

PROTOCOLS FOR REFERENCE WATERSHED APPROACH

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Abstract

The Virginia Department of Environmental Quality (DEQ) requested the Academic Advisory Committee (AAC) to: 1) review reference watershed selection literature and approved TMDL reports, and 2) recommend protocols to ensure consistency of the reference watershed selection process. This report, describes the concept of the reference watershed approach, and provides an overview of selected TMDL reports and the current literature. The AAC concludes that it is rather impossible and impractical to develop uniform protocols for selecting a reference watershed but presents recommendations on how DEQ can improve the uniformity of the process, and to enhance the application and validity of the reference watershed approach for TMDL development

Introduction

The reference watershed approach is used to estimate total maximum daily load (TMDL) target loads (endpoints) for biologically impaired waters (aquatic life support) and other impaired waters where the chemical or pollutant (stressor) under consideration has no established water quality numeric criteria. In Virginia, biological monitoring and assessment is used to determine if the aquatic life designated use of waters is being met. Common stressors for which numeric criteria are not available include sediment, nutrients, organic materials, and total dissolved solids. For TMDL purposes, it is assumed that the reference watershed approach can reasonably estimate acceptable pollutant loads; and when the pollutant control measures are implemented, the improved in-stream water quality will support the aquatic life designated uses of water. Although there are uncertainties in this approach, implementation of controls that address impairments are generally being implemented in a “phased or adaptive” approach so that impacts due to uncertainties in load estimates are kept in check. Continued monitoring will indicate if and when the TMDL water quality goal is achieved.

Discussion

Elements of the Reference Watershed Approach

Three critical elements of a successful reference watershed approach are: *defining the reference condition*, *selecting a reference watershed*, and *calculating pollutant loads*. All three elements collectively affect the validity of the reference watershed approach to estimate TMDL target loads.

1.--Defining Reference Condition

In the TMDL literature, *reference stream*, *reference site*, and *reference condition* are sometimes used interchangeably. However, there are certain distinctions between these terms. In Virginia, a *reference site* generally refers to a biological monitoring site that was selected by DEQ biologists to represent a stream segment that was least impacted or minimally influenced by human activities within a given physiographic area or ecoregion. A *reference stream* is the stream segment containing the biological monitoring site, and a *reference watershed* is the upstream area that drains to the *reference site*. In Virginia, a set of *reference conditions* is used to assess waterbody compliance with Virginia's General Standard, whose intent is to protect its aquatic life uses.

A *reference condition* set consists of a series of physical, chemical, biological, and/or habitat characteristic measurement thresholds that are associated with biologically healthy streams. A set of *reference conditions* can also be developed for a single stressor (e.g. sediment), although this approach has not been used in Virginia. A *reference condition* set can be based on a single stream, or on an aggregation of data from several sites within a specific ecoregion.

Bioassessment is the basis for defining the reference condition set. In Virginia, the Rapid Biological Protocols (RBPII) method has historically been used for bioassessments. A limiting factor in the use of the RBPII, however, is the identification of appropriate locally available reference sites. Recently, bioassessments and some TMDL reports in Virginia have been based on the Virginia Stream Condition Index (VaSCI). The VaSCI is based on using a standardized, aggregate *reference condition* for Virginia (DEQ 2006). The VaSCI represents a standardized assessment approach for non-coastal waterbodies in Virginia and removes much of the variability in assessment results that could occur with the RBPII from site to site, and from sample to sample. However, long-term temporal stability of the VaSCI is not known as yet but a recent validation study on the first five years of probability monitoring indicates that the VaSCI has worked well to date in discriminating between sites with acceptable water quality and habitat and those with degraded water quality and habitat (DEQ, 2006). In 2004, the Academic Advisory Committee (AAC) for DEQ also addressed the processes for defining a set of reference conditions and presented a set of short-term and long-term recommendations (Smock et al. 2004, pages 4-6).

There are efforts in other states related to selecting a reference site or reference condition. For example, Oregon DEQ (Drake 2004) introduced a three step process for selecting a reference condition site: 1) Pre-screening; 2) Site visits; and 3) Site verification. Pre-

screening involves selecting a region, identifying the primary natural gradients, and using GIS information and best professional judgment to identify watersheds with minimal human disturbance. Site visits are used to record stream-reach-level human disturbances, and sites visits along with delineated watershed geographic information are used to score a Human Disturbance Index (HDI). Site verification involves reviewing the disturbance information and sampling data. In the Oregon approach, reference watershed selection is not based on in-stream conditions, but the final verification includes an evaluation of the biological, physical habitat, and water quality data for outliers that might indicate unidentified problems. Verification is completed with the assignment of a “site classification” grade.

The selection of a reference condition based on the subjective “minimal human disturbance” presents a major shortcoming of the current bioassessment procedures. The selection of a reference condition (within an ecoregion) based on minimally influenced streams (or minimal human disturbance) does not take into consideration land use characteristics within a watershed. Whereas the method can yield a uniform bench mark to define the status of stream impairment, it magnifies the influence of pristine or minimally influenced streams in index calculations that do not represent realistic stream conditions in mixed land use and highly urbanized watersheds. A preferred approach would be to use the “best of the stream” and land use characteristics in a given ecoregion for establishing the reference condition for estimating TMDL target load. While this discussion has taken place for the selection of biological reference sites, however, it has not been a criterion for selection of reference watersheds for modeling purposes as discussed in the next section.

2.--Selecting a Reference Watershed

The concept of using a reference watershed to estimate a TMDL target loads is based on using a pair of watersheds, i.e., the impaired watershed and the reference watershed. It is important to note that selection of a reference watershed is limited to stream sites within the same ecoregion where biological monitoring has been performed. This screening filter is applied because, according to biologists, differences in types of biological taxa and habitat for different ecoregions are significant. The primary qualification for selection is that the reference watershed hosts a healthy biological community, i.e., its stream is supportive of its aquatic life designated use documented by RBPII or VaSCI.

The process for using a reference watershed to estimate a TMDL target load can be summarized as follows: Pollutant loads are simulated to both the impaired and reference streams from their respective watersheds using appropriate watershed characteristics’ parameters and computer modeling techniques. The average annual unit-area pollutant load (i.e. kg/ha-yr) for the reference stream is used as the basis for defining the TMDL target load for the impaired stream. The required TMDL load reduction is calculated as the difference in unit-area pollutant loads multiplied by the area of the impaired watershed, or as the difference in loads between watersheds where the reference watershed has been scaled to the same size as the impaired watershed. In some TMDL reports (e.g., Goos Creek Benthic TMDL), the average annual loading rate for a stressor

is calculated for impaired and reference watersheds from area-weighted loading rates by land use for each watershed.

Reference watersheds ideally should have similar sizes, topographic features, soil types, land uses, stream characteristics and hydrologic/ecologic conditions as the impaired watershed. High variability in watershed characteristics can significantly affect relative model output loads, the TMDL target load, and subsequent pollutant load allocations. Because paired watersheds for target load estimation are mostly within the same ecoregion, similarity in ecoregions is usually the primary filter that gets applied to the list of potential references for any given site. Land use distribution, soil types, slope, elevation, and population are some of the factors that have been considered in judging comparability between an impaired and the potential reference watersheds. Since load quantification will be performed for the TMDL, the types and suspected sources of the identified pollutant (stressors) should also be considered when selecting the most appropriate reference watershed.

The critical question to be asked is what is the relative importance of these factors? In a recent paper, Wagner et al. (2006) conducted an analysis of factors (such as land use, slope, data source, modeling technique, etc.) that are critical to reference watershed selection using several watersheds as case study sites. The report concluded that despite its shortcomings, the reference watershed approach fills an important need in TMDL modeling approaches for estimating a numeric target load in the absence of numeric criteria. It is a useful tool since relative load reductions, when implemented, can guide initial strategies toward addressing the impairment. The study also concluded that land use comparability was the most important factor for selecting an appropriate reference watershed. However, in some cases this match may not be as close as desirable thus introducing a degree of uncertainty in the process.

3.--Calculating Pollutant Loads

In Virginia, the GWLF (*Generalized Watershed Loading Functions*) model and its derivatives (e.g., BasinSim, AvGWLF, Vensim GWLF, and a version modified by Virginia Tech) have been used almost exclusively for the development of TMDLs using the reference watershed approach. To date, sediment and phosphorus are the only two pollutants simulated using this model and approach. While other models could be used, data requirements of the GWLF model can be met primarily with available data, whereas more sophisticated models, such as HSPF (Hydrologic Simulation Program-FORTRAN), would require additional monitoring for parameter calibration. EPA allows for the use of simpler load calculations when data are unavailable, but these simple calculations usually provide little information about the spatial and temporal variations in load. Furthermore, it should be noted that data availability and model parameter estimation are critical factors in estimating loads. The uncertainty associated with these factors introduces uncertainty in the model results and thus in the TMDL calculated loads.

Review of Virginia's TMDL Reports

The TMDL website for DEQ shows 35 TMDL reports (as of January 3, 2007) for which sediment is listed as a stressor and for which a reference watershed approach is used for quantifying sediment TMDL target loads (DEQ 2007). A number of these reports also indicate nutrients and organic material as potential stressors although most streams in these reports were originally listed only for aquatic life use impairment. Sediment was identified as the most probable stressor in most of these watersheds. The rationale for declaring sediment to be the most probable stressor is that excessive sediment directly affects aquatic life habitat, and that sediment reduction would also lead to reductions of other potential stressors (e.g., nutrients and organic matter).

In Virginia's TMDL reports, different levels of effort have been expended and various levels of justification are provided for selecting a reference watershed. In some TMDL reports, data for several potential reference sites have been presented and analyzed to select the most appropriate reference site (e.g., Lewis Creek TMDL). In other reports, documentation of justification for reference watershed selection is lacking.

Watershed size and land use distributions can be critical factors, if significantly different between two paired watersheds. For example, the selected reference watershed for Bull Run (118,951 acres) was similar in size (110,614 acres) but not land use. The urban portion of the watershed represents 40% for Bulls Run but only 2% for the reference watershed, Goos Creek. In the Popes Head Creek TMDL (watershed area 12,120 acres), the reference watershed, Goos Creek (110,614 acres), is considerably larger and has considerably different land use. The agricultural land use for Goos Creek and Popes Head Creek is 55% and 4% respectively, and the urban land use is 2% and 58% respectively. In general, urban (impervious) land use above 10% significantly changes the hydrologic function of a watershed. Where impaired and reference watersheds are significantly different in size, the area-adjustments for purposes of estimating the channel erosion component of sediment loads also add a measure of relative uncertainty.

Another shortcoming of some TMDL reports is their lack of appropriate data documentation. For example, for the Ash Camp Creek TMDL, the adjacent Twittys Creek watershed was selected as the reference watershed based on its non-impaired rating using the Virginia Stream Condition Index (VaSCI). However, in the TMDL report, no comparative data was provided for physical features (size, land use, topography, etc.) with the impaired watershed. This critique does not imply that there is a problem with the Ash Camp Creek TMDL report but that better documentation of the process would make the selection more understandable and defensible.

Conclusions

The reference watershed approach is a practical way for estimating TMDL target loads (endpoints) for impaired waters where the chemical or pollutant (stressor) under consideration has no established water quality numeric criteria. However, the scientific basis for reference watershed approach has not been established. Uncertainty in the

process is introduced in all three steps: defining the reference condition, selecting a reference watershed, and calculating pollutant loads. Overall, the review of Virginia TMDL reports indicates that the reference watershed selection approach includes a large measure of “best professional judgment” on the part of contractors who develop the TMDLs, in consultation with DEQ TMDL Project Managers. There is a need for consistency in protocols and data documentation because the reference watershed selection approach affects quantification of TMDL target loads and consequent waste load allocation, even though phased implementation allows for continuous refinement of appropriate stressors, target loads and reductions. The uncertainty in the process is unknown, but could make the TMDL subject to challenges in court.

Recommendations

The following are some short-term recommendations to improve the uniformity of process and to enhance the application and validity of the reference watershed approach for TMDL development:

1. Require that all TMDL reports provide data and document justification for selecting the reference condition.
2. Require that all TMDL reports contain a section that fully documents the methods and data used to select a reference watershed.
3. Require that the selection process be transparent, with several candidate reference watersheds considered, and that the criteria and best professional judgment used in the selection process be clearly described. The relationship between land uses, pollutant types, and pollutant sources should also be addressed in this analysis.
4. Require that justification be provided in the TMDL report for use of models or modeling techniques used for estimating target loads, outside of currently accepted models and procedures.
5. Recommend that DEQ develop and distribute a starting list of potential reference watersheds to all contractors and require justification if alternative watersheds or reference conditions are used.
6. Recommend that DEQ request review of developed guidelines by the contractors used by DEQ, as these are the dominant reservoir of “best professional judgment” about the use of the reference watershed approach. They also have an interest in streamlining and making the procedure consistent.

References

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