Margin of safety

Introduction

The margin of safety is a required component of the total maximum daily pollutant load allocation for a receiving water. The margin of safety accounts for uncertainty about pollutant loadings and waterbody response. It reflects the degree of characterization and accuracy of the estimates of the source loads and the level of confidence in the analysis of the relationship between the source loads and the impact upon the receiving water. In concept, it ensures attainment and maintenance of water quality standards for the allocated pollutant. As such, it reduces the remaining pollutant allocation to nonpoint and point sources.

Section 303(d)(1)(C) of the Clean Water Act and Title 40, Section 130.7(c)(1) of the Code of Federal Regulations defines the margin of safety to take "...*into account any lack of knowledge concerning the relationship between effluent limitations and water quality*."

During the problem identification process, the total maximum daily load (TMDL) developer should decide, to the extent possible, how to incorporate a margin of safety into the analysis. The degree of uncertainty associated with the source estimates and water quality response should be considered with the value of the resource and the anticipated cost of controls. In general, greater margins of safety should be included when there is more uncertainty in the information used to develop the TMDL.

Implicit/explicit

The margin of safety can either be an explicit load component of the TMDL, or implicit assumptions used in the development of the TMDL. The table below provides six approaches for incorporation of a margin of safety into a TMDL.

Type of Margin of Safety	Approach
Explicit	Set target at a more conservative level than the water quality standard.
	Add a safety factor to pollutant loading estimates.
	Reserve a portion of the available loading capacity for the MOS.
Implicit	Use conservative assumptions in development of target pollutant load (e.g., WQ standard, flow at critical conditions).
	Use conservative assumptions in source assessment, pollutant delivery.
	Use conservative assumptions of restoration effectiveness.

For a waterbody impaired by a pollutant with a numeric water quality standard, the pollutant load target is the water quality standard multiplied by the flow rate of the impaired reach or the tributaries to a lake under critical conditions. The use of conservative assumptions in the establishment of water quality standards provides an implicit margin of safety. The use of conservative assumptions in the determination of critical conditions using monitoring data and or a water quality model also provides an implicit margin of safety. In lieu of or in addition to an implicit margin of safety, an explicit margin of safety can be designated as part of the total maximum daily pollutant load.

For some pollutants such as nutrients, considerable uncertainty is usually inherent in estimating loadings from nonpoint sources, as well as predicting water quality response. The effectiveness of various management measures, such as agricultural best management practices, in reducing loading is also subject to significant uncertainty. When developing an implicit margin of safety, conservative assumptions used in calculations and model development should be documented as they are applied and described in the TMDL. This may include conservative estimates of manure generation, fertilizer application, assumed constituent concentrations in runoff, assumed best management practice pollutant removal rates, etc.

A tradeoff can exist between the level of rigor in TMDL development and determination of the margin safety. TMDL development can vary from a simple screening level approach with limited data to a detailed analysis with extensive monitoring data and process–based models with a strong scientific backbone. A more detailed analysis can provide better predictive accuracy and greater temporal and spatial resolution, which can translate into greater stakeholder acceptance and a smaller margin of safety that usually reduces pollutant source management costs.

For impairments with minimal data for analysis and model calibration, the margin of safety should be higher than for impairments with adequate data. The MPCA Intensive Watershed Monitoring Program and additional monitoring has in many cases provided sufficient data to develop a TMDL with a relatively high degree of rigor. The margin of safety should be higher for an impairment where there is less scientific knowledge regarding the transport and fate of the pollutant than a pollutant with a strong knowledge base. An additional factor that can influence the margin of safety is the adequacy of the calibration and verification of the water quality model to monitoring data.

Phased Approach

The philosophy of the Phased Approach of TMDL development is that the various uncertainties should not delay TMDL development and implementation of control measures. Federal TMDL regulations stipulate that nonpoint load allocations "are best estimates of the loading, which may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading." Under the Phased Approach, load allocations and waste load allocations are calculated using the best available data and information, recognizing the need for additional monitoring data to determine if the load reductions required by the TMDL lead to attainment of water quality standards. The approach provides for the implementation of the TMDL while additional data are collected to reduce uncertainty.

For an impairment where there is a lack of data or a high level of uncertainty, a negative aspect of the Phased Approach is that a robust estimate of the margin of safety can be so large as to leave a relatively small load available for allocation to point and nonpoint sources. Such a TMDL would require such extensive controls on point and nonpoint sources as to make TMDL implementation impractical. The result is TMDLs with the least amount of information would have the highest degree of controls. This is contrary to the line of thinking that extensive pollution control efforts be based upon sound scientific understanding of the causes of the impairment.

Model uncertainty

When using models during the development of the TMDL, either to predict loadings or to simulate water quality, it is possible to address the inherent uncertainty in the predictions. Various techniques for doing so include sensitivity analysis, first-order analysis, and Monte Carlo analysis.

Sensitivity analysis determines the sensitivity of model output to variations of individual model parameters. Changes in parameters are limited by reasonable upper and lower bounds. First-order analysis (also called variance or analytical uncertainty propagation) determines the variance of model output as a function of the variances and covariances of model inputs and parameters. Assuming a distribution of the output values, one can obtain confidence intervals for the estimates that can translate into an explicit margin of safety. Monte Carlo simulation is a form of probabilistic uncertainty analysis. After assigning probability distributions to each model parameter, the model is repeatedly run with randomly varied values for the chosen parameters, which produces a probability distribution and associated variance of model output. A confidence interval for mean output value can translate into an explicit margin of safety. In using these probabilistic techniques, the level of protection, or the probability that the water quality standard will be attained if the TMDL is implemented, must be made *a priori* – as a policy decision.

Summary

The approach used to develop the margin of safety should be clearly identified in the submittal of the TMDL. For an implicit margin of safety, the conservative assumptions used should be documented as each assumption is incorporated into the analysis. The MPCA has traditionally dedicated 10% of the TMDL as an explicit margin of safety. This value has been used in example TMDLs provided in the form of federal guidance in the past. Short of using the first two explicit methods presented in the table or performing the statistical analysis described above, it is difficult to provide a scientific justification of this value. In such cases, a suggested reasoning of the margin of safety development is that it was determined by best professional judgement of the overall TMDL development, and provides a reasonable and achievable load allocation and waste load allocation.