Chesapeake Bay Program | Indicator Analysis and Methods Document

Reducing Pollution Indicators "Modeled Nitrogen, Phosphorus, and Sediment Loads to the Chesapeake Bay (1985-2025)" | Updated September 2021

Indicator Title: Reducing Pollution

Relevant Outcome(s): 2025 WIP Outcome – Provide for clean and safe water

Relevant Goal(s): Water Quality

Location within Framework (i.e., Influencing Factor, Output or Performance): Performance

A. Data Set and Source

(1) Describe the data set. What parameters are measured? What parameters are obtained by calculation? For what purpose(s) are the data used?

Progress for this indicator is estimated by using up-to-date wastewater discharge data and tracked Best Management Practice (BMP) implementation data reported to the Chesapeake Bay Program (CBP) office by Bay watershed jurisdictions. The CBP assesses the current or "progress" condition of nutrient and sediment loads to the Chesapeake Bay using Phase 6 of the Watershed Model (aka Chesapeake Assessment Scenario Tool (CAST)). The Watershed Model estimates pollution loads from all major sources including wastewater, agricultural runoff and discharges, urban and suburban runoff, septic tank loads, and air deposition – and reports these fluxes based on average weather conditions. Data are used for tracking, research, long-term monitoring, and estimating progress toward Total Maximum Daily Load (TMDL) goals and targets.

(2) List the source(s) of the data set, the custodian of the source data, and the relevant contact at the Chesapeake Bay Program.

- Source: Annual jurisdictional submissions of both monitored and estimated wastewater effluent concentrations and flows as well as BMP data for other sources of pollution tracked by jurisdictions and reported to CBP. The Phase 6 Watershed Model (CAST) uses many types of data from sources too numerous to describe here. Please see https://cast.chesapeakebay.net/Documentation/ModelDocumentation and https://www.chesapeakebay.net/who/group/modeling_team for the most recent Watershed Model documentation and peer reviews of the Chesapeake Bay Program models (2020). This document, and the accompanying data spreadsheet reports 2020 progress using the CAST-2019 version of the Phase 6 model (also referred to as CAST19). CAST-2019 accounts for all datasets incorporated into CAST up to the year 2019. Since 2009, every two years a milestone period occurs, new datasets are submitted by jurisdictions to undergo an approval process to be incorporated into the model. These datasets include, but are not limited to, BMP implementation, land use changes, changes in crop production, and other changing environmental conditions within the watershed. This means that the last milestone period was 2019, hence the version "CAST-2019". Introducing new datasets to the model does not change the model structure and allows us to stay as up to date as possible with current watershed conditions.

- Custodians:
  - Wastewater: Jessica Rigelman (j7 LLC) and Sucharith Ravi, CBP Nonpoint Source Data Analysis (University of Maryland Center for Environmental Science, Chesapeake Bay Program Office)
  - Best Management Practice and Watershed Model information: Vanessa Van Note, Implementation Analyst, U.S. EPA, Chesapeake Bay Program Office.

- Chesapeake Bay Program Contacts (name, email address, phone number): Vanessa Van Note, vannote.vanessa@epa.gov; Sucharith Ravi, sravi@chesapeakebay.net.

(3) Please provide a link to the location of the data set. Are metadata, data-dictionaries and embedded definitions included? Yes. https://cast.chesapeakebay.net/

B. Temporal Considerations

(4) Data collection date(s): annual 1985 – 2020

(5) Planned update frequency (e.g., annual, biannual, etc.):
- Source Data: annual
- Indicator: annual

(6) Date (month and year) next data set is expected to be available for reporting: March 2022

C. Spatial Considerations

(7) What is the ideal level of spatial aggregation (e.g., watershed-wide, river basin, state, county, hydrologic unit code)?

Wastewater: Root data is at point locations for significant facilities. Data can be aggregated to Hydrologic Units (HUC 12), counties/cities (FIPS), "land-river segments" (the intersection of county boundaries and Phase 6 Watershed Model river segments), jurisdictional portions of major basins (state-basin), major basins, jurisdictions, and the Chesapeake Bay watershed as a whole. The loading goals (Planning Targets) for all sources combined are at the spatial scales of state-basin.

Agriculture, Developed and Septic, Atmospheric Deposition: BMP implementation data can be reported for the annual model assessment at the many scales above. BMP and loads reports from CAST are, again, at various scales but are often presented publicly at the aggregated spatial scale of state-basins (a jurisdiction's portion of a major tributary), jurisdiction-wide, major basin, and the Chesapeake Bay watershed as a whole.

(8) Is there geographic (GIS) data associated with this data set? If so, indicate its format (e.g., point, line polygon).

Shapefiles are available for download as GIS layers and KMZ files. The GIS layers are simplified to produce the KMZ files. The KMZ layers are suitable for web mapping, but not for area or boundary calculations. Boundaries could be shifted by up to 10 meters with the simplification to remove polygon vertices. For most accurate layers, shapefiles should be used.

- Segmentation – GIS and KMZ
- Combined Sewer Overflow – GIS and KMZ
- Municipal Separate Storm Sewer System (MS4) – GIS and KMZ
- Federal Lands – GIS and KMZ
- Maryland Regulated Area – GIS and KMZ
- Direct Loads – GIS and KMZ (direct loads include Wastewater, Rapid Infiltration Basins, Large Monitored Septic Systems, and Developed Land Spray Irrigation)

(9) Are there geographic areas that are missing data? If so, list the areas.

Wastewater: Depending on the jurisdiction, effluent flows and concentrations may not be tracked and reported for some small non-significant facilities.

Agriculture, Developed and Septic, Atmospheric Deposition: The degree to which BMP implementation reported annually by stakeholders representing on-the-ground units or coverage – can be highly variable, ranging from over-reported to not being tracked and reported.

(10) Please submit any appropriate examples of how this information has been mapped or otherwise portrayed geographically in the past.

BMP and loading data are usually reported as tables and charts at spatial scales best suited for the audience. Maps/GIS can be appropriate when, for example, targeting of restoration efforts is the emphasis. However, how conditions change through time is often important to convey, e.g., improving or degrading. In these cases, tables and charts are often better than maps.

D. Communicating the Data

(11) What is the goal, target, threshold or expected outcome for this indicator? How was it established?

In December 2010, the Environmental Protection Agency (EPA) established a pollution diet formally known as the Chesapeake Bay Total Maximum Daily Load (TMDL). The TMDL is designed to ensure that all nitrogen, phosphorus and sediment pollution control efforts needed to fully restore the Bay and its tidal rivers are in place by 2025, with controls, practices and actions in place by 2017 that would achieve at least 60% of the reductions from 2009 necessary to meet the TMDL. The Partnership has set additional goals to achieve 75% of the 2009-2025 pollutant load reductions by 2020. The TMDL sets pollution limits (allocations) necessary to meet applicable water quality standards in the Bay and its tidal rivers.

As a result of the Bay-wide "pollution diet," Bay Program partners are implementing and refining Watershed Implementation Plans (WIPs) and improving the accounting of their efforts to reduce nitrogen, phosphorus and sediment pollution. The WIPs developed by Delaware, the District of Columbia, Maryland, New York, Pennsylvania, Virginia, and West Virginia identify how the Bay jurisdictions are putting measures in place by 2025 that are needed to restore the Bay. The restoration work formally began three decades ago prior to publication of the TMDL, mostly in a volunteer fashion. Implementation by jurisdictions and many stakeholders continued through, in part, Phase I and Phase II WIP commitments.

Planning targets were again established in July 2018 using new science and updated data and information for jurisdictions to plan for through the development of their Phase 3 WIPs. These planning targets, while shifting from the allocations published in the December 2010 TMDL, represent the actions, assumptions, and "level of effort" necessary to meet the TMDL allocations.

There are many ways to quantify progress toward goals or targets. This indicator focuses on changes in pollutant loads from the Phase 6 Watershed Model (CAST), estimates of the composite effects of BMP implementation, wastewater discharges, and changing conditions in the watershed. Other ways stakeholders use to track progress include 1) monitoring data trends in the tidal waters for, in particular, Dissolved Oxygen, chlorophyll-a, and clarity and SAV abundance, 2) monitoring data trends in non-tidal rivers throughout the Chesapeake Bay watershed – loads for nitrogen, phosphorus, and total suspended solids, 3) BMP implementation data reported annually to the CBPO in units of, for example, acres, feet, Animal Units, systems, etc., and 4) changes in restoration programs that were defined in jurisdictions' WIPs, e.g., new programs, strengthening existing programs – or a deficit of programmatic accomplishments.

(12) What is the current status in relation to the goal, target, threshold or expected outcome?

The current goals for these indicators are as follows for the Chesapeake Bay watershed as a whole:

Nitrogen Target:

- Reduce computer-simulated nitrogen (N) loads to the Bay by 82.92 million pounds N, from 297.80 million pounds in 2009 to 214.88 million pounds in 2025.

Nitrogen Status:

- Computer simulations show that pollution controls put in place by watershed jurisdictions between 2009 and 2020 have reduced nitrogen loads to the Bay by an estimated 38.89 million pounds. This is an 13% reduction since 2009. By 2020, the BMPs in place are estimated to have achieved 47% of the nitrogen load reductions necessary by 2025 to meet target water quality standards as compared to 2009 (the year before the U.S. EPA established the Bay TMDL).

Phosphorus Target:

- Reduce computer-simulated phosphorus (P) loads to the Bay by 3.859 million pounds P, from 17.173 million pounds in 2009, to 13.314 million pounds in 2025.

Phosphorus Status:

- Computer simulations show that pollution controls put in place by watershed jurisdictions between 2009 and 2020 have reduced phosphorus loads to the Bay by an estimated 2.456 million pounds. This is a 14% reduction since 2009. By 2020, the BMPs in place are estimated to have achieved 64% of the phosphorus load reductions necessary by 2025 to meet target water quality standards as compared to 2009.

Sediment Target:

- Reduce computer-simulated sediment (SED) loads to the Bay by 324 million pounds SED, from 18,911 million pounds in 2009, to 18,587 million pounds in 2025.

Sediment Status:

- Computer simulations show that pollution controls put in place by watershed jurisdictions between 2009 and 2020 have reduced sediment loads to the Bay by an estimated 769 million pounds. This is a 4% reduction since 2009. By 2020, the BMPs in place are estimated to have achieved 100% of the sediment load reductions necessary by 2025 to meet target water quality standards as compared to 2009.

(13) Has a new goal, target, threshold or expected outcome been established since the last reporting period? Why?

Yes. New York amended their Phase 3 WIP to meet the state's 2025 Planning Targets established in 2019. This adjustment to NY's Planning Targets was the result of an exchange between the nitrogen and phosphorus planning targets within the Susquehanna river basin– a calculation which has been previously used to adjust other state's planning targets by applying a specific exchange ratio for nitrogen and phosphorus to the existing planning targets for the basin. As of 2020 Progress, the N:P exchange ratio for the Susquehanna allows for 2.36 lbs of N to equal the effect of 1 lb of P. This means, for every 1 lb of phosphorus reduced by NY within the Susquehanna, 2.36 lbs of nitrogen can be added towards the basin's target.

To summarize the information above, NY's amended WIP and adjusted Planning Target loads will meet Bay water quality standards (WQS) when combined with other state's Planning Targets. These exchange ratios are updated when new planning targets are calculated based on updated models. Though the TMDL documentation has not been updated to reflect the ratios discussed above, the science regarding the relationship between nitrogen and phosphorus and the original technical basis for introducing these N:P exchange ratios can be found in **Section 6.4.6** of the TMDL Documentation, *Establishing Allocations for the Basins-Jurisdictions*: https://www.epa.gov/sites/production/files/2014-12/documents/cbay_final_tmdl_section_6_final_0.pdf.

Planning Targets for sediment, which had not been previously defined for the Phase III planning targets and WIPs, were established in 2019 and remain the same for the 2020 reporting period.

(14) Has the methodology of data collection or analysis changed since the last reporting period? How? Why?

No, the methodology of data collection and analysis are largely the same.

(15) What is the long-term data trend (since the start of data collection)?

Computer simulations of implemented pollution controls and changing conditions in the ecosystem between 1985 and 2020, for the entire Chesapeake Bay Watershed for all sources combined of nutrients and sediment:

- Nitrogen loads decreased by an estimated 111 million pounds from 370.13 million pounds/yr in 1985 to 258.91 million pounds/yr in 2020, a 30% reduction.
- Phosphorus loads decreased by an estimated 14.715 million pounds from 29.432 million pounds/yr in 1985 to 14.717 million pounds/yr in 2020, a 50% reduction.

- Sediment loads decreased by an estimated 2,224 million pounds from 20,366 million pounds/yr in 1985 to 18,142 million pounds/year in 2020, an 11% reduction.

Given that the Chesapeake Bay TMDL was established in 2010 (see 11), the baseline year for these indicators is 2009. Computer simulations of changing conditions and pollution controls implemented between 2009 and 2020, for the entire Chesapeake Bay Watershed for all sources combined of nutrients and sediment:

- Nitrogen loads to the Bay decreased by an estimated 38.89 million pounds, from 297.80 million pounds/yr in 2009 to 258.91 million pounds/yr in 2020, a 13% reduction.
- Phosphorus loads to the Bay decreased by an estimated 2.456 million pounds, from 17.173 million pounds/yr in 2009 to 14.717 million pounds/yr in 2020, an 14% reduction.
- Sediment loads to the Bay decreased by an estimated 769 million pounds, from 18,911 million pound/yr in 2009 to 18,142 million pounds/yr in 2020, a 4% reduction.

(16) What change(s) does the most recent data show compared to the last reporting period? To what do you attribute the change? Is this actual cause or educated speculation?

Comparing model-estimated changes in loads between the two periods, 2019-2020 and the average annual change since the TMDL (2009-2019), for the entire Chesapeake Bay Watershed for all sources combined of nutrients and sediment:

- Nitrogen loads to the Bay decreased by an estimated 10.08 million pounds/yr (3.7%) from 2019 to 2020 compared to the average annual load change of 2.88 million pounds/yr (1%) over a period of 10 years from 2009 to 2019. Since the TMDL, 66% of the nitrogen load reductions came from wastewater treatment plants, 23% from reductions in atmospheric deposition, and 10% from the agricultural sector. Over the past year, 61% of the nitrogen load reductions came from wastewater treatment plants, 34% from the agriculture sector, and 1% from reductions in atmospheric deposition. While not a key focus for Nitrogen reductions, an additional 3% of reductions came from the natural sector.

  Comparing the short-term changes to the average over the past decade, wastewater continues to contribute a significant amount to the total reduction in nitrogen. Additionally, it appears that unless extreme measures in air pollution control are put in place, we may not be able to rely on further significant reductions in atmospheric deposition.

- Phosphorus loads to the Bay decreased by an estimated 0.470 million pounds/yr (3.1%) from 2019 to 2020 compared to the average annual load reduction of 0.199 million pounds/yr (1.2%) from 2009 to 2019. Since the TMDL, 76% of the phosphorus load reductions came from wastewater treatment plants, 11% from the natural sector and 12% from the agricultural sector. Over the past year, 74% of the phosphorus load reductions came from wastewater treatment plants, 18% from the agriculture sector and 9% from the natural sector.

- Sediment loads to the Bay decreased by an estimated 168 million pounds/yr (0.9%) from 2019 to 2020 compared to the average annual load change of 60 million pounds/yr (0.3%) from 2009 to 2019. Since the TMDL, 48% of the sediment load reductions came from the agriculture sector, with 49% of reductions derived from the natural sector. Over the past year, a similar 51% of the sediment load reductions came from the natural sector, 32% from the agriculture sector, and 15% from the developed sector.

Wastewater source sector load estimates are not speculation but there can be errors associated with the data reporting. Wastewater discharges (municipal and industrial) are measured for all significant facilities and reported to Bay Program repositories. Non-significant facility discharges are either measured or follow default protocols for flows and concentrations directed by the Bay Program partnership.

All other source loads are model estimates from CAST that employ data and methods reviewed and directed by stakeholders primarily on Chesapeake Bay source sector workgroups under the Water Quality Goal Implementation Team. Data outside wastewater information includes practice and program implementation reported annually by localities and state and federal agencies from their BMP data sources.

In addition to restoration actions, CAST accounts for changes in loads due to changes in conditions in the watershed. The changes in conditions through time are updated yearly based on new data or projections from historic data following protocols directed by the Partnership. The conditions include, but are not limited to, the following:

- Land-use and land cover types and acres
- Crop types, acres and crop yields
- Animal populations, weight, and their manure and litter nutrient concentrations
- Chemical fertilizer sales and use
- Human population, housing, etc.
- Septic systems
- Atmospheric deposition of nitrogen

The reported loads are annual averages for a year of average hydrology or precipitation – even though the hydrodynamic version of CAST is calibrated at much finer time steps over a period going back to 1984.

This year, findings for the environmental indicator for tracking toward the Chesapeake Bay TMDL cite a revised history from CAST. Measures from the latest version of CAST, CAST-19, are the Partnership's best representation of how the ecosystem changed and where we are with respect to goals. As directed by stakeholders, the model incorporates the "best available" science, data, methods, etc. at 2-year time intervals in line with Milestone periods. The 2019 Progress scenario begins a Milestone period and it ends with the 2021 Progress scenario. The same version of CAST is used to assess progress at the end of the period as the beginning. According to partner direction, the model's loading history is revised when a new version of CAST is released to ensure the best estimate of how conditions and the resultant loads changed through time.

The "best available" data for 2020 Progress has been impacted by challenges select states face with their BMP tracking and reporting. In Delaware, the 2020 modeled loads are not reflective of true BMP implementation levels in Delaware as the state is working through issues with its BMP data warehouse. Delaware will remedy these issues in 2021-2022 to represent BMP implementation levels more accurately within the state.

(17) What is the key story told by this indicator?

- Excess nitrogen and phosphorus are two of the leading causes of the Chesapeake Bay's poor health. When nitrogen and phosphorus enter rivers, streams and the Bay, they fuel the growth of algae blooms that lead to low-oxygen "dead zones" that are harmful to fish, shellfish and other aquatic life. In general, nitrogen and phosphorus reach the Bay through a several primary sources, including wastewater treatment plants; urban, suburban and agricultural runoff; and air pollution. The TMDL limits the amount of nutrients and sediment that can enter the Bay if it is to achieve water quality standards for dissolved oxygen, chlorophyll-a, clarity and the degree of Submerged Aquatic Vegetation (SAV).

- Excess sediment is another one of the leading causes of the Chesapeake Bay's poor health. While loose particles of sand, silt and clay are natural parts of the environment, too much sediment can cloud the waters of the Bay and its tributaries, harming underwater grasses, fish and shellfish. Sediment enters the Bay when land, stream banks and shorelines erode. Erosion increases when land is cleared for agriculture and development. The TMDL limits the amount of sediment that can enter the Bay if it is to achieve water quality standards.

E. Adaptive Management

(18) What factors influence progress toward the goal, target, threshold or expected outcome?

The Phase 6 Model (CAST), accommodating protocols and direction by the Partnership, takes into account the key factors influencing progress. These include BMP implementation and verification of functioning BMPs as well as changes in technology that enable progress in the wastewater sector through reductions in discharges. The wastewater upgrades are aligned with permit limits and the availability of funds.

The model also accounts for changes in conditions in the watershed that can yield increases or decreases in nutrient loads and erosion to local water bodies and, in turn, tidal waters of the Chesapeake Bay. The changes in conditions through time are updated yearly based on new data or projections from historic data. The conditions include, but are not limited to, the following:

- Land use and land cover types and acres
- Crop types, acres and yields
- Animal populations, weight, and their manure and litter nutrient concentrations
- Chemical fertilizer sales and use
- Human population, housing, etc.
- Septic systems
- Atmospheric deposition of nitrogen

As an example of changing conditions in the watershed that influence progress toward the goal, a shift in crop types from pasture to corn would typically increase loads since applications of nutrients to corn are higher than those to pasture and the corn does not retain nutrients to the same degree as grasses or hays. Load increases can be reduced or offset through BMP implementation. Contrarily, lower over-applications of manure and chemical fertilizer nutrients on turfgrass and crops typically yields lower loads to local water bodies.

Other factors influencing progress are the following:

- **Funding for Implementation**. Assistance in the major source sectors to implement local-scale programs, plans, and practices. Likely emphasis will be in the agricultural sector.
- **Communication and Coordination**. Consistent efforts with diverse stakeholders. Other potential audiences include states and DC; local jurisdictions; and federal agencies such as USDA, DoD and EPA
- **Water Quality Monitoring**: Sustain and enhance monitoring and interpretation of results to help understand water quality response to management actions. It is important to demonstrate progress towards attainment of water quality standards.
- **Using Co-Benefits as a catalyst to increase implementation by aligning with priorities and goals beyond water quality**. Characterization of benefits beyond water quality improvements associated with existing BMPs to identify new funding opportunities and opportunities to increase implementation.

- **Climate Change**. Understanding and allocating impacts of climate change induced watershed loads for 2022-2023 milestones.

(19) What are the current gaps in existing management efforts?

Gaps in management efforts are quantified by comparing jurisdiction-reported BMP implementation to planned implementation that stakeholders have defined in their 2-year Milestones and WIPs. The information is updated annually and can be accessed publicly through CAST at https://cast.chesapeakebay.net/

Summary BMP reports can be queried through the "Results" tab and "Reports" in the drop-down menu. Under "Create Reports", select "BMP Summary Report" at the geographic scale and for the scenarios of interest. Comparisons can be made among reported BMPs for all historic "progress" scenarios, planned implementation such as WIPs, and all other what-if scenarios that a user develops and are shared with them.

The jurisdictions and EPA, through the WIPs and evaluations of the WIPs, respectively, identified gaps between the jurisdictions' current capacity and the capacity they estimate is necessary to fully attain the interim and final nutrient and sediment target loads for each of the 92 segments of the Bay TMDL. Such gaps that the jurisdictions continue to address through Phase III WIPs implementation and other efforts include:

- Financial capacity to oversee and implement municipal separate storm sewer systems (MS4s) and other stormwater programs.
- Financial, technical and regulatory capacity to deliver priority pollution reduction practices to priority watersheds.
- BMP tracking, verification and reporting programs.
- Financial capability to continue to maintain new and existing implementation practices.
- Specifically achieving the Phase III nitrogen planning targets by 2025 since the CBP partnership did not achieve the goal of 60% pollution reductions by 2017.

Necessary new capacity to address these issues includes additional incentives, new or enhanced state or local regulatory programs, market-based tools, technical or financial assistance and new legislative authorities. It also includes capacity from other federal agencies, local governments, the private sector and/or non-governmental organizations.

Through the Phase III WIP development and implementation processes, the Bay watershed jurisdictions are expected to discuss plans to work with federal, local, private sector and nonprofit partners to leverage capacity for achieving the Phase III planning targets.

(20) What are the current overlaps in existing management efforts?

There are no "overlaps" of existing management efforts with respect to BMP implementation. BMP implementation and control technologies that go beyond what was planned or anticipated would offset, to some degree, shortfalls in implementation that were planned or anticipated.

(21) According to the management strategy written for the outcome associated with this indicator, how will we (a) assess our performance in making progress toward the goal, target, threshold or expected outcome, and (b) ensure the adaptive management of our work?

(a) This management strategy identifies approaches for achieving the goal which is to reduce pollutants to achieve water quality necessary to support the aquatic living resources of the Bay and its tributaries and protect human health. One of the key outcomes for the Water Quality goal is the 2025 WIP Outcome, "By 2025, have all practices and controls installed to achieve the Bay's dissolved oxygen, water clarity/SAV and chlorophyll-a standards as articulated in the Chesapeake Bay TMDL document."

To assess our performance in making progress toward the goal – related to the indicator – the Bay Program estimates the impact of BMP implementation and changing conditions in the watershed using the Chesapeake Bay Program's Watershed Model, aka CAST. The partnership's modeling tools are calibrated to monitoring data and use implementation data and measures of control technologies collected from the seven Bay watershed jurisdictions.

The modeling assessments of progress are done annually and the estimated loads for nitrogen, phosphorus, and sediment are compared to trajectories needed to meet the 2025 loading Planning Targets. The process allows for a quantification of the gaps between the progress status and where we need to be at the time of the model assessment – to be on track to meet 2025 targets.

By accounting for changing conditions in the watershed, the model allows for measurements of the effects of growth on loads that, in turn, would need to be offset by practices and programs to yield net reductions in loads. Examples of growth that influence loads include increasing: human populations, impervious and pervious surfaces from development, septic systems, animal populations (which increase the pool of manure nutrients applied to agricultural lands), use of inorganic fertilizers on crops and turfgrass, and acres of leguminous crops. These factors can all increase the nutrients in the watershed balance.

In addition to the reporting of water quality management practices, the CBP partners have endorsed an integrated approach that includes other pieces of information to measure progress toward meeting water quality standards:

- Analyzing trends of nitrogen, phosphorus and sediment loads in the watershed from the non-tidal water monitoring network.
- Assessing attainment of dissolved oxygen, chlorophyll-a and water clarity/SAV standards in the tidal estuary.
- EPA reviewing progress on strengthening programs as submitted annually by each jurisdiction, comparing the reported progress to jurisdictions' programmatic commitments in their latest implementation plans.

The integrated approach to quantify and explain water quality trends in the Bay and its watershed relies on monitoring information, BMP implementation data and the use of several analytical tools (including statistical tools, the CAST and estuary models, the U.S. Geological Survey (USGS) SPARROW model and groundwater models). The measure of success for this integrated approach is to meet all applicable nutrient- and sediment-related water quality standards in the tidal Chesapeake Bay necessary to protect the designated uses for 92 segments in the tidal waters, each having up to five designated aquatic life uses.

All measures of restoration progress are directed toward ensuring EPA and the public have confidence the seven jurisdictions, and their local, regional, and federal partners have in place the funding, financing, cost-share, technical assistance, voluntary incentive, policy, program, legislative, and regulatory infrastructures necessary to achieve their Phase 3 WIP planning targets, thereby having all practices in place by 2025 that will achieve the Bay's dissolved oxygen, water clarity/SAV and chlorophyll-a standards. EPA recognizes that such commitments may need to be modified during the course of the 2020-2025 timeframe, and EPA expects the jurisdictions to update those programmatic and/or numeric commitments, as appropriate, through their two-year water quality milestones.

(b) Adaptively Managing

The Partnership uses the following approaches to ensure adaptive management:

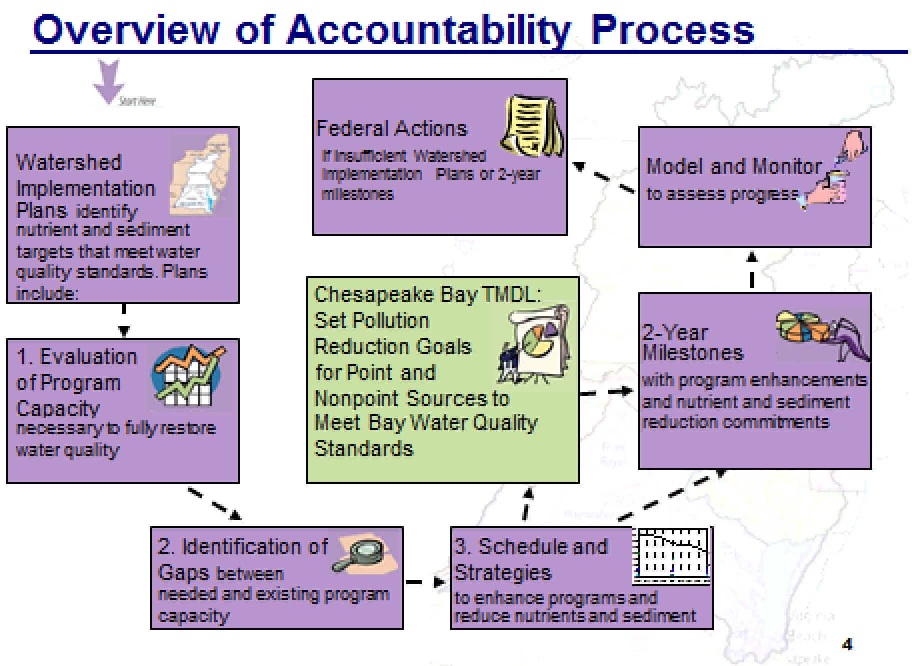
In a dynamic environment like the Bay watershed, changes during the next five to six years are inevitable. It may be possible to accommodate those changes within the existing Bay TMDL framework without the need to revise it in whole, or in part. The CBP partnership has committed to take an adaptive management approach to the Bay TMDL and incorporate new scientific understandings into the implementation planning in two-year milestones and in Phase 3 Watershed Implementation Plans. Future adjustments to WIPs and two-year milestones based on changing conditions and the availability of new information is consistent with the CBP's concept of adaptive management.

The CBP partnership will continue to examine the following questions to address implementation challenges and opportunities, incorporate new data and scientific understandings, and refine decision support tools and management strategies, as approved by the Bay Program's Principals' Staff Committee, toward the achievement of the water quality outcomes in the 2014 Chesapeake Bay Watershed Agreement:

- What progress has been made in implementing practices for the Bay TMDL?
- What are the changes in water quality and progress toward applicable water quality standards?
- Are there fundamental changes due to climate impacts or other factors that require reconsideration of the water quality standards that the Bay TMDL was originally based on?
- What are we learning about the factors affecting water quality changes to better implement practices?
- What refinements are needed in decision support tools, monitoring and science?
- How do we make program decisions in a business strategy that sustains and grows monitoring programs to meet ongoing and growing CBP information needs under recognized economic constraints?
- How do we best consider the combined impacts of land change and climate variability (storm events and long-term change) on nutrient and sediment loading and implications for the Bay TMDL?
- What partnership actions can be taken to refine and simplify BMP verification protocols, and what support can the partnership provide to jurisdictions in addressing BMP verification and reporting needs?
- How do we make the best implementation decisions under economic constraints at the state and local level?
- How do we best target nutrient and sediment reduction practices to achieve the best outcomes?
- How do we better leverage resources?

As the partners' track their progress toward goals for cleaner waters, verifying that practices are being implemented and maintained, and quality assurance and quality control procedures are being followed according to the Verification Protocols, will be critical in accurately measuring success in reducing nutrient and sediment pollution. EPA, the Bay watershed jurisdictions, local governments, the private sector and nongovernmental organizations use these data to inform accountability and adaptive decision-making and redirect management actions and resources.

Although the Chesapeake Bay TMDL accountability framework is not part of the Bay TMDL, Sections 7 and 10 of the Bay TMDL document describe how the accountability framework helps provide reasonable assurance that the needed pollutant reductions will occur and how adaptive management can be used as a tool to implement those pollutant reductions within the accountability framework.



As part of its efforts to carry out the Bay TMDL accountability framework, EPA interacts with the jurisdictions directly and through the CBP's WQGIT and its associated source sector workgroups. The WQGIT workgroups are focused on supporting the reduction of nitrogen, phosphorus and sediment pollutant loads from key sources described in Section 4 of the Bay TMDL: wastewater, agriculture, urban storm water, septic systems, forests and air.

EPA also works with the jurisdictions and the WQGIT on issues associated with two-year milestones, offsets and water quality trading. The WQGIT is supported by the CBP STAR team, which contains the modeling and monitoring workgroups, and other goal implementation teams, as necessary. The CBP partnership's models are used to assist the jurisdictions in assessing different options for management practices in the formulation of their WIPs and two-year milestone commitments.

F. Analysis and Interpretation

Please provide appropriate references and location(s) of documentation if hard to find.

(22) What method is used to transform raw data into the information presented in this indicator? Please cite methods and/or modeling programs.

There is an immense amount of raw data and methods employed by CAST. Documentation for the Phase 6 Watershed Model are available through CAST at https://cast.chesapeakebay.net/Documentation/ModelDocumentation

(23) Is the method used to transform raw data into the information presented in this indicator accepted as scientifically sound? If not, what are its limitations?

Yes, the methods are accepted as scientifically sound. Information about the Chesapeake Bay Program Phase 6 Watershed Model (CAST) review conducted by the Scientific and Technical Advisory Committee (STAC) (2017) can be found at: http://www.chesapeake.org/pubs/379_Easton2017.pdf

For more information on modeling at the Chesapeake Bay Program, visit https://www.chesapeakebay.net/what/programs/modeling

(24) How well does the indicator represent the environmental condition being assessed?

The Watershed Model allows scientists to simulate changes in physical, chemical, and biological processes in a large and complex ecosystem due to, for example, changes in human and animal populations, land uses and types, pollution management – so that technically sound environmental decisions can be made. Monitoring data provides observations in the past or the present, at discrete times, and at isolated locations while modeling scenarios can be used to represent the environment under different management regimes in different temporal and spatial scales.

The model simulations represent "what-if" management scenarios, providing comparisons among historic and current watershed conditions and a future condition that would restore water quality and living resources in the Chesapeake Bay. So that the comparisons are relevant, reported loads from the Watershed Model for sources of pollution other than wastewater treatment plants are estimates of what would occur under average weather conditions in a single year's watershed conditions (i.e., land uses, animal manure and chemical fertilizer inputs, human population, nonpoint source controls/practices, septic, and atmospheric deposition). This allows managers to understand trends in efforts to implement pollution reduction actions.

Wastewater loads reflect measured discharges from tracked waste treatment and industrial facilities that are influenced by annual weather conditions, using the model to account for changes in nutrients as the pollutants move downstream. The influence of weather, rain and snowfall can be quite large and can influence wastewater loads in any single year.

Pollutant loads to the Bay in any given year are influenced by changing conditions in the watershed and the implementation of management practices, as well as the amount of water flowing to the Bay (hydrology). Annual rain and snowfall influence the amount of water in rivers flowing to the Bay. Other indicators track annual changes in river flow and population, which are important to understanding the context for the model results for a given year and over time.

There are two types of indicators that report different pollutant load amounts in a particular year. For example, in the Nitrogen Loads and River Flow indicator (https://www.chesapeakeprogress.com/clean-water/water-quality), the USGS reports the load of nitrogen reaching the Bay each year using, primarily, data from different River Input Monitoring (RIM) stations around the watershed. For areas in the coastal plain or below the RIM stations, this indicator also includes measured wastewater discharges and modeled estimates of downstream nonpoint sources and atmospheric deposition to tidal waters.

The annual load to the Bay in 2018, as determined by the Nitrogen Loads and River Flow indicator, was 423 million pounds of nitrogen, based mostly on actual river flow during that year. This is 78 million more pounds than the long-term average of 345 million pounds for 1990-2018. The nitrogen load for 2018, according to this measure, was the 8th highest since 1990.

For the indicators described in this Methods document, "Modeled [Nitrogen] Loads to the Chesapeake Bay", loads are simulated using the CBP Watershed Model. The 2020 nitrogen loads were estimated to be 258.91 million pounds. This simulation does not represent how much nitrogen actually reached the Bay in 2020 since the loads from agriculture, urban runoff, septic, forest and atmospheric sources are based on long-term average hydrology rather than the actual amount of water flowing to the Bay in 2020. The wastewater portion of the modeled loads indicator shows, largely, actual loads reaching the Bay, but high- or low-flow years may confound progress associated with wastewater treatment upgrades.

For more information on the indicator "Pollution Loads and River Flow to the Chesapeake Bay (1990-2019)", please see the relevant Methods documentation here and the indicator page here.

To improve on the assessment of environmental conditions in the Chesapeake Bay watershed and how they change through time, all modeling tools are updated and upgraded regularly to accommodate new science and introduce new and expanded data and methods that better reflect changing on-the-ground conditions. The Phase 6 Watershed Model has a simplified structure that makes it easy to use. It brings more scientific and partnership input than ever before and includes new science, data and inputs from industries not previously involved.

The degree to which the indicator represents the environmental condition being assessed depends on the degree to which the modeled loads represent the "average" conditions in the environment and how these conditions change over time. When upgrading from Phase 5.3.2 of the CBP Watershed Model to Phase 6, the following short-list of improvements were made – as directed by the Partnership – mostly to better depict environmental conditions and how they change:

- Phase 6 better predicts the impacts of population growth and climate change and better accounts for the sediment build-up behind the Conowingo Dam on the Susquehanna River in Maryland.
- Ten additional years of water quality monitoring data doubles the amount of real-time data and provides more insight into how pollution loads have changed as BMPs have been implemented.
- High-resolution land cover data allow for a one-by-one-meter resolution, providing 900 times the amount of information than was previously available. This ground-breaking improvement will enable the prioritization and targeting of restoration, conservation, education and public access efforts.
- Additional categories of land use data are included.
- Because of its new features, the model has further improved the ability to answer questions about how different land use types or land management decisions can affect nutrient and sediment pollution levels.
- New inputs from the agricultural community, particularly the poultry industry, and improved and updated information on the application of fertilizer and manure improved accuracy.
- Additional BMPs are now credited and incorporated, including a few that have been reanalyzed for their effectiveness.
- Improved nutrient input data have been added.
- Combining multiple models (such as the former Scenario Builder) into one new model provides an entirely new approach to water quality simulation.
- A simulation period that runs over 20 years rather than 10 years allows for finer-scale analysis and planning.

(25) Are there established reference points, thresholds, ranges or values for this indicator that unambiguously reflect the desired state of the environment?

Yes. The desired state of the environment for the indicator is loads that are less than or equal to Planning Targets for nitrogen, phosphorus and sediment loads by the year 2025, for all source sectors as a whole and for each jurisdiction's portion of the major tributaries. These Phase 3 WIP Planning Targets represent a condition where all practices are in place by 2025 that will achieve the Bay's dissolved oxygen, water clarity/SAV and chlorophyll-a standards.

(26) How far can the data be extrapolated? Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

For the purposes of the indicator, loads for the year for progress assessments represent conditions in the watershed for that particular year. In some cases, data for the conditions are forecasted according to methods directed by the Partnership using historic data. Other data, such as BMP implementation information reported by jurisdictions, is for the particular progress year. Short-term forecasts are used until new data becomes available, at which time, information is interpolated to the previous data points and the new data is used for updating the short-term forecasts.

For the spatial scale, the model typically uses data at the finest scale of the raw data. However, there are parameters where larger scale data is spatially distributed to smaller areas according to rules established and approved by CBP workgroups and the Water Quality GIT.

As with most projections, the greater the time period from the last data point or the greater the spatial expanse from the root data, the greater the uncertainty in the predictions.

Changes in watershed conditions like animal and people populations; acres in agriculture, urban and forest settings; septic system growth; nutrient inputs to the land; etc. are extrapolated in time for what-if scenarios like the 2-year Milestones or 2025 Phase 3 WIPs. Methods for performing the projections are appropriate and agreed to by Bay Program partners. By building in anticipated future conditions in model scenarios, changes in loads are accounted for that are associated with the changing conditions in the watershed. The BMP plans can then accommodate the effect of these changing conditions. As an example, additional stormwater management would be needed to offset the growth in impervious surface as development occurs.

G. Quality

Please provide appropriate references and location(s) of documentation if hard to find.

(27) Were the data collected and processed according to a U.S. Environmental Protection Agency-approved Quality Assurance Project Plan? If so, please provide a link to the QAPP and indicate when the plan was last reviewed and approved. **If not, please complete questions 28-30.**

Yes. One of the key purposes of the annual Watershed Model assessment of progress toward loading goals is to estimate the composite effects of BMP implementation and control technologies at waste treatment facilities. The quality of the data, reported annually by stakeholders, is described in each jurisdiction's BMP Verification Program Plan published through the CBP site: https://www.chesapeakebay.net/what/programs/bmp_introduction_to_bmp_verification/bmp_additional_resources These are EPA-approved Quality Assurance Project Plans that are part of the Partnership's verification program. All elements of the Bay Program framework for BMP verification are documented at: https://www.chesapeakebay.net/what/programs/bmp_introduction_to_bmp_verification

BMP verification is "the process through which agency partners ensure practices, treatments and technologies resulting in reductions of nitrogen, phosphorus and/or sediment pollutant loads are implemented and operating correctly." It can be viewed as a life cycle process that includes initial inspection, follow-up checks and evaluation of BMP performance.

(28) If applicable: Are the sampling, analytical and data processing procedures accepted as scientifically and technically valid? N/A

(29) If applicable: What documentation describes the sampling and analytical procedures used? N/A

(30) If applicable: To what extent are procedures for quality assurance and quality control of the data documented and accessible? N/A

(31) Are descriptions of the study design clear, complete and sufficient to enable the study to be reproduced?

Please see the response to questions 22 and 23 for the locations of the most recent Phase 6 Watershed Model (CAST) documentation and scientific reviews. The study, annual model assessments of progress toward load goals, has been reproduced since the mid-1990s. However, the accuracy of the model predictions has improved each year as the quality of the data, the methods and, generally, the science have improved or advanced.

(32) Were the sampling, analytical and data processing procedures performed consistently throughout the data record?

Wastewater:

- Monitored discharge data were largely generated from the EPA-approved standard sampling and analysis methods and documented in the Data Monthly Reports from facilities to jurisdictions.

- Discharge data back to the earlier years of the record are inadequate for many regions in the Bay watershed; however, the Bay Program Wastewater Treatment Workgroup, with jurisdictional membership, established protocols for filling in data where missing that use the best judgement of experts to equitably portray on-the-ground conditions and how they changed through time.

- Facilities have been added to the point source database over the years either because they physically went on-line, or because they were previously untracked. In addition, facilities have been turned inactive in the wastewater database over time because they went off-line or combined with other facilities as new plants.

- Protocols of calculating discharges from measured or estimated flows and effluent concentrations have been adjusted throughout the data record to better reflect actual end-of-pipe loads.

Agriculture, Developed and Septic, Air:

- Although the reported BMP record goes back to 1985, jurisdictions are expected to improve the quality of the data during development of each phase of the Watershed Model. For Phase 6, guidelines were developed so that the re-reported historic BMP implementation record is logical and better represents what likely occurred on-the-ground through time, especially where and when tracked data is missing or illogical.

- For some BMPs and some jurisdictions, implementation levels reported for annual model assessments have increased or decreased significantly over the data record, not necessarily because of on-the-ground implementation, but because of the establishment of or changes to tracking mechanisms or because of new or revised resource assessments.

- Adjustments to BMP effectiveness and the methods of crediting BMP implementation have occurred over the period of the data record to better reflect conditions. There is an ongoing review program of BMP effectiveness by expert panels to establish the effectiveness of BMPs that have not historically been reported – as well as a fresh look at BMPs that are currently accounted for in the modeling tools. Once recommendations of expert panels have been approved through CBP workgroups and Goal Implementation Teams, they are introduced in the model simulation appropriately.

- Changes to data processing procedures by jurisdictions that report BMPs are documented in their Quality Assurance Project Plans.

- Changes to data processing procedures and databases used within the environmental tools such as the Watershed Model (CAST) are reviewed and approved through the relevant Bay Program source workgroup and Watershed Technical Workgroup.

(33) If data sets from two or more sources have been merged, are the sampling designs, methods and results comparable? If not, what are the limitations?

Wastewater:

Data sets from more than one source of wastewater information are typically merged at the relevant jurisdictional agency to accommodate different types of point sources, municipal and industrial, significant and non-significant. Data sets from seven jurisdictions, in turn, are merged at the Chesapeake Bay Program office. Continual peer-review of the thoroughness of discharge data and methods of managing the information by the Wastewater Treatment Workgroup promotes consistency and completeness of calculated end-of-pipe loads among the jurisdictions.

Agriculture, Developed and Septic, Air:

The means of collecting BMP data and methods for analyzing the information vary among jurisdictions depending on the sophistication of their tracking mechanisms and resources devoted to managing the data. Data sets from several sources can be merged. The procedures for managing the data and the quality of the results of the methods are described in each jurisdiction's BMP Verification Program Plan published through the CBP site: https://www.chesapeakebay.net/what/programs/bmp_introduction_to_bmp_verification/bmp_additional_resources. These are EPA-approved Quality Assurance Project Plans that are part of the Partnership's verification program. All elements of the Bay Program framework for BMP verification are documented at: https://www.chesapeakebay.net/what/programs/bmp_introduction_to_bmp_verification

The BMP data from the seven Bay Program jurisdictions are merged at the Chesapeake Bay Program office through NEIEN (National Environmental Information Exchange Network), a repository of BMP data covering hundreds of BMP types reported at many spatial scales and time periods across all sectors.

Continual peer-review of the BMP data and methods of applying the data by the Water Quality Goal Implementation Team workgroups promotes consistency and completeness among the jurisdictions. To improve uniformity in reporting BMPs among jurisdictions, summary and detailed information about the practices and reporting criteria are accessible through the CAST documentation and resources at https://cast.chesapeakebay.net/

(34) Are levels of uncertainty available for the indicator and/or the underlying data set? If so, do the uncertainty and variability impact the conclusions drawn from the data or the utility of the indicator?

No. Significant uncertainty and variability could be traced. Causes of the uncertainty and variability could be documented to limit its impact on the conclusion.

The CBP Phase 6 Watershed Model (CAST), employed to integrate wastewater technology controls and a large array of BMPs to reduce pollution from other sources, is best utilized when making comparisons among scenarios. For the indicators "Modeled [Nitrogen, Phosphorus, and Sediment] Loads to the Chesapeake Bay (1985-2025), these comparisons are among 1985, the 2009 Bay TMDL starting point, the yearly model assessments of loads, the target loads for the annual assessments, and the Phase 3 WIP planning targets.

By presenting trends and the status at the large scale of the 64,000 square-mile watershed over a 30+-year period, yearly changes in data tracking mechanisms by particular jurisdictions and localities and changes in methods of data analysis for particular wastewater plants and BMPs are somewhat masked.

The indicator is designed 1) to depict, generally, the degree of progress over the long term toward the implementation goals and 2) to clearly identify pollutant sources where gaps are large and to what extent. The environmental indicator connects efforts (pollutant controls) with results (loading reductions and subsequently, water quality and habitat health).

(35) For chemical data reporting: How are data below the MDL reported (i.e., reported as 0, censored, or as < MDL)? If parameter substitutions are made (e.g., using orthophosphate instead of total phosphorus), how are data normalized? How does this impact the indicator? N/A

(36) Are there noteworthy limitations or gaps in the data record? N/A

H. Additional Information (*Optional)*

(37) Please provide any further information you believe is necessary to aid in communication and prevent any potential misrepresentation of this indicator.

Modeled Load Sources

Loads to Bay were simulated using the CBP Phase 6 Watershed Model (CAST). In addition to the load sources of agriculture, developed, wastewater, septic, and natural, atmospheric deposition is an explicitly modeled source of nitrogen. Atmospheric deposition is simulated using the Chesapeake Bay Airshed Model (a combination of a regression model of wet deposition and a continental-scale air quality model of North America called the CMAQ for estimates of dry deposition). For information about the data and simulation of this source of nitrogen to the land and estuary, see the model documentation at https://cast.chesapeakebay.net/Documentation/ModelDocumentation under the heading "Terrestrial Inputs".

For tracking toward the TMDL, each model scenario incorporates atmospheric deposition of nitrogen to all land and water surfaces in the Chesapeake Bay watershed, including direct deposition to the estuary. This flux of nitrogen varies spatially but remains the same among scenarios for TMDL-related tracking toward goals – at forecasted levels estimating the benefits of emissions controls due to, for example, the Clean Air Act.

Atmospheric deposition to the watershed, that is EPA's responsibility to reduce under the federal Clean Air Act, is calculated by subtracting watershed loads for the progress year assuming that existing requirements under the Clean Air Act are fully implemented (known as "allocation air") from watershed loads with the actual atmospheric deposition that occurred in the progress year.

Urban Runoff and Septic loads typically increase with development unless offset by BMPs due to growth in impervious surfaces, turf, the number of septic systems, and their associated loads.

Forest loads will increase due to buffer and tree plantings, but this change lowers total loads since less pollution comes from an acre of forest than from agricultural or urban lands.

Model Peer Review

Data and methods used in the CBP Phase 6 Watershed Model (CAST) as well as the simulation itself and loading outputs are continually under external and internal review. Internal review mostly involves the CBP Water Quality Goal Implementation Team and its workgroups; the Modeling Workgroup within the Scientific, Technical Assessment and Reporting (STAR) Team; and special task groups established particularly for peer review. Scopes and purposes of these groups and their extensive considerations of the Watershed Model as a planning tool can be found at: http://www.chesapeakebay.net/groups/group/modeling_team.

An external panel assembled by the Scientific and Technical Advisory Committee (STAC) reviewed the Bay Program's Phase 6 Watershed Model (CAST) was completed in September, 2017 and can be found at: http://www.chesapeake.org/pubs/379_Easton2017.pdf Another more-specific STAC review titled, "Review of Nutrient Input Estimation for the Chesapeake Bay Watershed Model" is published at https://www.chesapeake.org/stac/document-library/scientific-and-technical-advisory-committee-review-of-nutrient-input-estimation-for-the-chesapeake-bay-watershed-model/

Understanding what the panels were investigating and the findings of STAC's reports can provide a sense of the quality of the information in the indicator. The larger STAC panel addressed the following review questions:

1) Please comment on the overall appropriateness of the approach taken in the Phase 6 structure of a deterministic hydrology and sediment transport management model combined with a nutrient model informed by multiple models and multiple lines of evidence. Please comment on the multiple model structure of the Phase 6 nutrient simulation particularly to its utility to watershed management in the Chesapeake restoration? How can the Phase 6 multiple model approach be improved going forward?

2) Please comment on the scientific rigor of the methods used for the average nutrient export rates.

3) How justified are the sensitivities of nutrient export from land uses to nutrient inputs, given the approach used and data available? Do the sensitivities to nutrient inputs derived from multiple models reflect our best understanding of the current condition of nutrient load processing and attenuation on the landscape? Is there any additional scientific information that should be included?

4) Please comment on the scientific rigor of the methods used in the use of Spatially Referenced Regression On Watersheds (SPARROW) for land to water factors. Are they reasonably implemented? Is there any additional scientific information that should be included?

5) Please comment on the overall appropriateness of the methods used in the application of multiple methods to estimate stream-to-river factors for nutrients? Is there additional scientific information that should be included?

6) Please comment on the scientific appropriateness of the approach taken for Phase 6 lag times given the current state of information and understanding of groundwater and particulate processes. How can the structure and processes of nutrient lag time simulation on the land be improved in Phase 6 or future watershed model applications? Is the application of the Ranked Storage Selection (rSAS) function for groundwater nitrate and Unit Nutrient Export Curves (UNEC) for all other nutrient species appropriate for the management questions?

7) Please comment on the scientific rigor of the methods used in the Phase 6 sediment simulation components using a detailed Revised Universal Soil Loss Equation 2 (RUSLE2), an interconnectivity metric, and the inclusion of sediment source/sink estimates from stream banks and flood plains.

8) Given the fine scale 1m x 1m land use data that's used in Phase 6, what opportunities does this open to the CBP and scientific community in the next phase of watershed model development? What are the advantages in a distributed representation of hydrology, land cover, and sediment? Given the availability of nutrient inputs from Agricultural Censes at the county scale only, does a higher resolution of the watershed model make sense?

9) Better simulation of the deposition and scour processes in the reservoir reach of the Lower Susquehanna is an important feature of the Phase 6 Model. It is crucial to 2017 Midpoint Assessment decision making to be able to represent the net deposition of sediment, nitrogen, and phosphorus in this reach of the Susquehanna as fully as possible. Does the Phase 6 representation of the dynamics of the reservoir system rely on the best science available at this time? Do the simulations approximately represent

the observed changes in storage of sediment, nitrogen and phosphorus as seen in the historical record from the last few decades? How can the representation of Conowingo infill be improved going forward beyond the Phase 6 Model?

10) Please comment on the scientific appropriateness of the methods used in the representation of climate change in watershed nutrient and sediment loads estimated for the 2025 and 2050 time periods.

11) For longer term CBP considerations, how can the overall approaches and procedures used in Phase 6 be improved and what alternative approaches and data gathering might you recommend?

12) Please comment on the Phase 6 documentation. Is it clear, well organized, concise, and complete (taking into account that it is the third Beta out of an expected four Beta versions and about six months ahead of final release)?