1.2.4 BENTHIC CONDITION

Background Information

Stream benthic macroinvertebrates are small, stream-dwelling animals that do not have vertebrae and are visible with the naked eye. Benthic macroinvertebrates include insects, crayfish, clams, snails, and worms. Because different types (taxa) of benthic macroinvertebrates differ in their sensitivity to stream impacts, these organisms are excellent biological indicators of water quality and watershed health, and the composition of the benthic macroinvertebrate community can provide important information about the relative health of a given watershed. Some benthic macroinvertebrates (such as mayflies, stoneflies, and most caddisflies) are very sensitive to pollution and cannot survive in degraded streams. Others (such as some groups of true fly larvae, some aquatic snails, and aquatic worms) are more tolerant and can be found in very degraded streams. Therefore, it is important to study these communities to gain a better understanding of the overall stream condition.

Numerous methodologies for assessing stream water quality through the evaluation of benthic macroinvertebrate communities exist and are used by regulatory agencies and citizen water quality monitoring programs to assess watershed health. In Virginia, the Department of Environmental Quality (DEQ), local governments, and citizen water quality monitoring programs use methodologies modified from either the Environmental Protection Agency's (EPA) Rapid Bioassessment Protocols or the Izaak Walton League of America's Save Our Streams (SOS) Program. The methodologies used by these organizations vary in the amount of time necessary to sample and identify organisms, the taxonomic level to which the organisms are identified, the level of training required to identify the organisms, and the complexity of the metrics used to arrive at a stream assessment score.

At the very minimum, established benthic macroinvertebrate assessment methodologies require the collection of benthic macroinvertebrates from a specified number of sample sites and/or collection for a specified amount of time; the collection of organisms during a specified spring (and sometimes fall) index period; random subsampling of the organisms collected to achieve a specified subsample size; identification of the organisms within the subsample to the order or, more commonly, to the family level (some more detailed methodologies require the samples to be returned to a laboratory where they are subsampled, sorted, and identified to the genus or even species level); counting of organisms within each taxonomic group in the subsample; and calculation of a water quality

BENTHIC CONDITION (cont)

rating or index score using multiple metrics related to taxa richness, community composition, pollution tolerance, feeding strategies, and/or life cycle strategies.

In summary, all commonly used benthic macroinvertebrate assessment methodologies are time consuming. The most complex methodologies, such as the more detailed version of the EPA Rapid Bioassessment Protocol used by the VA DEQ, may take as much as two days or more per assessment reach to collect organisms, sort and identify organisms to the genus or species level, and analyze data. Because organisms are identified to lower taxonomic levels, specimens must be returned to a lab for identification to insure proper identification and quality control.

Because of their complexity, even the most simplified methodologies can not be quickly and easily used by a non-biologist. Simplified versions of the EPA Rapid Bioassessment Protocol, such as the methodology used by citizen monitoring groups sponsored by the Audubon Naturalist Society (ANS), require identification of most benthic macroinvertebrates to the family level and generally take three to four hours per assessment reach to collect, sort, and identify the organisms. The Virginia SOS method, which is used by other citizen monitoring groups in Virginia, requires that most organisms are identified to the order level. This method generally takes an assessment team, depending on the number of organisms sampled and level of expertise of the monitors, one to two and a half hours to complete.

In the development of this Stream Impact Assessment Manual, an attempt has been made to incorporate a simplified benthic macroinvertebrate assessment that can be quickly and easily used by individuals having a minimal amount of training in stream assessment and benthic macroinvertebrate identification. Various candidate metrics and simplified indices were analyzed using data made available by the Maryland Department of Natural Resources (DNR) Maryland Biological Stream Survey (MBSS) and DNR's Stream Waders Program. The purpose of the data analysis was to identify a single metric that uses the total number of macroinvertebrate taxa (identified to the order level) found in the reach, with emphasis given to taxa that are sensitive to environmental stressors (specifically mayflies, stoneflies, and caddisflies – the EPT taxa: Orders Ephemeroptera, Plecoptera, and Trichoptera), to achieve a qualitative rating for the relative water quality within the stream.

BENTHIC CONDITION (cont.)

The data analysis performed to date has failed to identify a single metric that reliably correlates order-level taxa richness (i.e., the number of distinct orders found in a community or sample) to benthic condition or stream water quality. Further study and testing of other metrics is needed to identify a benthic macroinvertebrate assessment methodology that can be quickly and easily used and at the same time provides a reliable indicator of benthic condition.

Assessment of Benthic Condition in SIAM

Because the established benthic macroinvertebrate assessment methodologies are too cumbersome to include as part of this Stream Impact Assessment Manual, this Manual includes a very simplified assessment of benthic condition designed to allow the regulated public as well as the regulatory agencies to begin to understand how to utilize this assessment parameter and to collect data to better correlate the benthic macroinvertebrate community with the other stream condition parameters.

This Stream Impact Assessment Manual does not include a more detailed benthic macroinvertebrate assessment because all of the established benthic macroinvertebrate assessment methodologies are too complex and too cumbersome to include in a multi-parameter stream assessment method that is intended to be applied in a rapid, repeatable manner, without specialized equipment or significant training. This Stream Impact Assessment Manual does, however, provide guidance on collecting benthic macroinvertebrate data and encourages evaluators to collect data and use it to develop alternative methodologies to assess the stream's benthic condition and relate the benthic condition to overall stream condition. It is anticipated that as data is collected and analyzed, future versions of this assessment method will incorporate more rigorous sampling protocols and employ metrics designed to specifically evaluate the benthic condition.

Until such time as a workable methodology can be developed (within the necessary limitations of the stream assessment methodology presented in this Manual), benthic condition is tied directly to the in-stream habitat parameter. The benthic condition of the assessment reach should be determined from the in-stream habitat condition, as described below, and recorded on Form 1-1:

BENTHIC CONDITION (cont)

1. **Streams with poor In-Stream Habitat Condition are presumed to have <u>POOR Benthic Condition</u>:** Streams with" poor" benthic condition will generally have benthic macroinvertebrate communities represented by few benthic macroinvertebrate taxa. The taxa present will likely consist primarily of pollution-tolerant taxa such as aquatic worms, true fly larvae (such as chironomids), and lunged snails. Occasionally, streams with a poor benthic condition will contain many individuals of these pollution-tolerant taxa. Pollution-sensitive taxa such as mayflies, stoneflies, and caddisflies will generally be absent from streams with poor benthic conditions (though they may occur in small numbers).

2. **Streams with marginal In-Stream Habitat Condition are presumed to have <u>FAIR Benthic Condition</u>:** Streams with a "fair" benthic condition will generally have benthic macroinvertebrate communities represented by a moderate diversity of benthic macroinvertebrate taxa. The taxa present may include pollution-tolerant taxa as well as few individuals of pollution-sensitive taxa (most commonly caddisflies). Very sensitive taxa such as most mayflies and stoneflies will generally be absent from streams with fair benthic conditions.

3. **Streams with optimal In-Stream Habitat Condition are presumed to have <u>GOOD Benthic Condition</u>:** Streams with a "good" benthic condition will generally have benthic macroinvertebrate communities represented by a high diversity of benthic macroinvertebrate taxa. The taxa present will often contain one or more of the Orders of EPT taxa. Pollution-sensitive taxa such as mayflies, stoneflies, and caddisflies will generally outnumber pollution-tolerant taxa in streams with good benthic conditions.

It has been shown that in many situations there is not a direct correlation between available in-stream habitat and the benthic macroinvertebrate community (e.g., a stream with optimal in-stream habitat conditions may not necessarily have a diverse and abundant benthic macroinvertebrate community). Many factors outside and upstream of any given stream reach can contribute to the water quality of the stream and affect the benthic macroinvertebrate community within the assessment reach.

BENTHIC CONDITION (cont.)

As stated above, it is recommended that evaluators collect data on benthic macroinvertebrates in stream assessment reaches to which this Stream Assessment Impact Assessment Manual is applied. Evaluators are also encouraged to use the data to refine this benthic condition assessment indicator, and thus the evaluator may deviate from the "default" relationship between In-stream Habitat Condition and Benthic Condition provided above, given benthic data that supports such a change in valuation. If the benthic condition of the assessment reach is determined based on benthic macroinvertebrate data collected from the assessment reach rather than the "default" benthic condition rating described above, an explanation of the methods used to determine the benthic condition should be provided on Form B-1.

Recommended sampling procedures for collecting benthic macroinvertebrates are provided below, and a data form entitled "Benthic Macroinvertebrate Worksheet" is provided in Appendix A for ease of recording data. If more in-depth sampling procedures are desired, detailed explanations of sampling methodologies and data analysis can be obtained from the following sources:

1. The U.S. EPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*, Second Edition by M.T. Barbour, J. Gerritsen, B.D. Snyder, and J.B. Stribling (EPA 841-B-99-002). This document, including data forms and all appendices, can be downloaded from the following website: http://www.epa.gov/owow/monitoring/ rbp/download.html;

2. The Virginia DEQ *Virginia Citizen Water Quality Monitoring Program July 2003 Methods Manual*. This document can be downloaded at the following website: *http://www.deq.virginia.gov/cmonitor/guidance.html*; and,

3. The Virginia Save Our Streams Program website: *http://www.sosva.com/*.

Recommended Sampling Procedure

Benthic macroinvertebrates occur in a variety of stream habitats, and different types of organisms use different habitat types within streams. For this reason, benthic macroinvertebrates should be collected from the best available habitats (including gravel and cobble riffles, submerged snags, stick/leaf packs, undercut banks, submerged aquatic vegetation, and root mats) within the assessment

BENTHIC CONDITION (cont)

reach. Habitats should be sampled in relative proportion to the frequency they occur within the reach, and representative examples of all habitat types within the reach should be sampled. The length of time spent sampling will vary with the length of the assessment reach and the amount of habitat available to sample.

The sampling procedure used in this manual to assess the benthic condition is a simplified methodology based on the Izaak Walton League of America's Save Our Streams Program. The following materials will be needed to collect and sample benthic organisms within the assessment reach:

- Waders or water-proof boots,
- 12-inch D-frame dip net,
- 10x magnification hand lens,
- Forceps,
- Pencil,
- Light-colored tray (optional),
- Benthic macroinvertebrate identification key (a key to the orders of Virginia's common stream benthic macroinvertebrates is provided in Appendix A of this Manual), and
- The Benthic Macroinvertebrate Worksheet provided in Appendix A.

Before beginning to collect/sample the benthic macroinvertebrate community, walk the assessment reach and observe the types of habitats available. Is the streambed substrate composed primarily of gravels, cobbles and larger materials or is the substrate composed primarily of sands, silts, and fine-grained materials?

In Virginia, low-gradient Coastal Plain streams generally have fine-textured substrates and lack well-developed riffle habitats that are common in Piedmont and mountain streams with rocky substrates. Riffle habitats generally support a greater abundance and diversity of benthic organisms than other in-stream habitats. For these reasons, slightly different collection strategies should be applied in high-gradient rocky-bottom streams and low-gradient streams with fine-textured substrates. Sampling should always start at the downstream end of the assessment reach and proceed upstream to avoid suspending fine-textured sediments and obscuring visibility within the stream.

BENTHIC CONDITION (cont.)

A. **Sampling Benthic Macroinvertebrates in Streams with Rocky Substrates** - To sample benthic macroinvertebrates in streams with rocky substrates, use the following procedures:

1. Place the net perpendicular to the direction of flow immediately downstream of the feature to be sampled so that water flows across the feature and through the net. The sample area should be limited to a 1 foot by 1 foot area immediately upstream of the net.

2. Lift and rub the substrate to be sampled (rocks, woody debris, etc.) to dislodge any clinging organisms.

3. Rub all exposed surfaces of rocks that are too large to lift to dislodge organisms.

4. Stir up sand and small sediments between small rocks within the sample area to dislodge burrowing organisms.

5. Remove the net from the water with an upstream swooping motion to capture organisms dislodged from the substrate.

6. Larger rocks and large woody debris (i.e., logs) should be visually inspected. In riffles with larger sized substrates, lift large cobbles from the streambed, examine surfaces for clinging organisms, and return the stone to the streambed.

7. Sample other habitat types (i.e., woody snags, leaf packs, undercut banks, and submerged aquatic vegetation) in relative proportion to their occurrence within the assessment reach.

BENTHIC CONDITION (cont)

B. **Sampling Benthic Macroinvertebrates in Streams with Sandy or Muddy Substrates** - To sample benthic macroinvertebrates in streams with fine-textured substrates, follow the following procedures:

1. Sample within all velocity regimes by taking “jab” samples in the best available habitat within the assessment reach.

2. A single “jab” consists of aggressively thrusting the net into the target habitat for a distance of approximately 3 feet.

3. Follow the initial jab with two to three sweeps of the same area to capture any dislodged organisms.

4. Sample the representative examples of the best available habitat (i.e., woody snags, leaf packs, undercut banks, and submerged aquatic vegetation) in relative proportion to their occurrence within the assessment reach.

C. **Specific sampling techniques for non-riffle habitat areas**:

1. Woody Snags, Submerged Woody Debris and Leaf Packs

Snags or submerged woody debris are sampled by jabbing into tangles of medium-sized sticks and branches. Agitating or rubbing woody debris and leaf packs with one’s spare hand will help dislodge organisms. Large material such as logs may be sampled by scraping the net along the surface. Woody debris may be picked up and visually examined for organisms clinging to the surface. Similarly, submerged leaf packs can be picked up and visually examined for organisms hiding between the leaves.

BENTHIC CONDITION (cont.)

Specific sampling techniques for non-riffle habitat areas (cont.):

2. Undercut Banks

Undercut banks are sampled similar to submerged woody snags and woody debris. Jab the net under the bank, drawing the net upward from the stream bottom to the top of the undercut banks through any submerged roots or woody debris. Agitating or rubbing woody debris and leaf packs with one's spare hand will help dislodge organisms.

3. Submerged Aquatic Vegetation

Submerged aquatic vegetation is sampled by drawing the net through the vegetation from the stream bottom to the water surface. In shallow water, submerged vegetation is sampled by bumping the net along the bottom within the vegetation bed.

BENTHIC CONDITION (cont)

Specific sampling techniques for non-riffle habitat areas (cont.):

4. Root Mats

Root mats are sampled similar to submerged woody debris by jabbing the net into the root mat or dragging the net through fine roots. Agitating or rubbing woody debris and leaf packs with one's spare hand will help dislodge organisms.

Samples should be collected from ten locations within the assessment reach. In cases where the assessment reach is very short because the limits of the assessment reach have been defined by the stream's geomorphologic characteristics, it may not be possible to collect ten benthic macroinvertebrate samples due to the lack of suitable habitat. In such instances, the number of samples collected should be noted.

After sampling each habitat area within the assessment reach, examine the contents of the net carefully and record the number and types of organisms observed on the Benthic Macroinvertebrate Worksheet. A separate form should be used for each assessment reach. Organisms may be emptied into a shallow, light-colored tray for ease of observation.

The benthic macroinvertebrates collected should be identified to the lowest taxonomic level practicable. Under field conditions, it is generally only feasible to identify organisms to the order level (highly experienced individuals may be able to identify organisms to the family or even genus level in the field). Appendix B: Identification

BENTHIC CONDITION (cont.)

Guide to Stream Benthic Macroinvertebrates of Virginia provides an easy-to-use key for identifying Virginia's common stream benthic macroinvertebrates to the order level (or in some cases the phylum, class, or family levels). If identification to a lower taxonomic order is desired, many other resources are available. The following is a partial list of widely used benthic macroinvertebrate identification keys and field guides:

1. Jessup, Benjamin K. 2002. Family-Level Key to the Stream Invertebrates of Maryland and Surrounding Areas. Maryland Department of Natural resources Chesapeake Bay and Watershed Programs Monitoring and Non-Tidal assessment Division, CBWP-MANTA-EA-99-2(revised 2002). (*http://www.dnr.state.md.us/streams/pubs/ea992rev2002.pdf*)

2. McCafferty, W.P. and A.V. Provonsha. 1998. Aquatic Entomology: The Fisherman's and Ecologist's Guide to Insects and Their Relatives. Science Books International, Boston, MA.

3. Merritt, R.W. and K.W. Cummins. 1996. An Introduction to the Aquatic Insects of North America. Second Edition. Kendall/Hut Publishing Company.

4. Peckarsky, B.L., P.R. Fraissinet, M.A. Penton, and D.J. Conklin, Jr. 1990. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca, NY

5. Voshell, J.Reese, Jr. 2002. A Guide to Common Freshwater Invertebrates of North America. The McDonald & Woodward Publishing Company, Blacksburg, VA.

Seasonal Considerations

The evaluator should be aware that the results of benthic macroinvertebrate sampling efforts will vary with the season in which they are performed. In general, benthic macroinvertebrate diversity and abundance are greatest in the late winter and spring months when water levels are highest and water temperatures are relatively low. Diversity and abundance decrease in the summer and early fall as water levels fall and temperatures rise. In streams that do not have continuous flowing water throughout the year, available sampling sites may not be available in the summer and early fall months due

BENTHIC CONDITION (cont)

to a lack of water. For these reasons, established monitoring programs require that samples be collected during spring index periods when diversity and abundance are greatest. Some monitoring programs also sample organisms during a late fall index period.

For state and Federal regulatory purposes, however, this Stream Impact Assessment Manual must be used throughout the year (or in drought conditions) to determine the potential affects of proposed impacts to streams. Therefore, the benthic condition sampling procedures must be modified in cases where flow levels are either greatly reduced due to seasonal or climatic conditions. At this time there are no known established procedures for assessing benthic macroinvertebrate communities in streams where flow is absent (yet the majority of permitted stream impacts are in intermittent streams).

However, it is recommended that evaluators sample all streams to the extent possible (as described below), record their results, and examine the data to determine if any correlation can be made between the actually observed benthic macroinvertebrates and the assigned benthic condition of the stream.

During the low-flow periods of the year (typically from July through September), intermittent streams may have discontinuous flow, they may have widely spaced pools separated by areas of dry streambed, or they may be completely dry. If water is present within only a portion of the assessment reach at the time of the stream impact assessment, available habitat within any areas of pools or flowing water should be sampled as described above. In areas with no flowing water, examine the undersides of cobble-sized rocks for the stone cases of caddisflies, as the larvae of caddisflies in the genus *Neophylax* are known to seal themselves in their cases on the undersides of rocks in the summer months when stream flows are low and/or the water is warm. These caddisflies often occur in aggregations on the undersides of rocks, are easy to find, and may occur in large numbers in the streams where they are present.

Using Benthic Macroinvertebrates to Achieve a Benthic Condition Score

As discussed above, established benthic macroinvertebrate protocols involve an analysis of multiple metrics to arrive at a water quality rating or index score, and these protocols generally require

BENTHIC CONDITION (cont.)

Using Benthic Macroinvertebrates to Achieve a Benthic Condition Score (cont.)

expenditures of time and require that the evaluators be trained to identify benthic macroinvertebrates to at least the order level. At this time there is no known and accepted benthic macroinvertebrate assessment methodology that can be quickly and easily applied by a non-biologist with a minimal amount of training to gain a reliable qualitative rating of stream water quality.

Until such time as a workable methodology can be developed, benthic condition is tied directly to the in-stream habitat parameter. The benthic condition of the assessment reach should be determined from the in-stream habitat condition, as described above, and recorded on Form 1-1. Additionally, it is recommended that evaluators collect data on benthic macroinvertebrates in stream assessment reaches to which this Stream Assessment Impact Assessment Manual is applied and record the data on Form B-1. Evaluators are also encouraged to use the data to refine this benthic condition assessment indicator. Thus the evaluator may deviate from the "default" relationship between In-stream Habitat Condition and Benthic Condition, given benthic data that supports such a change in valuation. If the benthic condition of the assessment reach is determined based on benthic macroinvertebrate data collected from the assessment reach rather than the "default" benthic condition rating described above, an explanation of the methods used to determine the benthic condition should be provided on Form B-1.

It is anticipated that as benthic macroinvertebrate data is collected and analyzed, a benthic macroinvertebrate assessment methodology will be developed to quickly and easily provide a qualitative rating of a stream's benthic condition, and that methodology will be incorporated into future versions of this Manual.

NOTES: