream Comprehensive Evaluation Surveys* protocol. To obtain these protocols in their full form, contact Gary Walters at 717-772-5165 or gawalter@state.pa.us or visit www.depweb.state.pa.us.

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Biological Sampling

COLLECTOR'S PERMIT REQUIREMENTS

Field staff required to collect biological samples (particularly fish and benthic macroinvertebrates) as part of their duties, must have a valid Collector's Permit in their possession. Type II Collector Permits are issued annually by the Pennsylvania Fish & Boat Commission (PFBC)[1] to state agency personnel (upon application) and require the possession of a current Pennsylvania fishing license.

STATION SELECTION CONSIDERATIONS

Station selection considerations are critically dependent on the type of survey to be conducted.

Near-Field Investigations

Many traditional stream investigations are localized in their spatial scope. They usually involve "above and below" sampling regimes that bracket suspected problem sources - necessitating background or traditional reference station comparisons (e.g., cause/effect surveys, pollution incidences or other impact surveys).

In order to limit the complications arising from compounding variables, select background stations or reference waterbodies and impact stations that are physically similar in as many respects as possible. This includes matching drainage areas of similar size and setting. Substrate, depth, flow, gradient and aquatic plant growth should also be considered, as well as the location of tributaries, point source discharges and nonpoint source effects. A minimum of one background station must be selected, but select two if possible. Comparisons of background station(s) to impact station(s) include variation due to both natural and possible treatment (i.e., discharger) effects. An estimate of the natural variation sometimes can be made by comparing two background stations where the treatment effects are absent. A habitat assessment (Section IV) at each station may reveal physical limitations that would impact benthic communities.

Far-Field Investigations

Other stream investigations may involve much larger watershed or basin-wide study areas. These would include water quality surveys designed to characterize overall impacts from land-use activities instead of specific discharges or localized pollution incidences. In these instances, station selection must discern between and adequately reflect all land-uses with potential impacts on water quality.

Examples include Antidegradation surveys and assessments conducted as part of the Statewide Surface Waters Assessment Program. Generally, considerations listed above for "near-field" investigations may also be applicable to some far-field investigations, but certain reference or background station considerations may not apply. Antidegradation surveys do require “reference” comparisons, but since these stations are restricted to predetermined Exceptional Value (EV) watersheds, most of those selection considerations are already accounted for. The Statewide Surface Waters Assessment Program does not emphasize targeting “above and below” assessments of localized impact sources. The program does, however, accommodate assessment placement to distinguish point source impacts from nonpoint sources. In these cases, the assessments bracket the point source and become a near-field investigation for station selection purposes.

Station Length

Except for very small stream segments (<1-2 meter width), a station will approximate a 100-meter reach. For the smaller segments, reaches of less than 100 meters can be considered, based on the biologist’s best professional judgment of how much stream length effectively characterizes that segment’s water quality condition.

Database Management

Much of the biological, chemical and physical data collected during DEP’s numerous surveys is stored electronically, so it is important that the proper location information is recorded for each station surveyed. Such information provides reference points for data searches, retrievals, sorting and analyses. Once a station location has been determined, the following information should be recorded and provided in any resulting reports:

Stream Name

As recorded in the Pennsylvania Gazetteer of Streams.

Stream Code

A 5-digit number assigned to every named and unnamed stream in the Commonwealth.

Latitude/Longitude

For electronic formats (Access database and Geographic Information Systems (GIS)-based records), lat/long will be stored in decimal degrees. For maps, visual aids and report tables, lat/long can be reported in degrees - minutes-seconds, based on U.S. Geological Survey (USGS) 7.5-minute quadrangle maps. They can be determined using lat/long gridded overlay sets, electronic digitizers or other similar devices.

River Mile Index

The distance measured from the mouth upstream to the sampling point and reported in 1/10th-mile increments. If sampling points are very close together, then the mileage may be reported in 1/100ths. Depending on the needed precision, map wheels or electronic measuring devices may be used.

Narrative Description

A brief narration describing the station locations should be provided; preferably in tabular form. Local landmarks, special features and road route numbers should be included when applicable. Include as many features as possible to aid in return visits by another investigator.

Station Labeling

For new surveys that are not part of an already established, ongoing monitoring program (i.e., WQN monitoring), sampled stations shall be labeled in the following manner:

1. All biological station data and stream segment data entered into DEP's electronic database will be assigned a specific code number known as a GISkey, which requires 15 characters to complete. The syntax format for a GISkey number follows a date-time-initials format: YYYYMMDD-0000-XYZ. This unique identification number is extremely important because it is used to reference and link all related forms, samples, computer records and GIS map images.

   Date: Enter the assessment date in the following 8-digit format: YYYYMMDD (e.g., 1/31/01 = 20010131);

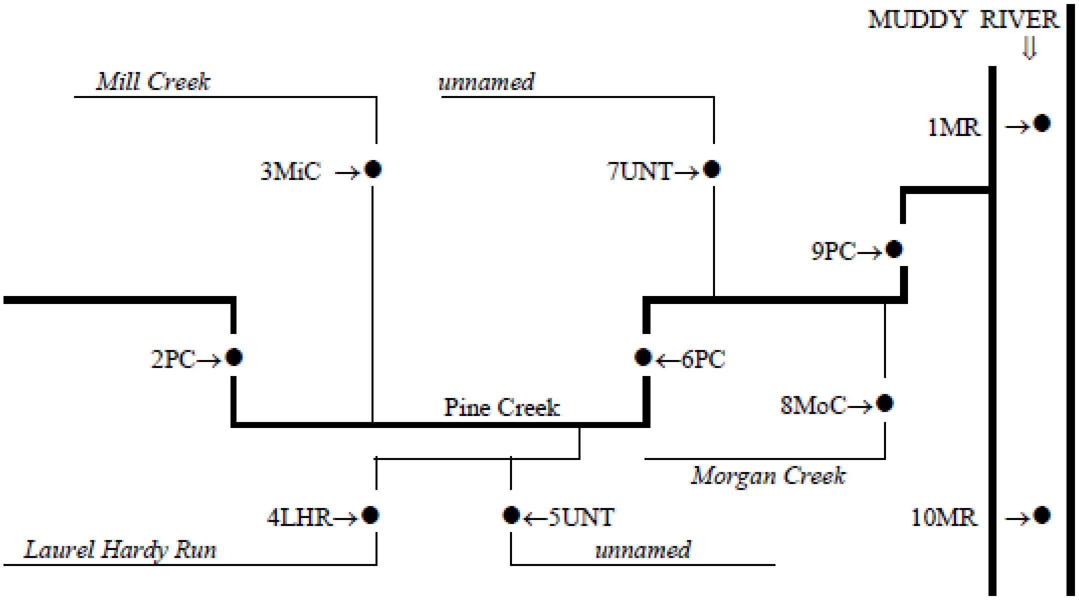
   Time: Enter the time you begin filling out the form stream-side. Use the 4 digit military format: 0000 (e.g., 8:30 AM = 0830; 8:30 PM = 2030). **Leading zeros must be used for times < 10:00 AM**;

   Initials: Use the collector initials that are assigned to you. Newly hired staff must contact the program manager or water quality database manager to receive their uniquely assigned collector initials before they begin any water quality assessments. Normally, these will be the three initials of the investigator's full, legal name. In situations where the investigator has no middle initial or where initials duplicate those of another collector, unique collector initials will be assigned on a first-come-first-served basis. By following this GISkey format, each station will have its own unique identifier, distinguishing it from any other station in the database. Likewise, the same will be true for stream segment data. **NOTE:** Since the water quality data records are to be entered in the Access and ArcView GIS databases as distinctly separate entities in station and stream segment tables, it is OK for a station GISkey to match its stream segment GISkey.

2. For stream reporting narratives, discussion purposes, maps and visual aids, it is desirable to use conventional station labels instead of a 15-digit GISkey. To facilitate a consistent station labeling method that encourages a logical comprehension of "upstream-downstream" cumulative water quality impacts, it is strongly suggested that the following guidelines be followed:

    a. The stations will be labeled in hydrologic order, in upstream to downstream order.
    b. The label will consist of a number followed by letter abbreviations of the stream and tributary names.

    Refer to the following schematic diagram as an example and notice the labeling of two stream names starting with the same letters:



The ordering and labeling is within the context of the drainage basin or area studied. If the study includes another basin entering Muddy River, then those stations would continue the sequence. For example, if another basin was studied in relation to the same project and it enters Muddy River downstream of 10MR, then its labeling sequence starts with “11”, beginning with the uppermost station. If there is another basin in your report, but it drains to a different receiving stream, a new sequence is used.

This labeling system aids the report reader in tracing the presentation of data and information in hydrological order. Water chemistry, benthic and fish data tables should present the data columns numbered with the station labels in ascending order from left to right. When presented in this manner, background, cause/effect, chronic discharge and dilution influences on cumulative changes in water quality can be grasped more quickly. If any of these labeled stations are resurveyed in the future, it is suggested that the same station labels be used.

Introduction

Detailed field observations on land use and potential sources of pollution in the study watershed are recorded on field data collection forms following a thorough reconnaissance of the watershed. Dissolved oxygen, pH, specific conductance, and temperature are measured in the field using hand-held meters calibrated according to manufacturer specifications. Total alkalinity can be measured using available field test kits or a water sample can be sent to the Bureau of Laboratories for analysis.

Chemical characterization of the water body is driven by the need to identify sources and causes of impairment and/or the needs of the Total Maximum Daily Load model.

Methods

Water samples for laboratory analyses are collected in 125 and/or 500 ml plastic bottles with appropriate fixatives added in the field (as needed) in accordance with the DEP Laboratory's prescribed Analytical Methods. If needed, separate water samples for dissolved metals and dissolved phosphorus analyses are filtered in the field through 0.45-micron filters using a portable filtration apparatus. Samples are collected throughout the watershed in such a manner to identify potential sources of impairment.

Measurement of stream discharge is required when water chemistry samples are collected according to the Department's Stream Flow Measurement Protocol

Point Sources of Abandoned Mine Drainage

For these follow-up surveys, representative water samples are collected from the discharge pipe, from upstream (control), and downstream locations at a minimum. Sampling stations located upstream of the discharge pipe should be in a non-impacted zone to serve as a control. If there are multiple discharges, then sample stations should be placed to bracket individual discharges in order to better characterize each source. For sampling downstream of the discharge pipe, the investigator should avoid the immediate vicinity of the discharge point and select a sample point far enough downstream to allow for mixing between the discharge and stream flow. Conductivity measurements may help determine the point of complete mix. If the point of complete mix is unclear or too far downstream for representative sampling, then multiple samples should be collected across a transect. For very large streams and rivers it may be necessary to composite samples collected along a cross channel transect to accurately characterize water quality of the sampled tream segment. At least one sample should be collected downstream of the discharge point, but multiple samples may be collected throughout the impacted reach if deemed necessary.

Non-Point Sources of Acid Mine Drainage

For acid mine discharges, samples should be collected from the points of discharge, if possible. In addition, flow from the discharge(s) should be measured to determine loading rates for Total Maximum Daily Load development. Flow and channel cross section are measured in the field according to standard USGS stream gauging techniques.

Parameters

The DEP recommends the following parameters be analyzed when sampling acid mine drainage waters.*

- Acidity, total hot as CACO3
- Alkalinity, total as CACO3
- Aluminum, total
- Calcium, total by trace elements
- Hardness, total
- Iron, total
- Manganese, total
- pH
- Sulfate
- Total Suspended Solids
- Zinc, total

* Note that current draft DEP protocols do not appropriately specify these parameters. Instead, Gary Walters DEP Water Program Specialist, recommends that he be contacted if there are questions regarding the aforementioned parameters or their sampling methodologies.

Mr. Walters can be reached at 717-772-5165 or gawalter@state.pa.us.

Introduction

The estimate of stream discharge (Q) requires careful field measurements during variable flow conditions. Since stream discharge is a volume estimate, three dimensions must be measured. Stream width (W) and stream depth (D) are simple measurements equivalent to the cubical width and height. Since streams are flowing, the cubical length equivalent becomes a distance/time dimension (velocity, or V).

Methods

The following protocol provides guidelines outlining procedures designed to assure that W, D, and V are measured as accurately and consistently as possible. This protocol follows a "6/10th" depth method similar to that described in USGS field methodology manuals and other sources.

Equipment needs

(a) Flow meter (This protocol is written for "electromagnetic probe" type flow meters similar to Marsh-McBirney models.)

(b) Standard wading rod

(c) 100' cloth tape measure (English/metric in 1/10ths)

(d) two rods/stakes for anchoring measuring tape

(e) clip board & data entry form or field data book

(f) pencils and spare meter batteries

(g) flow calculation program

(h) proper wading gear

Stream reach selection and site conditions

(a) Select stream reach location that properly reflects the cumulative flow from up stream study area.

  (i) Avoid sampling immediately downstream from road crossings, road drainage ditches, tributary "plumes" (in the mixing zone - before the "zone of complete mix").

  (ii) Be sure to sample or place the transect far enough downstream to reflect up stream discharges: point sources, nonpoint sources, and tributaries.

(b) Be sure flow conditions are measurable (water is moving) and wadeable (<1 meter deep & <1m/sec).

Transect Placement - Open channel/flow considerations

(a) Strive for the “ideal transect” - stretch your tape across the stream; perpendicular to the direction of mid-channel flow, where you find the best combination of the following “ideal” conditions:

  (i) Straight channel - try to find a stream section with a straight distance that is 2X the stream width. For stream widths > 10’, straight distances <2X width can be considered IF there are no (or very few) obstacles, large vortices, or midchannel flow diversions.

  (ii) Laminar flow - the channel bottom should be as smooth as possible.

  (iii) No obstacles - avoid sections where there are protruding boulders, sandbars, deflecting structures (logs, brush, debris, etc.).

  (iv) Uniform depth -“U-shaped” channel with steady, gradual, tapering depths. Avoid abrupt, almost vertical changes in depth.

  (v) No backwater flow.

(b) In many cases, instream conditions may be altered to reduce the overall inaccuracy by moving some submerged materials and obstacles that deflect flow or cause associated turbulence.

Meter and wading rod preparation

(a) Check batteries.

(b) Calibrate meter according to manufacturer’s specifications.

(c) Attach meter probe to wading rod so that the signal wire exits from the top and is parallel to the wading rod’s vertical shaft.

Velocity measurements

Once the tape transect has been positioned, flow measurements may begin following these guidelines:

(a) Meter operation - (This protocol is written for “electromagnetic probe” type flow meters similar to Marsh-McBirney models. If other models are used, follow the manufacturer’s instructions to render a velocity reading.)

(i) Meter is “readied” (turn on and set scale to “ft/sec”).

(ii) Meter is set for any “time constant.”

(iii) Velocity is read once it has stabilized.

(b) Wading rod placement and operation (“6/10th depth” method)

(i) With the operator standing downstream from the tape, the wading rod is held behind the tape at straight-arm length, aligned at the first width increment, and rested on the stream bottom in a perpendicular position.

(ii) Measure depth and adjust meter probe to proper depth setting by depressing the sliding rod lock and sliding it up to align with the “tenth scale” depth. Thes sliding rod is calibrated with single lines in 1.0 foot increments. The appropriate foot marker on the sliding rod is aligned with its corresponding “1/10th” foot reading.

For example, the depth was measured to be 2.3 feet. The “2” foot marker on the sliding rod is aligned with the “3” line on the “tenth scale”. Because of the wading rod’s construction, the meter’s probe depth is now properly positioned at “6/10ths of the total depth” from the surface.

(iii) After each velocity reading, move the rod to the next width increment, reset the meter probe depth and measure the velocity.

(iv) Repeat until all required width increments have been measured.

Cross-section measurements (“Mid-section” Method)

Cross-section measurements are taken to provide the “W” and ”D” dimensions for Q calculations. Since the stream depth and velocities vary widely across any given transect, the cross-section will be divided into many smaller sub-sections (at least 20); each with its own W, D, and V measurements. This is to assure that no more than 5 percent of the total transect Q flows through any one sub-section and that inaccuracies introduced by widely variable depths and velocities are minimized.

(a) Anchor tape to both stream banks and measure width.

(b) Record W, D, and V entries on a flow data sheet for each width increment. It is more convenient for data recording to measure width increments in ascending order across the transect. The first depth and velocity entries should begin at the shoreline and be recorded as “0” and “0”, respectively.

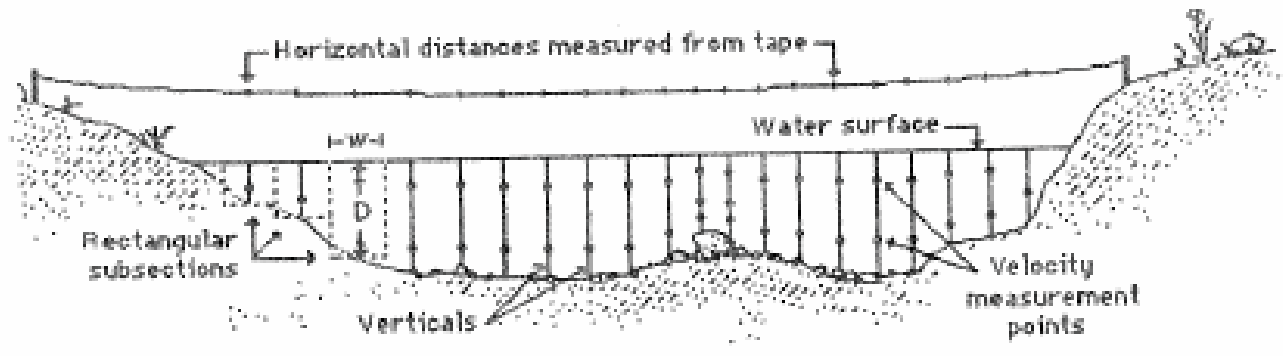
(c) Repeat, measuring at least 20 subsections. The final W, D, V readings recorded should be measured at the water’s edge on the opposite bank and, again be entered as ”0” and “0”, respectively.

(d) Special conditions or situations to consider:

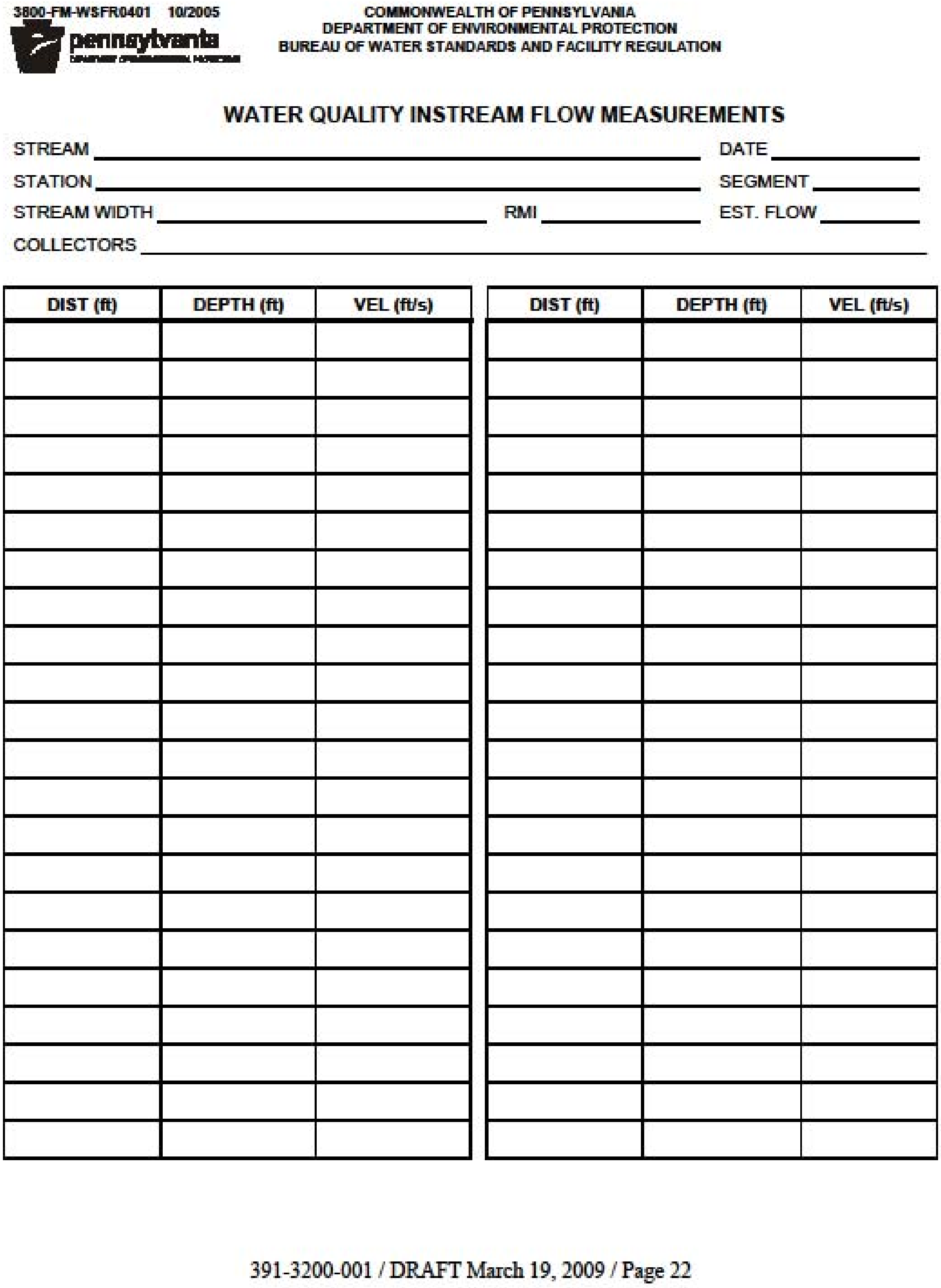
(i) For meter operation, probe must be completely submerged (approx. 3” depth).

(ii) Sub-section increments must be shortened significantly whenever velocities or depths change dramatically. Measuring smaller width increments may increase the number of sub-sections in any given transect.

(iii) Avoid placing transects in areas where backflow occurs.



* Note that DEP protocols do not include the calculations required to determine discharge. Therefore, a U.S.G.S. publication containing this calculation has been addended to this section.



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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER STANDARDS AND FACILITY REGULATION

WATER QUALITY INSTREAM FLOW MEASUREMENTS

STREAM ____________________ DATE __________

STATION ____________________ SEGMENT __________

STREAM WIDTH __________ RMI __________ EST. FLOW __________

COLLECTORS ____________________

DIST (ft)	DEPTH (ft)	VEL (ft/s)	DIST (ft)	DEPTH (ft)	VEL (ft/s)

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STANDARD OPERATING PROCEDURE
FOR
STREAMFLOW MEASUREMENT

Compiled by Forrest John
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Introduction

For sites where a flow measurement is necessary, always measure flow, read the USGS flow gage, or obtain a flow value at a later date from the USGS. Measure and record flow after recording visual observations. Do not collect water samples in the area disturbed during a flow measurement. At sites with a USGS flow gage, observe and record the gage height to the nearest hundredth of a foot in the field logbook. Contact the office responsible for the gage and obtain the flow (in cubic feet per second) that corresponds to the gage height. If there is any doubt about the accuracy of the gage-height reading, sampling personnel should measure the flow if possible. USGS gage heights can be measured by one of the three methods: staff gage, wire weight, or bubble gage. Staff gages are black and white steel plates with the appearance of large measuring tapes bolted to a stable structure. Gradations in feet, tenths of a foot, and two-tenths of a foot should be recorded (where the water level hits the gage) to the nearest hundredth of a foot. Wire-weight gages house a weight attached by wire cable to a graduated reel (gradations are tenths and hundredths of a foot) with a counter at one end. The weight should be lowered to touch the surface of the water (causing a slight ripple). At that position, the counter value should be recorded to the nearest whole number and the point indicated by the stylus on the graduated reel to the nearest hundredth of a foot. The wire-weight gage could be a movable type to accommodate braided streams. If the gage needs to be moved, use the correction value on the bridge near the repositioned gage location.

Bubble gages are installed in USGS gage houses, which are locked with a USGS key. The bubble gage uses a data logger attached to a pressure transducer system to indicate gage height in feet. Gage houses can also contain stilling wells with staff gages on the inside wall of the well. If no nearby USGS flow gages can be accessed to determine streamflow, personnel should measure flow. A summary description of the conventional current-meter flow-measurement procedure is included here for general guidance (mid-section method to determine discharge). A current-meter measurement is the summation of the products of individual subsection areas of the stream cross section and their respective average velocities. In the mid-section method of computing a flow measurement, it is assumed that the velocity sample at each vertical represents the mean velocity in the individual subsection areas.

Streamflow Measurement

Flow-measurement equipment required includes: (1) current meter or flowmeter, (2) top-setting wading rod (marked in tenths of a foot), and (3) tape measure or tagline (marked in tenths of a foot). The current meter or flowmeter brands or equivalent can be: Marsh-McBirney electronic, Montedoro-Whitney electronic, Price pygmy (with timer and beeper), Price meter, Type AA (with Columbus weight) or YSI FlowTracker Handheld ADV.

Determining the Number of Flow Cross Sections

The first step in streamflow measurement is selecting a cross section across the total width of the stream. Select a straight reach where the streambed is uniform and relatively free of boulders and aquatic growth. The flow should be uniform and free of eddies, dead water near banks, and excessive turbulence. Determine the width of the stream by stringing a measuring tape from bank to bank at right angles to the direction of flow. Next, determine the spacing or width of the verticals. ***Space the verticals so that no subsection has more than 10 percent of the total discharge***. If the stream width is less than 5 ft, use vertical spacing widths of 0.5 ft. If the stream width is greater than 5 ft, the minimum number of verticals is 10 to 25. The preferred number of verticals is 20 to 30.

Determining the Mid-Point of the Cross Section

To determine the mid-point of a cross section, for example, divide the cross section width in half, if the total stream width is 26 feet with 20 cross sections and each cross section width is equal to 1.3 feet. Divide 1.3 feet in half and the mid-point of the first section is 0.65 feet. In this example, the tape at waters edge is set at zero feet. By adding 0.65 to zero, the mid-point of the first section is 0.65 feet. Each subsequent mid-point is found by adding the section with (1.3 feet) to the previous mid-point. For example, the first mid-point = 0.65+0.0 = 0.65 feet; the second mid-point = 0.65+1.3 = 1.95 feet; the last midpoint = 24.05+1.3 = 25.35 feet.

Adjusting the Sensor Depth at a cross Section

Adjust the position of the sensor to the correct depth at each mid-point. The purpose of the top setting wading rod is to allow the user to easily set the sensor at 20%, 60% and 80% of the total depth. The total depth can be measured with the depth gauge rod (see Figure 2). Each single mark represents 0.10 foot, each double mark represents 0.5 foot, and each triple mark represents 1.00 foot.

Depths $\leq$ 2.5 Feet: If the depth is less than 2.5 feet, only one measurement id required at each measurement section. To set the sensor at 60% of the depth, line up the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod. For example, if the total depth is 2.0 feet, then line up the 2 on the foot scale with the 0 on the tenth scale.

Depths >2.5 Feet: If the depth is greater than 2.5 feet, two measurements should be taken at 20% and 80% of the total depth. To set the sensor at 20% of the depth, multiply the total depth by two. For example, the total depth is 2.7 feet the rod would be set at 5.4 feet. Line up the 5 on the foot scale and the 4 on the tenth scale.

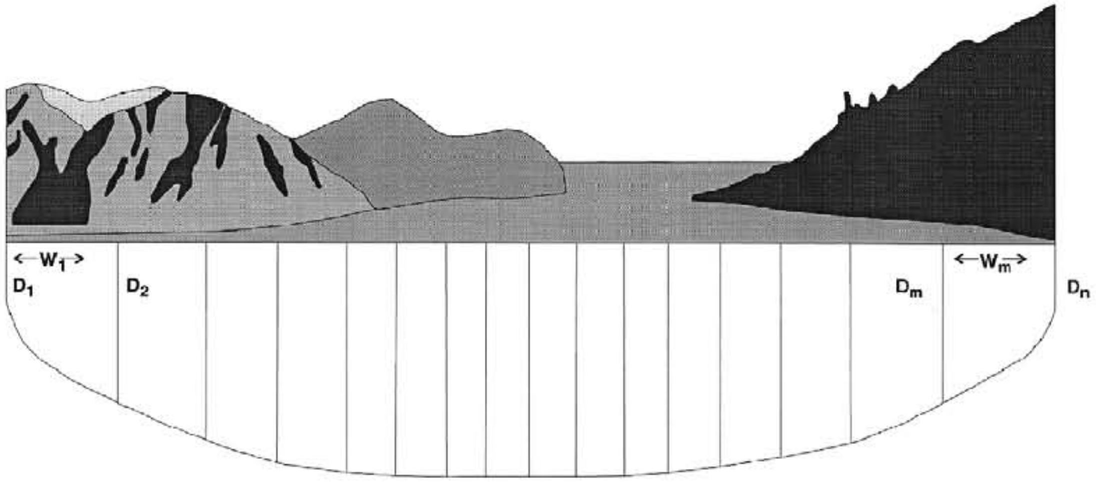
To set the sensor at 80% of the depth, divide the total depth by two. For example, the total depth is 2.7 feet the rod would be set at 1.35 feet. Line up the 1 on the foot scale with the 0.35 on the tenth scale. The average of the two velocity measurements is used in the flow calculation.

Measuring Velocity

The wading rod should be kept vertical and the flow sensor kept perpendicular to the tape rather than perpendicular to the flow while measuring velocity with an electronic flowmeter. When using a pygmy meter, the instrument should be perpendicular to the flow. Move to the next vertical and repeat the procedure until you reach the opposite bank.

Calculating Flow

Once the velocity, depth, and distance of the cross section have been determined, the mid-section method can be used for determining the discharge (formula in fig. 1). Compute the discharge in each increment by multiplying the averaged velocity or single velocity in streams less than 2.5 ft deep in each increment by the increment width and averaged depth (or single depth in streams less than 2.5 ft deep). (Note that the first and last increments are located at the edge of the stream and have a depth and velocity of zero.) Add the discharges for each increment to compute total stream discharge. Record the flow in liters (or cubic feet or cubic meters) per second in your field book.



$$Q = \left(\frac{D_1 + D_2}{2}\right)\left(\frac{V_1 + V_2}{2}\right)W_1 + \ldots + \left(\frac{D_m + D_n}{2}\right)\left(\frac{V_m + V_n}{2}\right)W_m$$

Q = discharge, D = depth, V = velocity, W = width (Rantz and others, 1982)

Figure 1. Stream cross section illustrating mid-section method to determine discharge.

Introduction

DEP has adopted the habitat assessment methods outlined in the Environmental Protection Agency's (EPA) Rapid Bioassessment Protocols (RBP) and subsequently modified. The matrix used to assess habitat quality is based on key physical characteristics of the waterbody and surrounding lands. All parameters evaluated represent potential limitations to the quality and quantity of instream habitat available to aquatic biota. These, in turn, affect community structure and composition.

The main purpose of the habitat assessment is to account for the limitations that are due to existing stream conditions. This is particularly important in cause/effect and cumulative impact studies where the benthic community at any given station may already be self-limited by background watershed and habitat conditions or impacts from current land uses. In order to minimize the effects of habitat variability, every effort is made to sample similar habitats at all stations. The habitat assessment process involves rating 12 parameters[2] as excellent, good, fair, or poor, by assigning a numeric value (ranging from 20 - 0[2]), based on the criteria included on the Water Quality Network Habitat Assessment Riffle/Run Prevalence form and Habitat Assessment Field Data Sheet Glide Pool Prevalence form available on DEP's Web site at www.depweb.state.pa.us .

The 12 habitat assessment parameters used in the PADEP-RBP evaluations for Riffle/Run prevalent (and Glide/Pool prevalent) streams are discussed below. The Glide/Pool parameters that differ from the Riffle/Run parameters are shown in italics. The first four parameters evaluate stream conditions in the immediate vicinity of the benthic macroinvertebrate sampling point:

Methods

Instream Fish Cover

Evaluates the percent makeup of the substrate (boulders, cobble, other rock material) and submerged objects (logs, undercut banks) that provide refuge for fish.

Epifaunal Substrate

Evaluates riffle quality, i.e., areal extent relative to stream width and dominant substrate materials that are present. (In the absence of well-defined riffles, this parameter evaluates whatever substrate is available for aquatic invertebrate colonization.)

Embeddedness

Estimates the percent (vertical depth) of the substrate interstitial spaces filled wi-fine sediments. (**Pool substrate characterization:** evaluates the dominant type of substrate materials, i.e., gravel, mud, root mats, etc. that are more commonly found in glide/pool habitats.)

Velocity/Depth Regime

Evaluates the presence/absence of four velocity/depth regimes - fast-deep, fast-shallow, slow-deep and slow-shallow. (Generally, shallow is <0.5m and slow is <0.3m/sec. (*Pool variability:* describes the presence and dominance of several pool depth regimes.)

The next four parameters evaluate a larger area surrounding the sampled riffle. As a rule of thumb, this expanded area is the stream length defined by how far upstream and downstream the investigator can see from the sample point.

Channel Alteration

Primarily evaluates the extent of channelization or dredging but can include any other forms of channel disruptions that would be detrimental to the habitat.

Sediment Deposition

Estimates the extent of sediment effects in the formation of islands, point bars and pool deposition.

Riffle Frequency (pool/riffle or run/bend ratio)

Estimates the frequency of riffle occurrence based on stream width. *(Channel sinuosity:* the degree of sinuosity to total length of the study segment.)

Channel Flow Status

Estimates the areal extent of exposed substrates due to water level or flow conditions.

The next four parameters evaluate an even greater area. This area is usually defined as the length of stream that was electroshocked for fish (or an approximate 100-meter stream reach when no fish were sampled). It can also take into consideration upstream land-use activities in the watershed:

Condition of Banks

Evaluates the extent of bank failure or signs of erosion.

Bank Vegetative Protection

Estimates the extent of stream bank that is covered by plant growth providing stability through well-developed root systems.

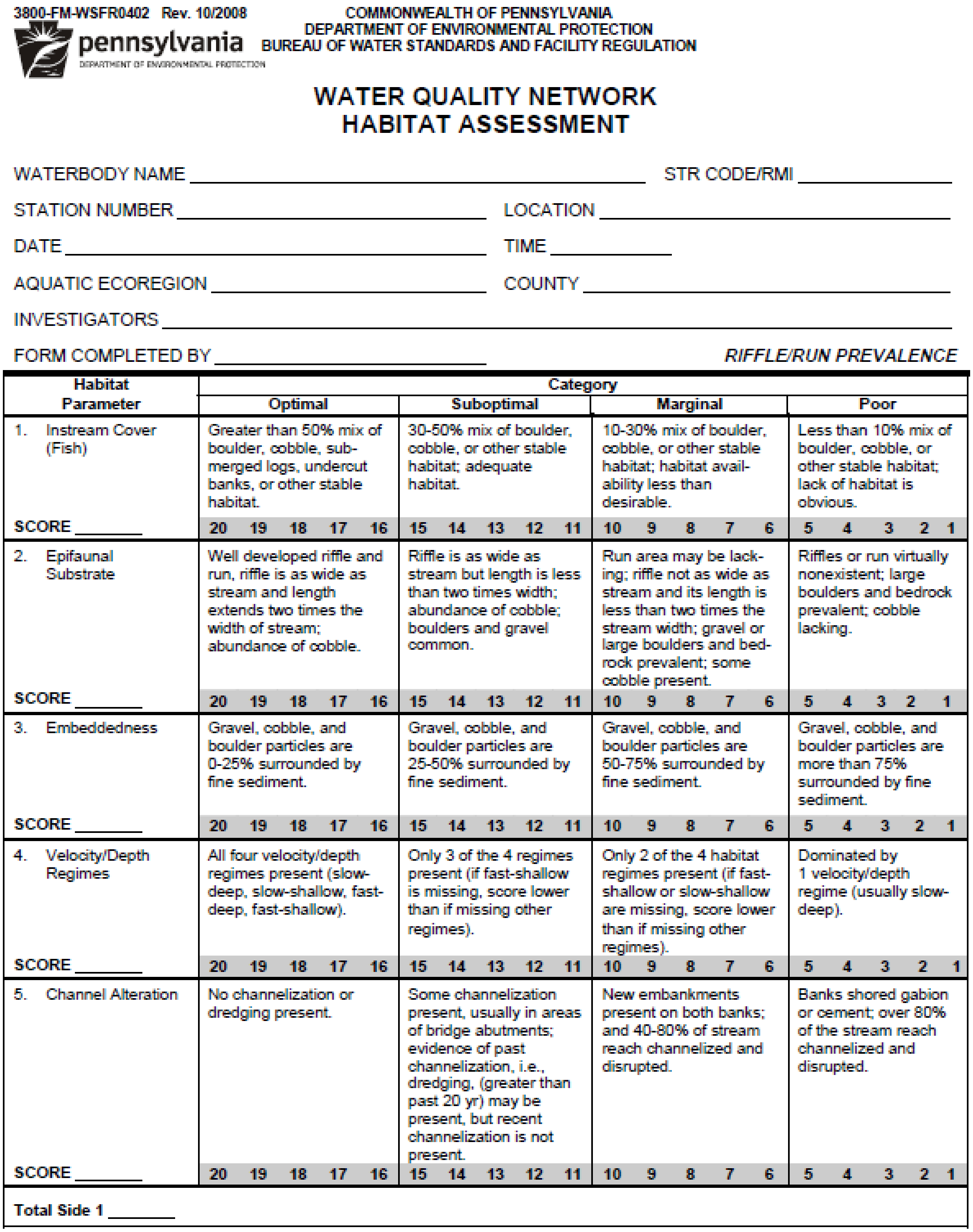
Grazing or Other Disruptive Pressures

Evaluates disruptions to surrounding land vegetation due to common human activities, such as crop harvesting, lawn care, excavations, fill, construction projects and other intrusive activities.

Riparian Vegetative Zone Width

Estimates the width of protective buffer strips or riparian zones. This is a rating of the buffer strip with the least width.

It is best to conduct the habitat assessment after sampling since the investigator has observed all conditions in the sampled segment and immediate surrounding watershed. After all parameters in the matrix are evaluated and scored, the scores are summed to derive a habitat score for that station. The “optimal” category scores range from 240-192; “suboptimal” from 180-132; “marginal” from 120-72; and “poor” is 60 or less. The gaps between these categories are left to the discretion of the investigator’s best professional judgment.



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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WATER STANDARDS AND FACILITY REGULATION

WATER QUALITY NETWORK
HABITAT ASSESSMENT

WATERBODY NAME ______________________ STR CODE/RMI __________

STATION NUMBER ______________________ LOCATION ______________________

DATE ______________________ TIME __________

AQUATIC ECOREGION ______________________ COUNTY ______________________

INVESTIGATORS ______________________

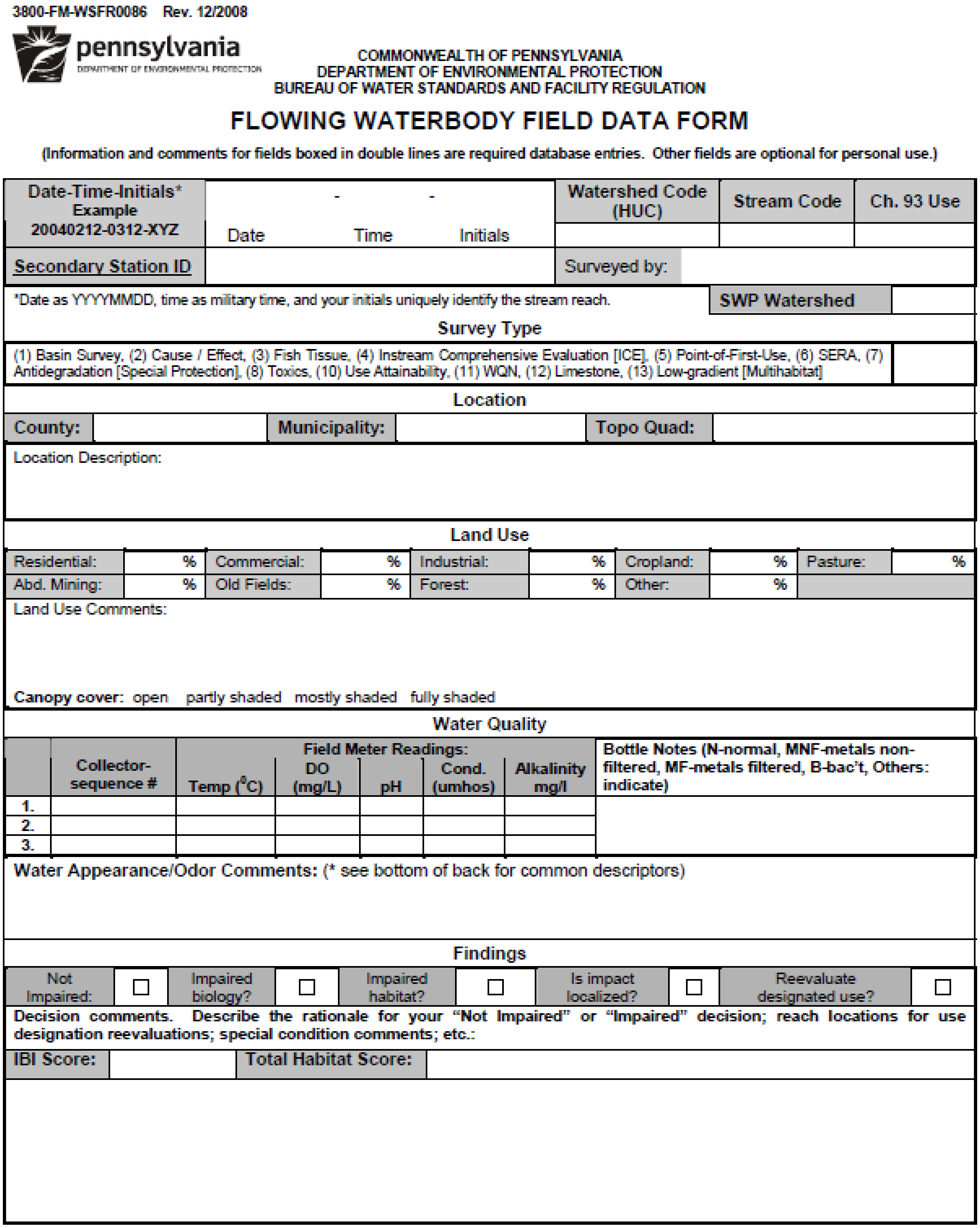
FORM COMPLETED BY ______________________ *RIFFLE/RUN PREVALENCE*

Habitat Parameter	Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Instream Cover (Fish)	Greater than 50% mix of boulder, cobble, submerged logs, undercut banks, or other stable habitat.	30-50% mix of boulder, cobble, or other stable habitat; adequate habitat.	10-30% mix of boulder, cobble, or other stable habitat; habitat availability less than desirable.	Less than 10% mix of boulder, cobble, or other stable habitat; lack of habitat is obvious.
SCORE ________	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
2. Epifaunal Substrate	Well developed riffle and run, riffle is as wide as stream and length extends two times the width of stream; abundance of cobble.	Riffle is as wide as stream but length is less than two times width; abundance of cobble; boulders and gravel common.	Run area may be lacking; riffle not as wide as stream and its length is less than two times the stream width; gravel or large boulders and bedrock prevalent; some cobble present.	Riffles or run virtually nonexistent; large boulders and bedrock prevalent; cobble lacking.
SCORE ________	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
3. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE ________	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
4. Velocity/Depth Regimes	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score lower than if missing other regimes).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE ________	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**
5. Channel Alteration	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	New embankments present on both banks; and 40-80% of stream reach channelized and disrupted.	Banks shored gabion or cement; over 80% of the stream reach channelized and disrupted.
SCORE ________	**20 19 18 17 16**	**15 14 13 12 11**	**10 9 8 7 6**	**5 4 3 2 1**

Total Side 1 ________

RIFFLE/RUN PREVALENCE

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
6. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from coarse gravel; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, coarse sand on old and new bars; 30-50% of the bottom affected; sediment deposits at obstruction, constriction, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE ________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7. Frequency of Riffles	Occurrence of riffles relatively frequent; distance between riffles divided by the width of the stream equals 5 to 7; variety of habitat.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream equals 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is between ratio >25.
SCORE ________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
8. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills > 75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE ________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
9. Condition of Banks	Banks stable; no evidence of erosion or bank failure.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach have areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; on side slopes, 60-100% of bank has erosional scars.
SCORE ________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
10. Bank Vegetative Protection	More than 90% of the streambank surface covered by vegetation.	70-90% of the streambank surface covered by vegetation.	50-70% of the streambank surfaces covered by vegetation.	Less than 50% of the streambank surface covered by vegetation.
SCORE ________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
11. Grazing or Other Disruptive Pressure	Vegetative disruption, through grazing or mowing, minimal or not evident; almost all plants allowed to grow naturally.	Disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Disruption of vegetation is very high; vegetation has been removed to 2 inches or less in average stubble height.
SCORE ________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
12. Riparian Vegetative Zone Width	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters; little or no riparian vegetation due to human activities.
SCORE ________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
Total Side 2 ________				
Total Score ________				



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FLOWING WATERBODY FIELD DATA FORM

(Information and comments for fields boxed in double lines are required database entries. Other fields are optional for personal use.)

Date-Time-Initials* Example 20004212-0312-XYZ	- - Date Time Initials	Watershed Code (HUC)	Stream Code	Ch. 93 Use
Secondary Station ID		Surveyed by:		

*Date as YYYYMMDD, time as military time, and your initials uniquely identify the stream reach.

SWP Watershed

Survey Type

(1) Basin Survey, (2) Cause / Effect, (3) Fish Tissue, (4) Instream Comprehensive Evaluation [ICE], (5) Point-of-First-Use, (6) SERA, (7) Antidegradation [Special Protection], (8) Toxics, (10) Use Attainability, (11) WQN, (12) Limestone, (13) Low-gradient [Multihabitat]

Location

County: **Municipality:** **Topo Quad:**

Location Description:

Land Use

Residential:	%	Commercial:	%	Industrial:	%	Cropland:	%	Pasture:	%
Abd. Mining:	%	Old Fields:	%	Forest:	%	Other:	%		

Land Use Comments:

Canopy cover: open partly shaded mostly shaded fully shaded

Water Quality

		Field Meter Readings:					Bottle Notes (N-normal, MNF-metals non-filtered, MF-metals filtered, B-bac't, Others: indicate)
	Collector-sequence #	Temp (^{o}C)	DO (mg/L)	pH	Cond. (umhos)	Alkalinity mg/l	
1.							
2.							
3.							

Water Appearance/Odor Comments: (* see bottom of back for common descriptors)

Findings

Not Impaired: ☐ Impaired biology? ☐ Impaired habitat? ☐ Is impact localized? ☐ Reevaluate designated use? ☐

Decision comments. Describe the rationale for your "Not Impaired" or "Impaired" decision; reach locations for use designation reevaluations; special condition comments; etc.:

IBI Score: **Total Habitat Score:**

Macroinvertebrate sampling

Sampling method: Std. kick screen: ☐ D-frame: ☐ Surber: ☐ Other: ☐ method?: ____________________

Comments/Abundance Notes:

Habitat Impairment Thresholds	Metric Score
#3 Riff/Run: embeddedness <u>or</u> #3 Glide/Pool: substrate character + #6 Sediment Deposition = 24 or less *(20 or less for warm water, low gradient streams)*	
#9 Condition of Banks + #10 Bank Vegetation = 24 or less *(20 or less for warm water, low gradient streams*	
Total habitat score 140 or less for forested, cold water, high gradient streams *(120 or less for warm water, low gradient streams)*	

Habitat Comments:

Special Condition

Use this block to describe conditions that justify attainment/impairment of stations with IBI score <63 and >53.

*Common descriptors: **Water Odors** - none normal sewage petroleum chemical other; **Water Surface Oils** - none slick sheen globs flecks; **Turbidity** - clear slight turbid opaque; **NPS Pollution** - no evidence some potential obvious; **Sediment Odors** - none normal sewage petroleum chemical anaerobic; **Sediment Oils** - absent slight moderate profuse; **Deposits** – none sludge sawdust paper fiber sand relict shells other. **Are the undersides of stones deeply embedded black?**

Introduction

Because aquatic organisms are excellent indicators of water quality, and are routinely sampled as part of Pennsylvania's ongoing water quality management program, benthic macroinvertebrates will be collected in most instances to assess the attainment of aquatic life uses.

At least one of the biological sampling methods listed below will be applied in each Instream Comprehensive Evaluation survey conducted. The biological method selected for use must be the most appropriate for assessing the attainment of designated use of interest. In most instances benthic macroinvertebrates will be the primary biological assessment method. To quantify the precision of the overall method 10 percent of biological samples are replicated. Replicate samples should be collected within the same reach and by the same investigator to minimize variability. The primary method used to collect these organisms will be the semi-quantitative method described below.

a) Semi-Quantitative Method

For this method, benthic macroinvertebrate samples are collected with a hand held D-frame net employing the semi-quantitative "kick" method in shallow, fast and slow riffle areas. Sample collection consists of 6 D-frame sample efforts from each station, composited and returned to the lab for further processing and identification. This 6 D-frame sample collection method applies year round.

b) Quantitative Method

In some instances, such as establishing baseline conditions, it may be necessary to collect quantitative benthic samples from wadeable streams. In these cases, the traditional quantitative sampling methods should be used in place of the D-frame net. Recommended gear includes Surber- type samplers, artificial substrate (multi-plate) samplers, and grab sample devices. Sample processing will follow procedures set forth in PaDEP "Methods", Section V.C.

c) Sample Preservation

Samples collected using any of the above benthic methods are placed in labeled containers, preserved with 70-80 percent ethanol and returned to the laboratory for identification. In the laboratory, the organisms are sorted from debris and are identified using standard taxonomic references.

Methods

The DEP developed an index of biotic integrity (IBI) for benthic macroinvertebrate communities in Pennsylvania's wadeable, freestone, riffle-run type streams as a scientifically credible biological assessment tool. This indicator assists in guiding and evaluating legislation, policy and management strategies as well as setting goals for aquatic resources by enabling direct quantification of important ecological attributes along a gradient of biological conditions and ecosystem stressors. This indicator serves as a measure of the extent to which anthropogenic stressors impair the capability of a stream to support a healthy aquatic community.

This IBI applies to benthic macroinvertebrate samples collected any time of the year from wadeable, freestone, riffle-run streams in Pennsylvania using a D-frame net with 500-micron mesh. Field sampling and laboratory methods are more fully described in the Department's Standardized Biological Field Collection and Laboratory Methods, Section V. Sampling biologists composite six kicks from riffle areas distributed throughout a 100-meter stream reach, working progressively upstream, with each kick disturbing approximately one square meter immediately upstream of the net for approximately one minute to an approximate depth of 10 cm, as substrate allows. Composited samples are preserved with 95% ethanol in the field and transported back to the laboratory for processing. In the lab, each composited sample was placed into a 3.5 inch deep rectangular pan (measuring 14" long x 8" wide on the bottom of the pan) marked off into 28 four-square inch (2" x 2") grids. Four of the grids are randomly selected, their contents are extracted using a four-square inch circular "cookie cutter," and placed into another identical empty pan. From this second pan, organisms are picked from randomly selected grids until a 200-organism sub-sample (+/- 40 organisms) is obtained. If less than 160 identifiable organisms are sub-sampled from the original four grids, additional grids are extracted from the first pan, transferred to the second pan and picked until the target number of organisms are obtained. If more than 240 identifiable organisms are sub-sampled from the original four grids, one grid at a time is randomly selected and removed from the second pan until the target number of organisms is obtained. Any grids selected during this entire process are picked in their entirety and the total numbers of grids selected for each part of the sub-sampling process are recorded.

Organisms in the sub-sample are identified and counted. Midges are identified to the family level of Chironomidae. Snails, clams and mussels are all also identified to family levels. Roundworms and proboscis worms are identified to the phylum levels of Nematoda and Nemertea, respectively. Moss animacules are identified to the phylum level of Bryozoa. Flatworms and leeches are identified to the class levels of Turbellaria and Hirudenia, respectively. Segmented worms, aquatic earthworms, and tubificids are identified to the class level of Oligochaeta. All water mites are identified as Hydracarina, an artificial taxonomic grouping of several mite superfamilies. All other macroinvertebrates are identified to genus level.

Most of the samples used to develop the IBI were taken from relatively small, mostly first through third order riffle-run type streams draining less than 25 square miles, so this IBI should be applied with discretion to other stream types (e.g., limestone type streams) and larger stream/river systems. Currently, DEP does not apply any regionally-based classification to wadeable, freestone, riffle-run streams in the Commonwealth for purposes of applying this IBI.

The Metrics

A number of different metric combinations were evaluated during index development and the following six metrics were selected for inclusion as core metrics in the IBI based on various performance characteristics. These six metrics all exhibited a strong ability to distinguish between reference and stressed conditions. In addition, these six metrics measure different aspects of the biological communities represented by the sub-samples, and when used together in a multimetric index, they provide a solid foundation for assessing the biological condition of benthic macroinvertebrate assemblages in Pennsylvania’s wadeable freestone riffle-run stream ecosystems.

Total Taxa Richness

This taxonomic richness metric is a count of the total number of taxa in a sub-sample. Generally, this metric is expected to decrease with increasing anthropogenic stress to a stream ecosystem, reflecting loss of taxa and increasing dominance of a few pollution-tolerant taxa. Other benefits of including this metric include its common use in many biological monitoring and assessment programs in other parts of the world as well as its ease of explanation and calculation.

Ephemeroptera + Plecoptera + Trichoptera Taxa Richness (Pollution Tolerance Value 0 - 4 only)

This taxonomic richness metric is a count of the number of taxa belonging to the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) in a sub-sample – common names for these orders are mayflies, stoneflies, and caddisflies, respectively. The aquatic life stages of these three insect orders are generally considered sensitive to, or intolerant of, pollution (Lenat and Penrose 1996); in fact, this metric only counts EPT taxa with pollution tolerance values (PTVs) of 0 to 4, excluding a few of the most tolerant mayfly and caddisfly taxa. This metric is expected to decrease in value with increasing anthropogenic stress to a stream ecosystem, reflecting the loss of taxa from these largely pollution-sensitive orders. This metric has a history of use across the world and is relatively easy to use, explain and calculate (Lenat and Penrose 1996).

Beck's Index, version 3

This taxonomic richness and tolerance metric is a weighted count of taxa with PTVs of 0, 1, or 2. The name and conceptual basis of this metric are derived from the water quality work of William H. Beck in Florida. This metric is expected to decrease in value with increasing anthropogenic stress to a stream ecosystem, reflecting the loss of pollution-sensitive taxa. It should be noted that the version of the Beck's Index metric used for this project, although similar in name and concept, differs slightly in its calculation from the Beck's Index used in DEP's multihabitat protocol for assessing biological condition of low gradient pool-glide type streams.

Shannon Diversity

This community composition metric measures taxonomic richness and evenness of individuals across taxa of a sub-sample. This metric is expected to decrease in values with increasing anthropogenic stress to a stream ecosystem, reflecting loss of pollution- sensitive taxa and increasing dominance of a few pollution-tolerant taxa. The name and conceptual basis for this metric are derived from the information theory work of Claude Elwood Shannon.

Hilsenhoff Biotic Index

This community composition and tolerance metric is calculated as an average of the number of individuals in a sub-sample, weighted by PTVs. Developed by William Hilsenhoff, the Hilsenhoff Biotic Index generally increases with increasing ecosystem stress, reflecting increasing dominance of pollution-tolerant organisms.

Percent Sensitive Individuals (PTV 0 – 3)

This community composition and tolerance metric is the percentage of individuals with PTVs of 0 to 3 in a sub-sample and is expected to decrease in value with increasing anthropogenic stress to a stream ecosystem, reflecting loss of pollution-sensitive organisms.

Example calculations for each metric are provided below for a sample from Lycoming Creek.

Total Taxa Richness

There are ***33 taxa*** in this sub-sample

Total Taxa Richness = 33

Beck's Index, version 3

Beck's Index, version 3 =
(3 x (number of taxa with PTV = 0)) +
(2 x (number of taxa with PTV = 1)) +
(1 x (number of taxa with PTV = 2))

There are ***7 taxa in this sub-sample with PTV = 0***.
There are ***6 taxa in this sub-sample with PTV = 1***.
There are ***7 taxa in this sub-sample with PTV = 2***

Beck's Index, version 3 = 3(7) + 2(6) + 1(7)
Beck's Index, version 3 = 21 + 12 + 7

Beck's Index, version 3 = 40

EPT Taxa Richness (PTV 0 – 4 only)

There are ***9 Ephemeroptera taxa*** (Acentrella, Isonychia, Epeorus, Leucrocuta, Rhithrogena, Stenonema, Ephemerella, Serratella, Paraleptophlebia), ***5 Plecoptera taxa*** (Pteronarcys, Taeniopteryx, Leuctra, Agnetina, Paragnetina) and ***8 Trichoptera taxa***(Chimarra, Dolophilodes, Rhyacophila,Glossosoma, Brachycentrus, Micrasema, Apatania, Psilotreta) in this sub-sample ***with PTVs < 4.***
EPT Taxa Richness (PTV 0 – 4) = 9 + 5 + 8 .

EPT Taxa Richness (PTV 0 – 4) = 22

Benthic macroinvertebrate sample from
Lycoming Creek in Lycoming County
taken on November 19, 2001

Taxa Name	Number of Individuals	Pollution Tolerance Value
Acentrella	1	4
Isonychia	4	3
Epeorus	6	0
Leucrocuta	1	1
Rhithrogena	9	0
Stenonema	8	3
Ephemerella	32	1
Serratella	1	2
Paraleptophlebia	4	1
Pteronarcys	1	0
Taeniopteryx	1	2
Leuctra	2	0
Agnetina	1	2
Paragnetina	1	1
Chimarra	1	4
Dolophilodes	1	0
Cheumatopsyche	25	6
Hydropsyche	22	5
Rhyacophila	16	1
Glossosoma	2	0
Brachycentrus	3	1
Micrasema	1	2
Apatania	2	3
Psilotreta	1	0
Psephenus	3	4
Optioservus	7	4
Atherix	1	2
Antocha	2	3
Hexatoma	5	2
Prosimulium	1	2
Chironomidae	49	6
Ancylidae	2	7
Oligochaeta	1	10

Hilsenhoff Biotic Index

$$\text{Hilsenhoff Biotic Index} = \sum_{i=0}^{10} [(i * n_{indvPTVi})] / N$$

where $n_{indvPTVi}$ = the number of individuals in a sub-sample with PTV of i and N = the total number of individuals in a sub-sample.

There are 22 individuals with PTV = 0; There are 22 individuals with PTV = 5;
There are 57 individuals with PTV = 1; There are 74 individuals with PTV = 6
There are 11 individuals with PTV = 2; There are 2 individuals with PTV = 7;
There are 16 individuals with PTV = 3; There are 0 individuals with PTV = 8 or 9;
There are 12 individuals with PTV = 4; There is 1 individual with PTV = 10.

There are a total of 217 individuals in the sub-sample, so

Hilsenhoff Biotic Index = [(0 * 22) + (1 * 57) + (2 * 11) + (3 * 16) + (4 * 12) + (5 * 22) + (6 * 74) + (7 * 2) + (8 * 0) + (9 * 0) + (10 * 1)] / 217

Hilsenhoff Biotic Index = 3.47

Shannon Diversity Index

$$\text{Shannon Diversity Index} = [-\sum_{i=1}^{Rich} (n_i / N) \ln (n_i / N)]$$

where n_i = the number of individuals in each taxa (relative abundance); N = the total umber of individuals in a sub-sample; and Rich = the total number of taxa in a sub-sample (total taxa richness).

There are 33 taxa in this sub-sample. The numbers of individuals in each taxa are shown in the table above. There are a total of 217 individuals in the sub-sample

Shannon Diversity Index = – (1 / 217) ln (1 / 217) + (4 / 217) ln (4 / 217)+ (6 / 217) ln (6 / 217) + (1 / 217) ln (1 / 217) +(9 / 217) ln (9 / 217) + (8 / 217) ln (8 / 217) + (32 / 217) ln (32 / 217) + (1 / 217) ln (2 / 217) + *(do this for all 33 taxa)* … (1 / 217) ln (1 / 217)

Shannon Diversity Index = 2.67

Percent Sensitive (PTV 0 – 3) Individuals

$$\text{Percent Sensitive (PTV 0 – 3) Individuals} = (\sum_{i=0}^{3} n_{indvPTVi}) / N * 100$$

where $n_{indvPTVi}$ = the number of individuals in a sub-sample with PTV of i and N = the total number of individuals in a sub-sample

There are 22 individuals with PTV = 0; There are 11 individuals with PTV = 2;

There are 57 individuals with PTV = 1; There are 16 individuals with PTV = 3.

There are a total of 217 individuals in the sub-sample.

Percent Sensitive (PTV 0 – 3) Individuals = (22 + 57 + 11 + 16) / 217 *100

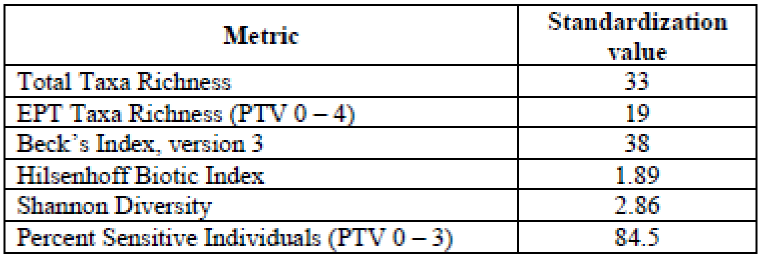
Percent Sensitive (PTV 0 – 3) Individuals = 106 / 217 * 100

Percent Sensitive (PTV 0 – 3) Individuals = 48.8%

The Index

An index is simply a means to integrate information from various measures of biological integrity, or various metrics. In order to compare and combine sundry measures (e.g., percentage of individuals, counts of taxa, unitless numbers) of biological condition in a meaningful manner, it is necessary to standardize metrics with some mathematical transformation that results in a logical progression of values.

The one selected core metric that increases in value with increasing anthropogenic stress (i.e., the Hilsenhoff Biotic Index) was standardized to the 5th percentile of metric scores for all samples in the IBI development dataset. Core metrics that decrease in value with increasing stress (i.e., total taxa richness, EPT taxa richness, % sensitive individuals, Shannon diversity, Beck's Index) were standardized to the 95th percentile of metrics scores for all samples in the IBI development dataset. The following table presents the standardization values used for each core metric.



Metric	Standardization value
Total Taxa Richness	33
EPT Taxa Richness (PTV 0 – 4)	19
Beck's Index, version 3	38
Hilsenhoff Biotic Index	1.89
Shannon Diversity	2.86
Percent Sensitive Individuals (PTV 0 – 3)	84.5

The values for standardized core metric values were set to a maximum value of 1.00, with values closer to zero corresponding to increasing deviation from the expected reference condition and progressively higher values corresponding more closely to the biological reference condition. The adjusted standardized metric values for the six core metrics were averaged and multiplied by 100 to produce an index score ranging from 0 to 100. This number represents the multimetric index of biological integrity (IBI) score for a sample. The following table shows the standardized metric and index scoring calculations for the Lycoming Creek sample discussed above.

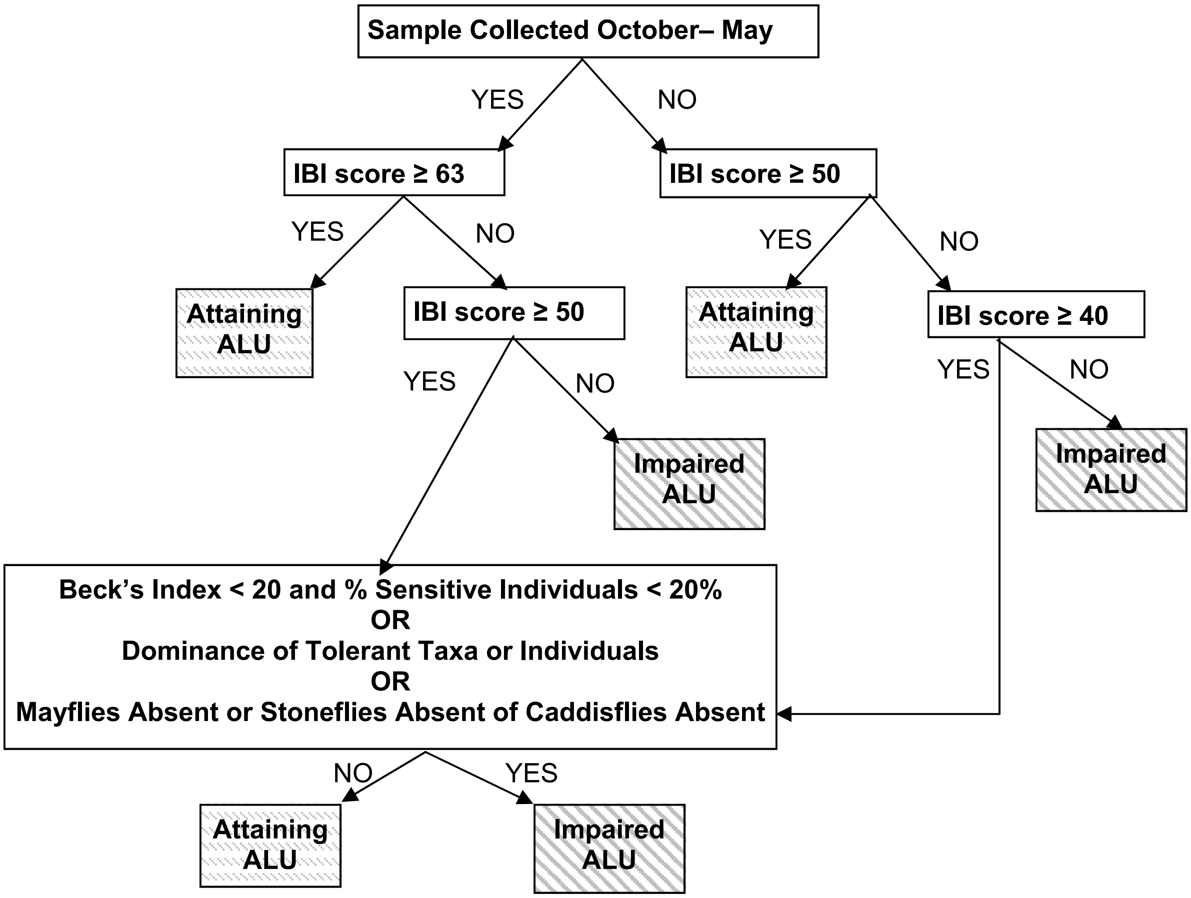
Metric	Standardization Equation	Observed Metric Value	Standardized Metric Score	Adjusted Standardized Metric Score Maximum = 1.000
Total Taxa Richness	observed value / 33	33	1.000	1.000
EPT Taxa Richness	observed value / 19	22	1.158	1.000
Modified Beck's Index	observed value / 38	40	1.053	1.000
Hilsenhoff Biotic Index	(10 – observed value) / (10 – 1.89)	3.47	0.805	0.805
Shannon Diversity	observed value / 2.86	2.67	0.934	0.934
Percent Sensitive Individuals	observed value / 84.5	48.8	0.578	0.578
Average of adjusted standardized core metric scores * 100 = **IBI Score** =				**88.6**

Aquatic Life Use Attainment Benchmarks

Based on the results of classification analyses (details available upon request), DEP decided not to establish separate reference conditions and thresholds for wadeable freestone, riffle-run type streams in separate regions of the Commonwealth. However, due to the influences of annual seasons and drainage area seen in the IBI development dataset, DEP recognizes different use attainment thresholds are appropriate for samples collected during different times of the year and from different size stream systems.

Based on the results of the analyses presented above, the results of workshops and feedback from DEP biologists and policy considerations, DEP implements a multi-tiered benchmark decision process for smaller wadeable freestone riffle-run streams in Pennsylvania that incorporates sampling season as a factor for determining aquatic life use (ALU) attainment and impairment for the cold water fishes (CWF), warm water fishes (WWF) and trout stocking (TSF) protected uses; this process is outlined in the diagram on the next page.

The first step in the ALU assessment process for smaller wadeable freestone riffle-run streams in Pennsylvania considers sampling season (i.e. June through September versus October through May). These seasonal index periods are intended as general guidelines and may vary slightly year-to-year depending on climatological conditions; for example, a sample collected during the last week of May in a particularly hot, dry year may be more properly evaluated using procedures set forth for the summer months.



For samples collected from smaller streams between October and May, an IBI score > 63 results in ALU attainment and an IBI score < 50 results in ALU impairment; an IBI score between 50 and 63 requires further evaluation to determine ALU impairment – three guidelines may be used: (1) if the Beck's Index score is < 20 and the % Sensitive Individuals in the sub-sample is < 20%, the ALU should be impaired without compelling reason otherwise; (2) if the sample is dominated by tolerant taxa or individuals, the ALU should be impaired without compelling reason otherwise; or (3) if mayflies, stoneflies or caddisflies are absent from the sub-sample the ALU should be impaired without compelling reason otherwise.

For samples collected between June and September from smaller streams, an IBI score > 50 results in ALU attainment and an IBI score < 40 results in ALU impairment; an IBI score between 40 and 50 requires further evaluation to determine ALU impairment, guided by the same three guidelines outlined above for October to May samples scoring between 50 and 6 (although the absence of mayflies in samples collected immediately after spring hatches may be relaxed in some cases).

For larger wadeable freestone riffle-run type streams, DEP believes more samples are necessary to accurately establish ALU attainment and impairment benchmarks. Given the nature of flowing water bodies as gradually changing continuums, it is difficult to define a specific numeric cutoff to separate larger streams from smaller streams. However, the present dataset suggest that scores for some index metrics begin to decline for reference-quality streams drainage areas that reach the 25 to 50 square mile range. Workshops conducted by DEP confirm that biological expectations or potential for most of the relatively pristine larger freestone streams in Pennsylvania are less than the biological expectations or potential for the relatively pristine smaller freestone streams.

The use assessment decision process and accompanying attainment/impairment benchmarks set forth above are intended as general guidelines, not as hard-and-fast rules. While the above guidelines will provide an accurate assessment of benthic macroinvertebrate community condition for the vast majority of samples collected from wadeable, freestone, riffle-run streams in Pennsylvania, there will be instances where a biologist’s local knowledge of conditions may warrant a decision not arrived at using these guidelines. For instance, if a sample is heavily dominated by Simuliidae or Chironomidae larvae, often times this will make the metric and IBI scores difficult to interpret and the investigating biologist must rely on a more qualitative analysis of the metric scores and sample composition to arrive at an assessment decision. Similarly, samples from streams in areas receiving a substantial amount of flow from groundwater attributable to limestone geology are naturally expected to have less diversity than “true freestone” streams, so use attainment benchmarks may be justifiably relaxed for samples from these types of streams.