# Facilitating Adaptive Management in the Chesapeake Bay Watershed through the Use of Online Decision Support Tools

Cassandra Mullinix, Scott Phillips, Kelly Shenk, Paul Hearn, Olivia Devereux

## Abstract

The Chesapeake Bay Program (CBP) is attempting to more strategically implement management actions to improve the health of the Nation's largest estuary. In 2007 the U.S. Geological Survey (USGS) and U.S. Environmental Protection Agency (USEPA) CBP office began a joint effort to develop a suite of Internet-accessible decision-support tools and to help meet the needs of CBP partners to improve water quality and habitat conditions in the Chesapeake Bay and its watersheds. An adaptive management framework is being used to provide a structured decision process for information and individual tools needed to implement and assess practices to improve the condition of the Chesapeake Bay ecosystem. The Chesapeake Online Adaptive Support Toolkit (COAST) is a collection of web-based analytical tools and information, organized in an adaptive management framework, intended to aid decisionmakers in protecting and restoring the integrity of the Bay ecosystem. The initial version of COAST is focused on water quality issues. During early and mid-2008, initial ideas for COAST were shared and discussed with various CBP partners and other potential user groups. At these meetings, test cases were selected to help improve understanding of the types of information and analytical functionality that would be most useful for specific partners' needs. These discussions added considerable knowledge about the nature of decisionmaking for Federal, State, local and nongovernmental partners. Version 1.0 of COAST, released in early winter of 2008, will be further reviewed to determine improvements needed to address implementation and assessment of water quality practices. Future versions of COAST may address other aspects of ecosystem restoration, including restoration of habitat and living resources and maintaining watershed health.

**Keywords:** Chesapeake Bay, adaptive management, online decision support tools, nutrients

## Introduction

The Chesapeake Bay is designated as an impaired water body under the Clean Water Act because of poor water quality conditions for fisheries and submerged aquatic vegetation. The Bay is impaired largely because of low dissolved oxygen conditions and poor water clarity conditions due to excess nutrients and sediments. Unless water quality standards are met by 2010, the Chesapeake Bay Program (CBP) partners must prepare a total maximum daily load for the entire Chesapeake Bay. In an effort to meet standards, CBP partners—which include Federal, State, and local governments, and nongovernmental organizations (NGOs)—are implementing voluntary plans to reduce nutrients and sediments in the watershed to improve water quality in the Chesapeake Bay. Additionally, the CBP partners are working to meet Government Accountability Office and Congressional recommendations to develop a comprehensive, coordinated implementation strategy to better utilize existing resources. The CBP partners have developed the Chesapeake Action Plan (CAP), which

Mullinix is a physical scientist, U.S. Geological Survey (USGS) Eastern Geographic Science Center, USGS National Center, Reston, VA 20192, MS 521. Phillips is the USGS Chesapeake Bay Coordinator, USGS MD-DE-DC Water Science Center, 5522 Research Park Drive, Baltimore, MD 21228. Shenk is an environmental scientist, U.S. Environmental Protection Agency Chesapeake Bay Program Office, Annapolis, MD. Hearn is a physical scientist, USGS Eastern Geographic Science Center, USGS National Center, Reston, VA 20192, MS 521. Devereux is a non-point source data analyst, University of Maryland, College Park, MD. Email: ccladino@usgs.gov; swphilli@usgs.gov; shenk.kelly@epa.gov; phearn@usgs.gov; odevereu@chesapeakebay.net.

the application of adaptive management principles to improve the implementation and assessment of management actions (U.S. Environmental Protection Agency 2008). In 2007, a joint collaboration between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (USEPA) CBP was initiated to develop the Chesapeake Online Adaptive Support Toolkit (COAST), a web-based framework of tools and information to help CBP partners utilize an adaptive management approach to decisionmaking. COAST provides improved access to web-based analytical tools, data, and interpretive science products to help improve the management of the Bay ecosystem.

COAST was designed to enable CPB partners to:

1. understand the CBP restoration goals and the strategies to achieve these goals;
2. select areas in greatest need of mitigation and provide benefit to the Bay;
3. identify partner activities and resources;
4. conduct scenarios using watershed models to identify the optimal combination of management actions;
5. utilize monitoring results to document water quality changes and assess progress; and
6. understand the factors affecting water quality to adapt the mitigation strategies accordingly.

These six components are designed to be both sequential and cyclical and to constitute the structural framework of an active adaptive management strategy for the Chesapeake Bay watershed (Figure 1).

## Approach

Before the project began there were several factors to consider in designing the COAST framework. From the beginning the main priority of COAST was to support the major restoration goals described under the CAP. The CAP goals include restoration and protection of fisheries, habitat, water quality, and watersheds, and enhancement of stewardship. Of these goals, water quality was chosen for the initial version of COAST. The CAP also promotes the use of adaptive management in the management process, therefore design. Several approaches to adaptive management, including the U.S. Department of the Interior technical guidance document (Williams et al. 2007), were used to adaptive management became another priority in develop the organizational structure for COAST. Finally, the audience of the initial version of COAST was defined as CBP partners (Federal,

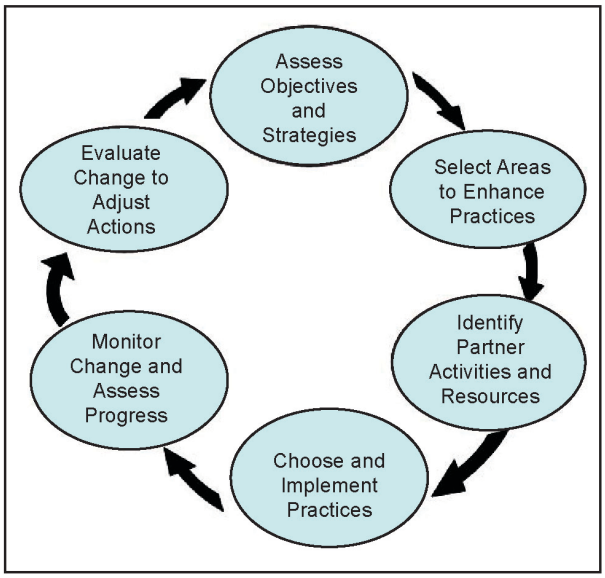


Figure 1. Steps in the Chesapeake Online Adaptive Support Toolkit adaptive management cycle.

State, and local governments and NGOs) who implement water quality management actions to meet the goals of CBP tributary strategies and improve local water quality. To accommodate such a large and diverse group of users, COAST and its decision support tools were chosen to be delivered in a publicly accessible online format.

### Selecting data

The COAST was not intended to be a data warehouse, in that storing and serving data would not be a task under the project. Rather, the goal was to use publicly available information to develop selected decision support tools for the steps of the adaptive management cycle in COAST. Preliminary meetings with potential user groups helped define the technical level of information that would be appropriate to highlight in COAST. Instead of gathering many data products for each adaptive management step, key products including results from models, monitoring networks, and CBP Health and Restoration Assessment reports were chosen to support different aspects of COAST. Results from the CBP Health and Restoration Assessments (Chesapeake Bay Program 2008), based on environmental indicators, were used to define restoration goals and determine progress toward aspects of the CBP water quality goal. Results from the USGS SPARROW (SPAtially Referenced Regressions On Watersheds attributes watershed

Watersheds attributes watershed modeling application) (Brakebill et al. 2004) and the CBP watershed models (Chesapeake Bay Program Nutrient Subcommittee 1998) were used to help users select areas for mitigation actions and to choose the suite of actions to be implemented. Results from the CBP nontidal and estuary monitoring networks (Langland et al. 2006) were provided to help assess water quality change to factors affecting water quality, including management practices.

## Developing decision support tools

Decision support tools (DSTs) are an interactive way of providing information on a topic for users who need to make specific decisions. DSTs can integrate tabular and static datasets with each other or with spatial data, or can provide analytical functionality to compute derivative data products. DSTs are essential to COAST in providing a way to integrate many types of data needed within the adaptive management process. The first DST developed for COAST, the Nutrient Yields Mapper (NYM), was designed to support restoration management in step 2 of the COAST adaptive management cycle: *Locate areas in greatest need of mitigation*.

The NYM uses Mapbuilder, an open source geographic information systems interface, and Geoserver, a data serving application for hosting web-map services. The tool utilizes output from the USGS Chesapeake Bay, Version 3.0 SPARROW model (Brakebill et al. 2004) to display the spatial distribution of nitrogen and phosphorous yields in subwatersheds within the Chesapeake Bay drainage basin. The SPARROW data are aggregated into quartiles to show relative high and low nutrient yields to major tributary basins and also to the Chesapeake Bay in a map viewer, which can be overlaid with additional information on water quality characteristics. These maps help managers identify the watersheds where actions to reduce nutrient runoff would have the greatest benefit to the Chesapeake Bay and also improve local water quality (Figure 2).

Another DST under development will address step 4 in the COAST adaptive management cycle: …*optimize management actions by developing scenarios using watershed models to choose the optimal combination of*

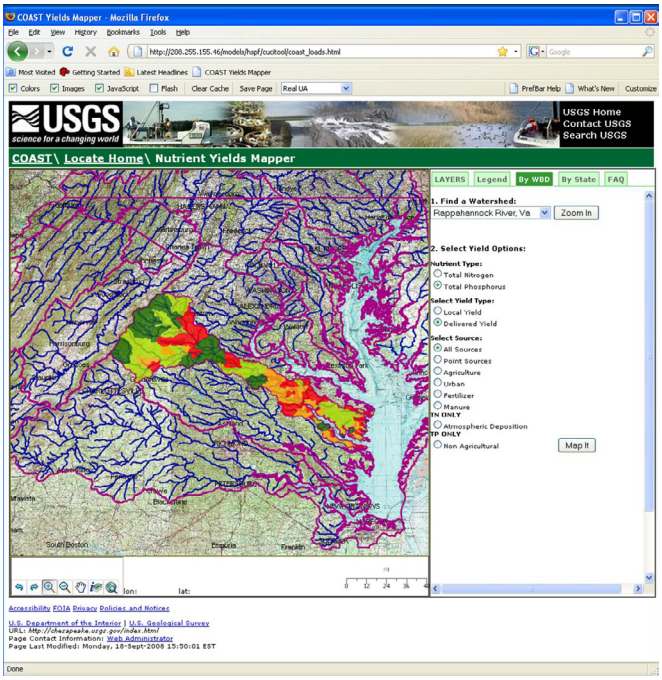


Figure 2. Output from the Chesapeake Online Adaptive Support Toolkit Nutrient Yields Mapper depicting the variation in total phosphorous delivered to the Chesapeake Bay from SPARROW (spatially referenced regressions on watersheds) modeling segments, subwatersheds, within the Rappahannock River watershed.

*management actions.* An interface to the CBP watershed model is being developed by the University of Maryland and the USEPA-CBP, which will allow local managers to test alternative mitigation strategies for selected watersheds. The tool will compute mass balances for nitrogen and phosphorus, utilizing sources from farm animals, chemical fertilizer, manure, atmospheric deposition, and septic and sewer systems. The tool is designed to provide rapid scenario development for managers to understand factors that reduce loading to the land and contamination by understanding the effect of forecasted land use change, best management practices (BMPs), geographic location, crop production practices, and animal populations. Output will include graphed and tabular reports of manure and fertilizer loading to the land by segment in pounds per acre, BMPs implemented along with their associated nutrient reduction, and bare soil area. A prototype version of the tool will be available in midsummer 2009 with a full version release anticipated in fall 2009.

### Test cases

Test cases are being conducted to assess the types of information and methods of presentation that will be most useful to decisionmakers. The test case moves the theory of adaptive management into a real-world application by interacting with small groups of decisionmakers at each management level (Federal, State, county, and NGO) to determine the best mix of existing information and models to improve their management process. In 2008 the COAST team started with agriculturally focused test cases because it would address a large audience of CBP partners.

The objectives of the agricultural test cases are to demonstrate:

- at a Bay-wide and state scale how COAST can be used to prioritize where to direct resources, identify the optimal agricultural nutrient conservation activities, and determine how to assess their effectiveness; and
- to States and counties how COAST can be used as a springboard from which to engage in locally driven analysis to identify opportunities for achieving further nutrient reductions in priority agricultural areas.

These test cases explore several components of the COAST tool associated with water quality and nutrients at regional, State, and county scales. They do not focus on testing the web-based application of the tool, but rather focus on the logic used, the questions asked, and the data layers employed to guide managers in their decisionmaking.

The questions the COAST teams are exploring during these test cases are:

- What are the right questions to ask for the associated decision process?
- What is the most useful information to use in answering those questions?
- How important is additional local data?
- How should the local data be factored into COAST?
- How should we structure the web interface of COAST to maximize utility of the tool to multiple users for multiple purposes?

The COAST team is setting up similar test cases for urban and developed lands to be conducted in the year 2009. Version 1.0 of COAST will be updated based on the outcomes of these test cases.

## Results

The development of the COAST tool kit is still at an early stage; however, a number of preliminary findings can be reported. Perhaps the most significant of these is that the decision processes and supporting data for implementing water quality management actions vary greatly at different levels of government and between agencies within levels of government. It is also significant, while the adaptive management process is promoted by the CBP office, that many implementing agencies are focused on the initial steps of the adaptive management cycle (identifying the types and locations of actions) and need to improve the use of monitoring and assessment to make more informed decisions in the future. Most groups we interviewed agreed that information is needed at several geographic scales: the entire watershed, state units (ideally not just the portion in the Chesapeake Bay watershed), and counties. Political boundaries were the most common decisionmaking units, but there was open-mindedness toward providing information on a watershed basis varying from 10-digit hydrologic unit code (HUC) to 12-digit HUC approximately 16 to 391 $mi^2$ in size (Natural Resources Conservation Service 2004). Lastly, in deciding the location and type of on-ground mitigation, county managers tend to consider cost sharing and (or) cooperative opportunities more than environmental impact.

## Conclusions

While there is progress in use of adaptive management by the CBP partners, the type and scale of information will have to be greatly improved to enhance implementation and assessment of water quality and other ecosystem restoration practices. While watershed-wide information is needed, it is clear that we need to provide information at least at the State scale that can compliment county-scale decisionmaking. Invariably, local knowledge of nutrient sources and local conditions is superior to data that can currently be provided by COAST. However, COAST can provide supplementary information at the Statewide or Chesapeake Bay-wide perspective to help verify county priorities and more closely link county to State and regional priorities. There is also a need for additional datasets such as state information on stream impairments based on the

USEPA Clean Water Act section 303d water quality standards and section 305b integrated assessment reports (U.S. Environmental Protection Agency 1972) to be integrated into COAST, as well as higher spatial resolution datasets such as 10-digit HUC or 12-digit HUC level that extend beyond the Chesapeake Bay watershed boundary to cover the entire multistate region. The data that make up the basis of COAST information also need to be timelier to reflect current conditions. Some ability for local users to upload finer-scale data into COAST has obvious advantages and will be considered as a new functionality is added to the tool kit in the future. Although COAST emphasizes the adaptive management cycle in its structure, there is a need to make it clear that users can utilize any component of the adaptive management process depending on their current status of implementation of management actions. This year's test cases were very successful in defining a product for Chesapeake Bay managers. It was also useful for selecting priority watersheds based on environmental data and not just local opportunity. Future test cases in other subwatersheds where multiple types of information exist will need to be conducted to enhance COAST's effectiveness at local scales.

## Acknowledgments

The authors appreciate the reviews of Andrew LaMotte and Susan Price.

## References

Brakebill J.W., and S.D. Preston. 2004. Digital data used to relate nutrient inputs to water quality in the Chesapeake Bay Watershed, Version 3.0. U.S. Geological Survey, Open-File Report 2004-1433.

Chesapeake Bay Program. 2008. Chesapeake Bay Health and Restoration Assessment. Chesapeake Bay Program partners, (CBP/TRS-291-08; EPA-903-R-08-002), Annapolis, MD.

Chesapeake Bay Program Nutrient Subcommittee. 1998. Chesapeake Bay Watershed Model Application and Calculation of Nutrient and Sediment Loadings. U.S. Environmental Protection Agency, Chesapeake Bay Program, Annapolis, MD.

Langland M.J., J.P. Raffensperger, D.L. Moyer, J.M. Landwehr, and G.E. Schwarz. 2006. Changes in streamflow and water quality in selected nontidal basins in the Chesapeake Bay watershed, 1985–2004. U.S. Geological Survey, Scientific Investigations Report 2006-5178.

Natural Resources Conservation Service. 2004. Federal Standards For Delineation Of Hydrologic Unit Boundaries, ver. 2.0. U.S. Department of Agriculture, Natural Resources Conservation Service.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. U.S. Department of the Interior, Adaptive Management Working Group, Washington DC.

U.S. Environmental Protection Agency. 1972. Clean Water Act (33 U.S.C. 1251 et seq.). [online] URL: http://www.epa.gov/lawsregs/laws/cwa.html. Accessed 23 September 2008.

U.S. Environmental Protection Agency. 2008. Strengthening the Management, Coordination, and Accountability of the Chesapeake Bay Program: Report to Congress. U.S. Environmental Protection Agency Chesapeake Bay Program Office, (CBP/TRS-292-08), with Chesapeake Bay Program partners, Annapolis, MD.