# CHESAPEAKE BAY ENVIRONMENTAL MODELING - BACKGROUNDER

**The Importance of Modeling**

Protecting and restoring an ecosystem requires an extensive understanding of its characteristics and the impact of various environmental management actions to reduce pollution. The incredible complexity and large size of many ecosystems often requires the use of computer models to gain this critical knowledge. This is especially the case for the Chesapeake Bay and its vast watershed – it is the largest estuary in the United States and the third largest in the world, and the watershed includes 64,000-square miles of diverse topography and tens of thousands of streams, creeks and rivers. As a result, computer models are a vital tool used by scientists and restoration managers.

The Chesapeake Bay models are used by government partners and private stakeholders to project the flow and loads of pollution and simulate how changes to pollution controls, land use, atmospheric deposition and precipitation could impact the ecosystem, particularly water quality and living resources like fish and wildlife. These simulations are a valuable part of the decision-making for reducing pollution and meeting water quality standards through achievable, equitable and cost-effective approaches. The results of model simulations are never viewed as perfect forecasts, but serve as best estimates based on state-of-the-art, extensively peer-reviewed science. Models are not used in isolation, but are part of a broader toolkit that includes monitoring and research, which are used in a complementary fashion to gain the highest possible level of accuracy.

**The Suite of Chesapeake Bay Models**

The Bay partners and stakeholders use a suite of computer models that are among the most sophisticated, studied and respected in the world, and represent the cutting edge of estuary restoration science. The models provide a comprehensive view of the Chesapeake ecosystem, from the depths of the Bay to the upper reaches of the watershed, and from the development occurring on land to the air over the region.

<u>Watershed Model</u> – The Watershed Model incorporates information about land use, fertilizer applications, wastewater plant discharges, septic systems, air deposition, farm animal populations, meteorology and other variables to estimate the amount of nutrients and sediment reaching the Chesapeake Bay, as well as where it originates. The model divides the 64,000-square-mile Chesapeake Bay watershed into more than 2,000 segments delineating political and physical boundaries. Each segment contains information generated by several sub-models.

- The hydrologic sub-model uses rainfall, evaporation and meteorological data to calculate runoff and sub-surface flow for all land uses, including forest, agricultural and urban lands.
- The surface and sub-surface flows ultimately drive the non-point source sub-model, which simulates soil erosion and pollutant loads from the land to the rivers.
- The river sub-model routes flow and associated pollutant loads from the land through lakes, rivers and reservoirs to the Bay.

Estuary Model – The Estuary Model examines the effects of pollution loads generated by the Watershed Model on Bay water quality. In the Estuary Model, the Bay is represented by over 57,000 computational cells and is built on the hydrodynamic sub-model, which simulates the mixing of waters in the Bay and its tidal tributaries, and the water quality sub-model, which calculates the Bay's biological, chemical and physical dynamics.

Scenario Builder – Scenario Builder can generate simulations of the past, present or future state of the watershed to run through the Watershed Model to explore the potential impacts of actions and evaluate alternatives. Scenario Builder produces inputs for the Watershed Model based on factors from a wide range of land uses and management actions. Using agriculture as an example, information such as acres of different crops, numbers of animals and extent of conservation practices is used to generate Watershed Model inputs of for agricultural land use types.

Airshed Model – The Chesapeake Bay's airshed – the area where nitrogen emitted into the air can make its way to the Bay — is about 570,000 square miles, or seven times the size of the Bay's watershed. The Airshed Model uses information about nitrogen emissions from power plants, motor vehicles and other sources to estimate the amount and location deposited on the Bay and watershed. That information is fed into the Watershed Model.

Land Change Model – The Chesapeake Bay Land Change Model analyzes and forecasts urban land uses and populations on sewer and septic systems in the watershed. The forecasts are based on reported changes in housing, population and migration from the U.S. Census Bureau, land cover trends derived from satellite imagery; sewer service areas; and county-level population projections. Conversion of farmland and forest land to development is based on a thorough examination of urban development and land conversion trends derived from satellite imagery dating back more than 25 years.

**Determining Land Uses and Pollution Loads**

To accurately simulate the Chesapeake ecosystem, the models are built on the current and specific uses of land in the watershed, such as forests, farms and development. The land uses are determined using authoritative sources including the USDA Census of Agriculture and satellite imagery. The models are further refined through the input of land management features, such as cover crops on farm fields and stormwater controls in urban areas.

The types and amounts of pollution, such as nitrogen and phosphorus, which runoff a particular land use are based on comprehensive reviews of the latest scientific literature – for example the pollution loads incorporated into the Watershed Model are based on research in more than 100 academic papers. This comprehensive literature review provides the average pollution loading rates for various land uses. These pollution loads are also cross-checked with previous versions of the model and other regional and national models. These pollution loads are further adjusted based on in-stream monitoring data, which increases accuracy for land use and location. Conservation practices, management actions and pollution controls that are implemented in specific places are then entered into the model to simulate reductions from these factors.

**Developing and Improving the Models**

The suite of Chesapeake Bay models have been developed and utilized during the past 20 to 30 years through collaboration with federal, state, academic and private partners. Developers include the U.S. Environmental Protection Agency, U.S. Geological Survey, Natural Resources Conservation Service, U.S. Army Corps of Engineers, University of Maryland, Virginia Polytechnic Institute and State University, Penn State University, and the Chesapeake Research Consortium. Advisors include the states of Delaware, Maryland, New York, Pennsylvania, Virginia and West Virginia; and the District of Columbia.

Use and development of the models is fully transparent and open. Anyone can participate in the improvement process, including working with the EPA Region III's Chesapeake Bay Program Office (CBPO) to have credible data and restoration practices incorporated into the models. The models undergo extensive independent scientific peer review by a wide spectrum of federal, state and academic scientists, as well as modeling experts.

Over the years, the models have improved significantly in precision, scope, complexity and accuracy. For example, the current Watershed Model is calibrated to monitoring stations in the region, with the number of linked stations expanded from 20 in the previous version to 296 in the current version. The segments in the model have grown from 94 to over 2,000, providing information at the watershed, county and conservation district level. River segments in the model expanded twentyfold, from 94 to more than 2,000. The types of land uses that can feed into the model were increased from 9 to 25. The simulation is now run over a 20-year period, rather than 10 years. By working with partners and stakeholders, the CBPO continues improving the quality of the data for land use, agricultural practices, precipitation, wastewater, urban and suburban runoff and air pollution.

The development and improvement of the models is a highly collaborative process involving a wide range of partners, stakeholders and experts. During this process, revised versions of the models are regularly shared openly with partners throughout the Bay community. This allows for review, testing and suggestions during the development and improvement, which is vital for federal, state and local officials who utilize the model results as a tool to inform a wide variety of management decisions. During this period of actively developing and improving a new version of a model, the outputs and numbers generated by the model can fluctuate and caution is urged against using such interim versions to draw definitive quantitative conclusions until the new version of the model is finalized and fluctuations in output subside.

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