Chesapeake Bay UAAs

Abstract

Complexity: Very complex
Region: 3
Type of Action: Refined aquatic life uses and restoration variance
131.10(g) Factors: 1, 3, 6

Chesapeake Bay waters have been impaired by nutrients and sediment from point and nonpoint sources. These impairments have led to low levels of dissolved oxygen and inability to meet designated uses. Two use attainability analyses (UAAs) were conducted, with several states involved, to evaluate three of the 131.10(g) factors: natural conditions, human-caused conditions, and economics. Maryland collected a significant amount of monitoring data and developed a model to use the data to assess whether the bay's waters were meeting their designated uses. One result of the UAAs was the decision to refine the aquatic life uses. Five designated uses were identified, and the seasonality of each was considered. Maryland promulgated these designated uses in its water quality standards, and EPA approved the new standards in 2005.

In addition, restoration variances were added to Maryland's proposed water quality standards as refinements to proposed criteria. These variances can be applied over an entire segment of the Bay, rather than directed at a specific discharger or group of dischargers. The temporary modifications allow for realistic recognition of current and attainable conditions while retaining the designated use and setting full attainment as a future goal. In addition, the variance allows for incremental improvements in water quality goals.

Background

Over the past 22 years, since the creation of the Chesapeake Bay Program, progress has been made toward restoring the Chesapeake Bay (Figure 1), but a number of problems remain. Portions of the bay and its tidal tributaries are listed as impaired primarily because of low dissolved oxygen levels, which do not support the living resources of the bay. Nutrients emanate from many activities—agriculture, urbanization, septic systems, deforestation and removal of streamside buffers, air deposition, and point sources (e.g., wastewater treatment plant discharges). Many of the nutrients entering the bay are dissolved in runoff; some are associated with sediment in runoff. The result of the excessive nutrients in the bay are increased algae growth (measured as chlorophyll *a*), decreased water clarity (measured as turbidity), and decreased dissolved oxygen levels.

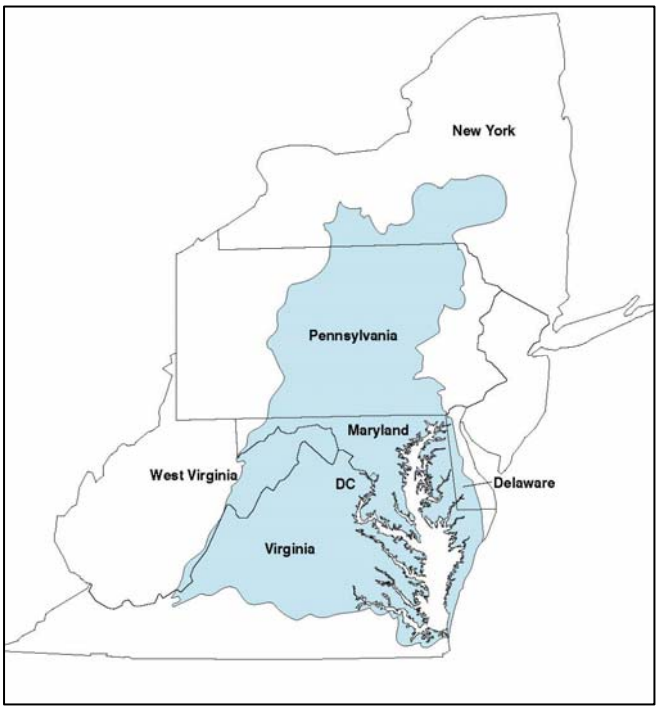

Figure 1. Chesapeake Bay watershed (USEPA, 2003b).

Through the collaboration of the Chesapeake Bay Program, states, the District of Columbia, citizens, and EPA are striving to develop strategies, tools, and activities to reduce nutrient and sediment pollution inputs to the bay. The *Chesapeake 2000* agreement sets an aggressive goal of reducing nutrients and sediment inputs to the Chesapeake Bay to levels that will support the restoration of the bay's living resources by 2010. An indicator for meeting this goal is the

removal of the Chesapeake Bay and its tidal tributaries from the list of impaired waters required under Clean Water Act (CWA) section 303(d) (i.e., the 303(d) list).

EPA Guidance

In April 2003 EPA Region 3 issued *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries (*Regional Criteria Guidance) as technical guidance to help the jurisdictions surrounding the Chesapeake Bay to better achieve and maintain the water quality conditions necessary to protect the existing uses in the bay. This Regional Criteria Guidance provides states with two important mechanisms to help them implement an overall nutrient reduction strategy. First, it defines the water quality conditions for nutrients called for in *Chesapeake 2000* through the development of Chesapeake Bay-specific water quality criteria for dissolved oxygen, water clarity, and chlorophyll *a*. EPA intended the Regional Criteria Guidance to assist the Chesapeake Bay jurisdictions in adopting revised state water quality standards for these critical parameters. Second, the Regional Criteria Guidance provides states with suggestions for revised tidal water designated uses within the Chesapeake Bay. The water quality criteria and refined designated uses presented in the Regional Criteria Guidance represent the collaboration of the various partners and stakeholders of the Chesapeake Bay region.

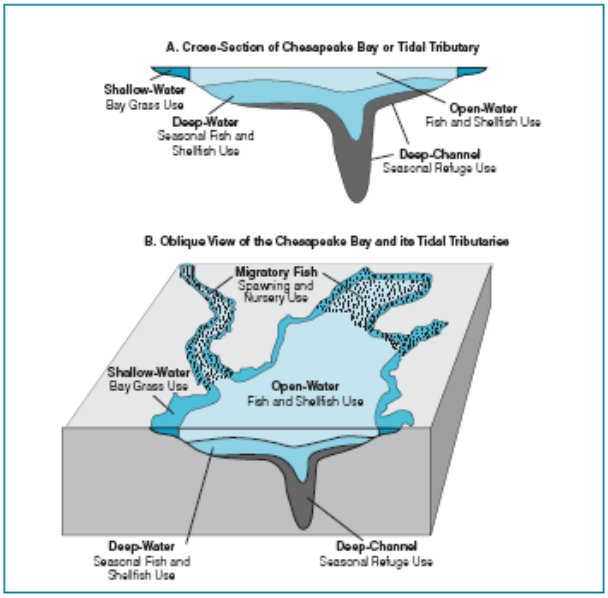

Figure 2. Conceptual illustration of the five Chesapeake Bay tidal water designated use zones (USEPA, 2003b).

EPA developed the *Technical Support Document for Identifying Chesapeake Bay Designated Uses and Attainability* (Technical Support Document) to help the states document and justify the recommended refined designated uses for the Chesapeake Bay and its tributaries. The Technical Support Document outlined the following objectives:

- Document why current aquatic life designated uses are not protective and are unattainable in all parts of the Chesapeake Bay system because of natural and human-caused conditions that cannot be remedied.
- Document the rationale and scientific basis for the proposed refined designated uses.
- Document that the refined designated uses are attainable.
- Provide technical background information for Maryland, Virginia, Delaware, and the District of Columbia to develop UAAs in support of changing their respective current designated uses (as of 2003).

The Regional Criteria Guidance and Technical Support Document identify five designated uses that, if adequately protected, will lead to the improvement and protection of the living resources

of the Chesapeake Bay and its tidal tributaries. Figure 2 illustrates these five designated uses, which are coupled with the three water quality criteria (dissolved oxygen, water clarity, and chlorophyll *a*) to form the basis of the Chesapeake Bay Program's strategy to safeguard the bay from nutrient pollution. To protect the bay's aquatic resources, program managers must accurately delineate locations to apply these tidal-water designated uses, which are the following:

- ***Migratory fish spawning and nursery designated use*** protects migratory and resident tidal freshwater fish during the late winter to late spring spawning and nursery season in tidal freshwater to low-salinity habitats. Located primarily in the upper reaches of many bay tidal rivers and creeks and the upper main stem Chesapeake Bay, this use will benefit several species, including striped bass, perch, shad, herring, sturgeon, and largemouth bass.
- ***Shallow-water bay grass designated use*** protects underwater bay grasses and the many fish and crab species that depend on the vegetated shallow-water habitat provided by underwater grass beds.
- ***Open-water fish and shellfish designated use*** focuses on surface water habitats in tidal creeks, rivers, embayments, and the main stem Chesapeake Bay and protects diverse populations of sport fish, including striped bass, bluefish, mackerel and sea trout, as well as important bait fish such as menhaden and silversides.
- ***Deep-water seasonal fish and shellfish designated use*** protects animals inhabiting the deeper transitional water column and bottom habitats between the well-mixed surface waters and the very deep channels. This use protects many bottom-feeding fish, crabs and oysters, and other important species such as the bay anchovy.
- ***Deep-channel seasonal refuge designated use*** protects bottom sediment-dwelling worms and small clams that bottom-feeding fish and crabs consume naturally. Low to occasional no dissolved oxygen conditions occur in this habitat zone during the summer.

Water Quality Criteria

The Regional Criteria Guidance reflects EPA's *National Strategy for the Development of Regional Nutrient Criteria* by establishing waterbody-specific (estuarine) and nutrient eco-region specific criteria. The three Chesapeake Bay criteria—dissolved oxygen, water clarity, and chlorophyll *a*—should be viewed as an integrated set of criteria applied to their respective sets of designated use habitats and addressing similar and varied ecological conditions and water quality impairments. The criteria provide the basis for defining the water quality conditions necessary to protect the five essential Chesapeake Bay tidal-water designated uses.

Dissolved Oxygen Criteria. In the Chesapeake Bay's deeper waters, there is a natural tendency toward reduced dissolved oxygen conditions because of the bay's physical morphology and estuarine circulation. The Chesapeake Bay's highly productive shallow waters, coupled with strong density stratification, long residence times (weeks to months), low tidal energy, and a tendency to retain, recycle, and regenerate nutrients from the surrounding watershed, set the stage for low dissolved oxygen conditions. Specifically, three dissolved oxygen criteria were established for the five designated uses:

- Criteria for the migratory fish spawning and nursery, shallow-water bay grass, and open-water fish and shellfish designated uses were set at levels to prevent impairment of growth and to protect the reproduction and survival of all organisms.

- Criteria for deep-water seasonal fish and shellfish designated use habitats during seasons when the water column is significantly stratified were set at levels to protect juvenile and adult fish, shellfish, and the recruitment success of the bay anchovy.
- Criteria for deep-channel, seasonal-refuge designated use habitats in summer were set to protect the survival of bottom sediment-dwelling worms and clams.

Water Clarity Criteria. The water clarity criteria establish the minimum level of light penetration required to support the survival, growth, and continued propagation of underwater bay grasses. The decline of underwater bay grasses is mainly attributed to nutrient over-enrichment and increased suspended sediments in the water, as well as associated reductions in light availability. Other factors such as climatic events and herbicide toxicity might also have contributed to the loss of bay grasses. To restore these critical habitats and food sources, enough light must penetrate the shallow waters to support the survival, growth, and repropagation of diverse, healthy underwater bay grass communities. The water clarity criteria are applied only during the bay grass growing seasons.

Chlorophyll a. From a water quality perspective, chlorophyll *a* is the best available, most direct measure of the amount and quality of phytoplankton and the potential to lead to reduced water clarity and low dissolved oxygen impairments. The Chesapeake Bay's ability to produce and maintain a diversity of species depends in large part on how well phytoplankton meet the nutritional needs of their consumers. Chlorophyll *a* is the primary photosynthetic pigment in algae and cyanobacteria (blue-green algae), a measure of photosynthesis, and a measure of the primary food source of aquatic food webs. Chlorophyll *a* also plays a direct role in reducing light penetration in shallow-water habitats, which has a direct impact on underwater bay grasses. Uneaten by zooplankton and filter-feeding fish or shellfish, excess dead algae are consumed by bacteria, and in the process they remove oxygen from the water column. Phytoplankton assemblages can become dominated by single species that represent poor food quality or even produce toxins. States are encouraged to adopt numerical chlorophyll *a* criteria for application to tidal waters in which algae-related designated use impairments are likely to persist even after the applicable dissolved oxygen and water clarity criteria are attained.[1]

Maryland UAAs

Maryland's Designated Uses and Water Quality Criteria

Maryland's designated uses for the Chesapeake Bay included aquatic life, commercial shellfish harvest, and water contact recreation uses. To protect the aquatic life uses in the bay and its tidal tributaries, Maryland set its dissolved oxygen criteria at 5 mg/L applied year-round throughout all tide-influenced waters. Caps on nitrogen and phosphorus loads were established through the 1992 Amendment to the Chesapeake Bay Agreement and were allocated to each of the 10 major tributary basins in Maryland. In 1996 Maryland listed all portions of the Chesapeake Bay and

[1] The technical information supporting states' quantitative interpretation of the narrative chlorophyll *a* criteria is published in the body of the Chesapeake Bay water quality criteria document.

most of its tidal tributaries as impaired by nutrients or sediment on the state's 303(d) list. With the signing of the Chesapeake 2000 Agreement, Maryland had committed to "correct the nutrient- and sediment-related problems in the Chesapeake Bay and its tidal tributaries sufficiently to remove the bay and the tidal portions of its tributaries from the list of impaired waters (303(d) list) under the Clean Water Act."

In 2004 Maryland published two documents, the *Use Attainability Analysis for Tidal Waters of the Chesapeake Bay Mainstem and Its Tributaries Located in the State of Maryland* and *Use Attainability Analysis for the Federal Navigation Channels Located in Tidal Portions of the Patapsco River*, to aid in this process. Prior water quality criteria were based on the assumption that all areas in the bay were identical, and they did not take into account the natural variability of the bay's waters. These documents provide the technical background and scientific data used to develop new water quality standards.

The *Use Attainability Analysis for Tidal Waters of the Chesapeake Bay Mainstem and Its Tributaries Located in the State of Maryland* explains why the current designated uses cannot be attained in all parts of Maryland's Chesapeake Bay and associated tidal tributaries. Maryland used natural conditions, human-caused conditions, and hydrologic modifications (40 CFR 131.10(g) factors 2, 3, and 4, respectively) to demonstrate that attaining the designated uses was not feasible. The document also provides scientific data indicating that refined designated uses are attainable and would continue to protect existing uses. Finally, the document summarizes economic analyses, including estimates of the cost for implementing the appropriate control scenarios.

Data Collection and Analysis

When Maryland was assessing attainability, it considered natural conditions by examining paleological evidence and using water quality monitoring data. Water quality models were used to determine bay water quality under forest and pristine conditions. Biological and chemical studies conducted over the past 10 years offered a wealth of data that showed a greater frequency and duration of seasonal anoxic conditions beginning in the 1930s. Maryland Department of the Environment (MDE) personnel documented that extensive land clearance during the 18th and 19th centuries had led to dissolved oxygen depression in the Chesapeake Bay below dissolved oxygen levels characteristic of the previous 2000 years. Although better than present conditions, pre-17th century dissolved oxygen proxy data suggested that dissolved oxygen levels in the deep channel of the bay were not above 5 mg/L all the time. The modeling showed that even under pristine conditions, the designated uses set for the bay would not be met.

Human-caused conditions were also examined by modeling theoretical levels of best management practice (BMP) implementation. MDE scientists were able to establish that anthropogenic impacts, such as all forms of nutrient enrichment caused by agriculture, urban nonpoint sources, and other nonpoint sources, could not be remedied. The theoretical levels of implementation tested in the water quality models included new technologies, management programs, and best practices not currently part of the state or local jurisdictional pollutant control strategies. Three scenarios were considered:

1. All-forest
2. Pristine
3. Everything, everywhere by everyone[2]

The results of these modeling scenarios demonstrated that, even under pristine conditions, the desired dissolved oxygen criteria could not be attained in the deep channels and deep waters of the Chesapeake Bay during the summer. For the Maryland portion of the Chesapeake Bay that is affected by hydrologic modification (i.e., deep water segments of the Patapsco River), MDE scientists collected and analyzed the following data:

- Data from the Chesapeake Bay Water Quality Model
- Data from the Maryland Department of the Environment and Department of Natural Resources Core Monitoring Programs
- Total Maximum Daily Load (TMDL) data gathered 1992–1997

The results showed 77 percent non-attainment in this segment due to federally authorized hydrologic modification under the Rivers and Harbors Act and a complex pattern of tidal circulation that moves hypoxic and anoxic waters within the Chesapeake Bay system.

Three types of economic analyses were performed in conjunction with developing revised water quality criteria for the Chesapeake Bay and its tidal waters. An analysis was undertaken to estimate the costs of implementing the hypothetical control scenarios. The same type of economic analysis was performed on the implementation plan for meeting the new bay water quality standards. An analysis was also performed to consider the substantial and widespread economic and social impacts if controls that were more stringent than those required by CWA sections 301 and 306 were implemented.

The total projected cost, including capital and operating costs, is approximately $10 billion through 2010. This is the statewide evaluation of sewage treatment upgrades and BMP implementation levels necessary to attain the water quality standards in the bay and tidal tributaries. However, there is considerable uncertainty about the cost estimates, the effectiveness of the BMPs, and the level of implementation that will actually be needed. It is anticipated that as innovative and more effective management practices are developed, the implementation will evolve and affect the costs.

The potential economic benefits of improving water quality in the Chesapeake Bay and its tidal tributaries were considered to determine whether controls more stringent than those required by

[2] Both the “all-forest” and the “pristine” scenarios were designed to represent pre-European settlement conditions to capture natural pollutant levels. The “all-forest” scenario incorporates nutrient and sediment loads reflecting pre-colonial land clearance, an atmospheric deposition reduced to 10 percent of current load, nitrogen soil storage that is elevated and incorporates some delivery to the Bay, and shoreline erosion at current levels. The “pristine” scenario is similar to the “all-forest” scenario except that the nitrogen storage level does not incorporate delivery to the bay and the shoreline erosion is set at 10 percent of current levels to account for pre-settlement distribution of Bay grasses. The “everything, everywhere by everyone,” or E3, scenario represents the boundary of what is considered physically implausible. It represents BMP implementation with no cost factors and few physical limitations. It also includes new technologies and management programs and practices not currently part of the state or local jurisdictional pollutant control strategies.

CWA sections 301(b)(1)(A) and (B) and 306 would result in substantial and widespread economic and social impacts. To estimate the potential economic benefits, a regional forecasting model and an economic impact model were used. Results indicated that the regional economy should expand as a result of restoration efforts. Although there is no comprehensive estimate of the benefits, data suggest that the bay affects industries that generate approximately $20 billion and 340,000 jobs.

Use Refinement

Because Maryland determined that the designated uses for the Chesapeake Bay and its tidal tributaries did not fully reflect natural conditions, MDE opted to refine the uses. Through the refinement of Maryland's tidal-water designated uses, the state hopes to replace nonattainable uses and general criteria with specific uses and criteria based on the actual needs of the biological community. Maryland engaged stakeholders early in the process and used the Chesapeake Bay Program's Regional Criteria Guidance and Technical Development Document as a basis for analyses and decision-making. As a result, Maryland was able to upgrade designated uses on some waters and downgrade designated uses on others (from the current bay-wide general aquatic life designation) as needed. Maryland set designated uses for segments of the Chesapeake Bay and its tidal tributaries so that the state would be able to assess and delist (from the 303(d) list of impaired waters) appropriate individual segments.

The first step MDE took in deriving attainable designated uses was delineating of areas where different uses exist. The refined uses were based on habitats of living resources that have different dissolved oxygen requirements and tolerance. In addition, some of the refined uses were based on water clarity requirements for submerged aquatic vegetation. Designated uses can be multi-dimensional in space and time. Temporal variation results in a seasonal application that occurs because of different living resources' life history requirements. For example, the seasonal spawning and early life habitat requirements of American shad would not require spawning and early life stage habitats year-round but only during the spring when shad spawn in the tributaries. Spatial variation occurs in both the horizontal and vertical dimensions of the bay. Horizontal components are based on bathymetry and geography; vertical components are based on bathymetry and pycnocline[3] delineation. The five designated uses outlined in the EPA *Regional* Criteria Guidance and Technical Support Document were proposed to reflect the habitat of an array of recreationally, commercially, and ecologically important species and biological communities.

MDE and its state partners, in collaboration with the Chesapeake Bay Program, took explicit steps to ensure that existing uses would continue to be protected. For the migratory spawning and nursery use, deep-water seasonal use, and deep-channel seasonal uses, the application of new dissolved oxygen criteria will result in improvements to existing water quality conditions. The refined open water fish and shellfish designated use will continue to provide a level of protection equal to that under the current state water quality standard. The shallow-water bay grass designated use will ensure protection of existing uses through the application of the single best

[3] The pycnocline is a natural zone of rapid salinity increase that marks the boundary between fresh river water flowing toward the ocean and "salty" ocean water flowing into the bay. The pycnocline acts as a barrier to mixing of surface waters and the deeper waters below (Beaman, 2005a).

year methodology that MDE developed. The single best year methodology is based on historical data starting in the 1930s and more recent underwater bay grass distributions. This method goes beyond the requirements of the Clean Water Act.

The Chesapeake Bay Program and Maryland assessed attainability for the refined designated uses by collecting a significant amount of monitoring data and developing a mathematical model to assess the bay's waters to determine whether they were meeting their designated uses. Biologically based reference curves were also established for each designated use to allow for scientifically defensible assessments that considered the natural variability of the waterbody.

The attainability of these uses was based on dissolved oxygen criteria for the migratory and spawning, open-water, deep-water, and deep-channel designated uses. Attainability for the shallow-water designated use was assessed based on historical and recent data on the existence of underwater bay grass acreage. The attainability for the chlorophyll *a* criteria was not assessed because this criterion is expressed in narrative terms and does not provide numeric values on which to perform analyses.

Restoration Variance

Even after achievement of nutrient and sediment cap load allocations, portions of the Chesapeake Bay mainstem were found to be unable to meet their designated uses. On the basis of Chesapeake Bay Water Quality Model simulations and analysis of existing water quality data, the deep-water and deep-channel uses in the middle of the Chesapeake Bay mainstem were shown to be unattainable. Maryland officials recognized that partial attainment would be possible, but making this change to the water quality standard was not politically or publicly palatable. In addition, the state did not believe that traditional approaches such as use removal, specific discharger variance, or establishment of less protective criteria would be consistent with the state's long-term water quality goals. To solve this problem, a restoration variance was added to Maryland's proposed water quality standards as a refinement to proposed criteria.

A restoration variance allows dissolved oxygen criteria to slightly exceed the requirement up to 7% in a couple of the deepest areas of the Bay. This modification to the Bay water quality standards was necessary because in those few deep areas, we may not meet the dissolved oxygen requirements. Even after spending billions of dollars to reduce nitrogen, phosphorus, and sediment pollution to clean up the rest of the Bay, essentially doing everything we know how to do at this time, the deep areas still could not attain the dissolved oxygen standard. This is a better, more protective alternative than lowering the standard based on current understanding. The information will be updated periodically to keep the water quality standard focused on protecting living resources, rather than proposing something less protective. The State is required to review the restoration variances at least every three years (based on EPA regulations), and adjust it accordingly. (Note: this paragraph was taken from MDE's website http://www.mde.state.md.us/programs/waterprograms/tmdl/wqstandards/faqs.asp on March 9, 2006)

An example of how this appears in Maryland's adopted and approved water quality standards is: "For the dissolved oxygen criteria restoration variance for Chesapeake Bay Mainstem Segment 4 mesohaline (CB4MH) seasonal deep-water fish and shellfish subcategory, not lower for

dissolved oxygen in segment CB4MH than the stated criteria for the seasonal deep-water seasonal fish and shellfish use for more than 7 percent spatially and temporally (in combination), from June 1 to September 30."

A restoration variance is a temporary modification that allows for the realistic recognition of current conditions, while retaining the designated use and setting attainment as a future goal. The variance allows for iterative refinements using quantified implementation, measured reductions, and monitoring data during triennial reviews. The restoration variance is applied to a designated use over an entire waterbody segment, rather than directed at a specific discharger or group of dischargers. Segments of the Chesapeake Bay that require variances are the Chesapeake Bay Mainstem under the deep-water seasonal fish and shellfish and deep-channel seasonal refuge use and the Patapsco River under the deep-water seasonal fish and shellfish use.

In addition to a restoration variance, MDE has also proposed a subcategory for the Patapsco River section of the Chesapeake Bay. An analysis of existing water quality data indicates that the dissolved oxygen criteria for the deep-channel seasonal refuge use cannot be met in this segment, even with projected nutrient reductions from point sources and the application of the Tributary Strategies reduction for nonpoint sources. Maryland developed a UAA to support this proposed subcategory.

The *Use Attainability Analysis for the Federal Navigation Channels Located in Tidal Portions of the Patapsco River* describes a number of federally authorized hydrologic modifications under the Rivers and Harbors Act and a complex pattern of tidal circulation that has caused nonattainment of existing designated uses in the Patapsco River. MDE ran six sensitivity scenarios of the Chesapeake Bay Model to estimate the influence of the different loading sources and estimate the extent of impairments due to natural- and human-caused conditions. Results showed 77 percent nonattainment, even at a simulated point source reduction level of "everything, everywhere, by everybody," or E3. Due to this significant nonattainment, MDE proposed that there be further refinement of water quality criteria in this segment with the applicable dissolved oxygen criteria being 0 mg/L from June 1 to September 30, inclusively. Both the restoration variance and the limited use designation for the navigation channel will be revised in the next Maryland triennial Water Quality Standards review in 2007. Maryland will promulgate adjustment to these new portions of the water quality standards, as appropriate.

Conclusion

Maryland promulgated new water quality standards that included refined aquatic life uses. In 2005 EPA approved the changes to the state's water quality standards.

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