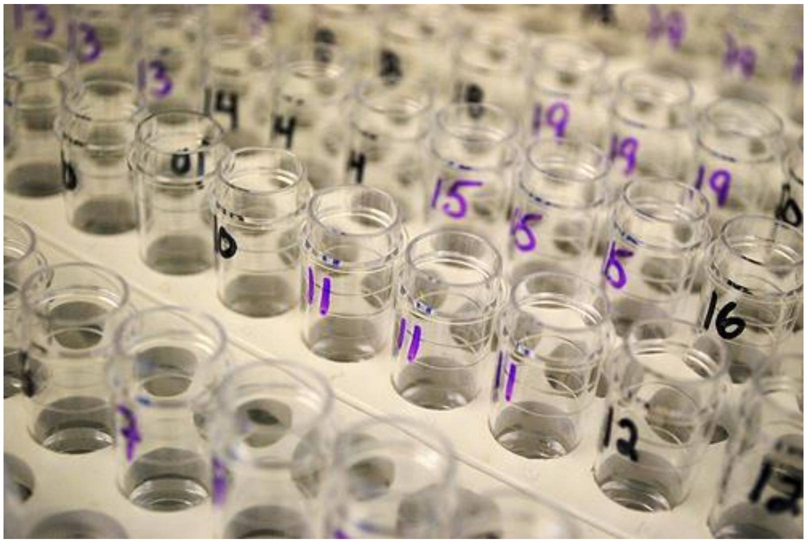
Toxics Contaminants Research Outcome

Management Strategy

2015–2025, v.2



I. Introduction

The Chesapeake Bay Agreement has a goal to ensure that the Bay and its rivers are free of effects of toxic contaminants on living resources and human health. The two associated outcomes are (1) research and (2) policy and prevention. The strategy for the research outcome will improve information about the occurrence, concentrations, sources and effects of toxic contaminants on fish and wildlife. The findings will be used by the Chesapeake Bay Program (CBP) Toxic Contaminant Workgroup (TCW) and Water-Quality Goal Implementation Team (WQ GIT) to consider policy and prevention approaches to reduce the effects of contaminants on living resources in the Bay watershed and make them safer for human consumption. The issues being addressed in the research strategy have been updated in 2020 to be:

- Synthesize information to make fish and shellfish safer for human consumption;
- Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife;
- Document the sources, occurrence, and transport contaminants in different landscape settings.
- Provide science to help mitigate contaminants and emphasize the co-benefits with nutrients and sediment reductions; and
- Gather information on issues of emerging concern.

II. Goal, Outcome and Baseline

This management strategy identifies approaches for achieving the following goal and outcome:

Toxic Contaminants Goal

Ensure that the Bay and its rivers are free of effects of toxic contaminants on living resources and human health.

Research Outcome

Continually increase our understanding of the impacts and mitigation options for toxic contaminants. Develop a research agenda and further characterize the occurrence, concentrations, sources and effects of mercury, polychlorinated biphenyls (PCBs) and other contaminants of emerging and widespread concern. In addition, identify which best management practices might provide multiple benefits of reducing nutrient and sediment pollution as well as toxic contaminants in waterways.

Baseline and Current Condition

The TCW originally worked with stakeholders in 2015 to identify the five priority issues to be addressed for this strategy. Aspects of these issues were updated during CBP review process in 2018 and issues remained the same in the 2020 update. They include:

- Synthesize information to make fish and shellfish safer for human consumption.
- Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife.
- Document the sources, occurrence, and transport of contaminants in different landscape settings.
- Provide science to help mitigate contaminants and emphasize the co-benefits with nutrients and sediment reductions.
- Gather information on issues of emerging concern.

The baseline information for different contaminant groups being addressed by these issues originally came from the report "Extent and Severity of Toxic Contaminants in the Chesapeake Bay Watershed" (Chesapeake Bay Program, 2013), and are summarized in table 1. A qualitative assessment of the baseline understanding for the sources, occurrence, and effects for these contaminant groups was prepared by the TCW for the original strategy (figure 1). The contaminant groups with the greatest uncertainty are the primary emphasis of the research efforts; however, the remaining science needs related to PCBs and mercury are included in the strategy.

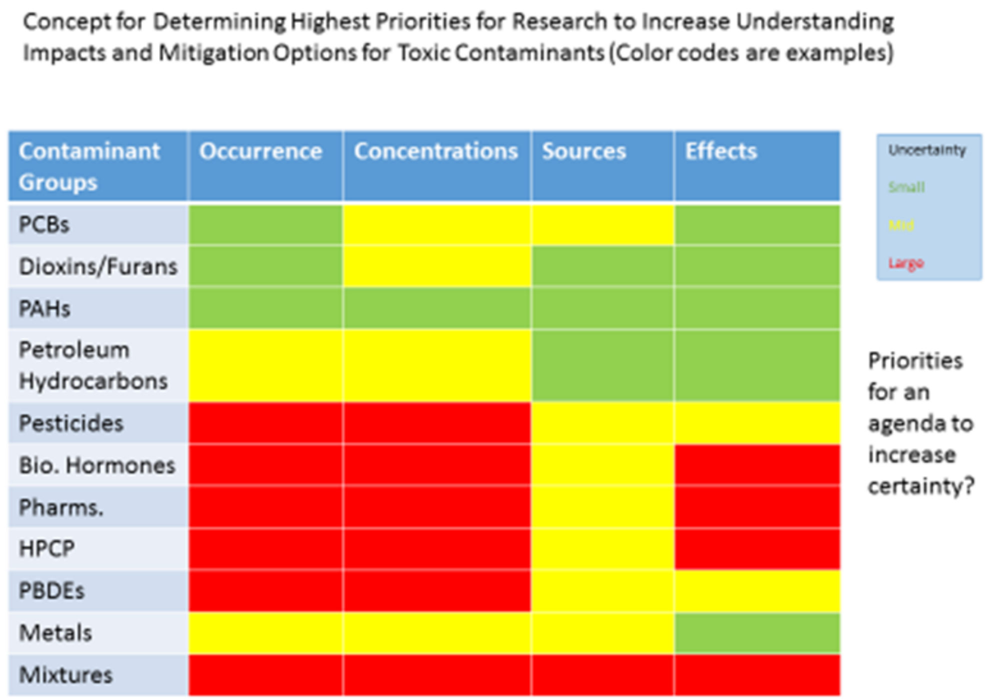


Figure 1: Level of uncertainty for ten contaminant groups about the occurrence, concentrations, sources, and effects on fish and wildlife. (Contaminants with the largest uncertainty are the primary focus on the research strategy, but gaps in PCB science area also included.)

Issue: Synthesize information to make fish and shellfish safer for human consumption.

PCBs and mercury are the primary causes of fish consumption advisories that have been issued in the Chesapeake Bay and its watershed. PCBs are suspected human carcinogens whereas methyl mercury (the dominant and toxic form of mercury that accumulates in fish) is known to cause impaired neurological development. In addition, these pollutants have adverse ecological impacts. The sources of these pollutants to fish and wildlife can be a combination of exposure to legacy deposits in sediments, ongoing inputs to the watershed from secondary sources that are highly site specific (e.g., PCB contaminated terrestrial sites, previously contaminated stormwater pipes), and ongoing releases (e.g., wastewater and stormwater releases, and atmospheric deposition, especially for mercury). Given these concerns, PCBs were the focus on the initial management strategy for Toxic Contaminant Policy and Prevention. Despite progress, there are still some science needs related to PCBs required to improve their management. Those science needs are included in this Research Strategy and associated Logic and Action plan. This is a change from the previous strategy, where these science needs were included in the Policy and Prevention strategy.

Current conditions highlight that fish consumption advisories continue to be widespread across the watershed, largely due to PCBs, mercury, and to a lesser extent organochlorine pesticide. Visualizing the impairments and associated management plans is an effective way to communicate and impacts across the watershed in the absence of watershed-wide TMDLs for these compounds. The impairments for both mercury and PCBs are shown below (figure 2) and the story maps are available for mercury https://gis.chesapeakebay.net/mercury/, and for PCBs http://chesbay.maps.arcgis.com/apps/MapSeries/index.html?appid=704ecbbb9f5943eca87d59b349edf1ab. Most emerging contaminants do not have thresholds to identify impaired waters or set fish consumption advisories. Therefore, the extent of impacts to waterways due to contaminants are likely more extensive than shown on the story maps.

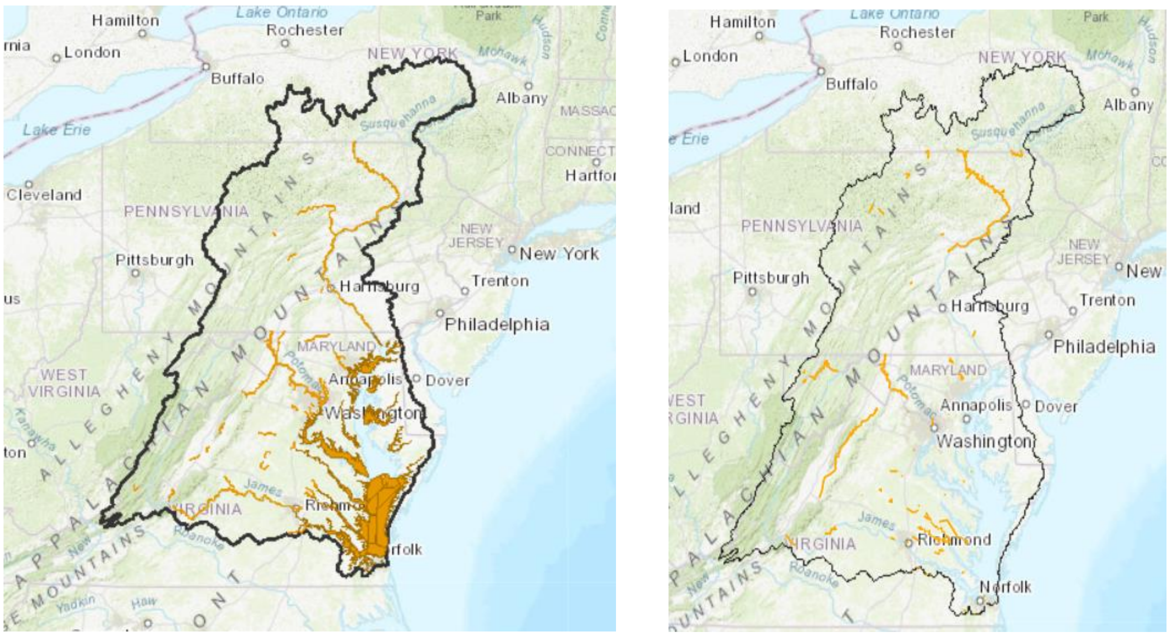


Figure 2. 2017 Impairments for PCBs (left) and mercury (right).

For mercury reductions in fish and shellfish, the jurisdictions in the Bay watershed are depending on national air emission controls and less use of coal for energy production, which should result in less mercury being deposited in the Chesapeake watershed. As part of the revised management strategy, efforts will be made to improve the understanding of baseline conditions by compiling information on the extent of mercury impairments across the watershed. The jurisdictions will also work through the TCW to inventory data and assess if information exists to document changes in mercury in response to air controls. The results will be used to help jurisdictions consider if additional efforts are needed to reduce the impacts of mercury.

The findings from a USGS study showed that mercury concentrations in fish were widespread but variable among across areas and among species within the freshwater portions of the watershed (see figure below), (Willacker and others, 2020; https://doi.org/10.1007/s10646-020-02193-5). Some highlights include:

- Mean concentrations of mercury in all fish species was 0.22 micrograms per gram, with a range that spanned four orders of magnitude.

- For individual fish species residing in the freshwater portion of the watershed, the highest concentrations of mercury were found in: Striped Bass (landlocked individuals not migratory estuarine individuals), Bowfin, Walleye, Largemouth Bass, Flathead Catfish, and Smallmouth Bass. The lowest concentrations were found in several trout species (including Brook Trout) and the Creek Chub. (see figure below from Willacker and others, 2020)
- Mean concentrations of mercury were highest in the Susquehanna watershed followed by the Potomac watershed and Coastal drainages, with lowest average concentrations in the York, Rappahannock and James watersheds.
- Forty-five, 48, and 35 percent of fish mercury concentrations in the present study exceeded benchmarks for human, avian piscivore, and fish health risks, respectively

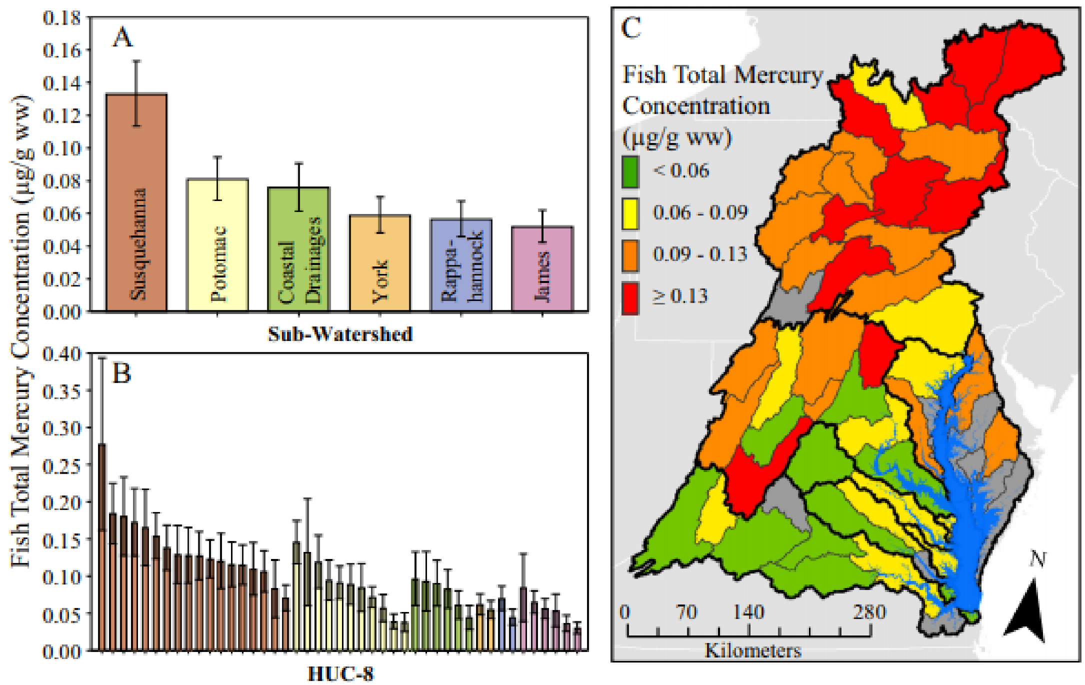


Fig. 3 Least-squares mean fillet total mercury (THg) concentrations wet weight) in fish sampled from freshwater habitats of the Chesapeake Bay Watershed. **a** Least-square mean fillet THg concentrations (±standard error) in the major sub-watersheds of the Chesapeake Bay Watershed accounting for the effects of species, hydrologic unit (8-digit HUC; nested within sub-watershed), and year. **b** Least-square mean fillet THg concentrations (±standard error) in HUCs comprising each major sub-watershed accounting for the effects of species, location within HUCs, and year. Bar colors correspond to major sub-watersheds in **a**. **c** Map of least-squares mean fillet THg concentrations by HUC accounting for the effects of species, location within HUCs, and year. Gray HUCs lacked sufficient data to estimate mercury concentrations. Heavy black lines delineate major sub-watersheds of the Chesapeake Bay Watershed

Figure 3. Results of mercury assessment (modified from Willacker and others, 2020).

There is a much broader set of issues related to the effects of toxic contaminants on human health. However, these issues are beyond the scope of the Chesapeake Bay Watershed Agreement, so they are not included in this Toxic Contaminants Research Management Strategy. Many of the human health issues, such as occupational exposure or exposure in residential setting (i.e., lead paint), are being addressed by other government agencies and research organizations and may be incorporated in future efforts if needed to meet the outcome.

Issue: Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife

There are numerous indications of reduced general and reproductive health of fish populations throughout the watershed. Research findings to date strongly suggest the influence of toxic contaminants. Observed conditions include widespread occurrence of intersex and other gonadal abnormalities, reduced reproductive success of semi-anadromous fishes, occurrence of skin and liver tumors, skin lesions, high parasite loads and opportunistic infectious disease. The impact of endocrine-disrupting chemicals (EDCs) on reproductive systems of fish and wildlife has been documented by the U.S. Geological Survey (USGS), the U.S. Fish and Wildlife Service (FWS), and the National Oceanographic and Atmospheric Administration (NOAA). Chemical contaminants, including legacy and chemicals of emerging concern (CECs), particularly EDCs have had effects on fish (reproductive systems in several species) and selected waterbirds in the Bay ecosystem.

Toxic contaminants may also contribute to fish and wildlife kills, in addition to degrading health, in the Bay and its watershed. Kills are generally defined as large numbers of fish or wildlife dying within a relatively short period of time. Some of the known fish and wildlife kills and their causes include:

- Acute kills of fish and wildlife due to hydrocarbon spills.
- Localized kills have been linked to a sequence of events resulting in algal blooms and die-off of the algae depleting available oxygen.
- Algal blooms of toxin-producing species have occurred in several years at Poplar Island, resulting in the deaths of hundreds of waterbirds. These are linked to Microcystis and possibly with avian botulism.
- Fish kills in the Chesapeake Bay watershed have also been associated with one or more pathogens and disease.

Fish kills have been associated with multiple potential causes, such as pathogens, parasites, disease, and contaminants. Kills of adult bass and sunfish in the Potomac basin and young-of-the-year smallmouth bass in the Susquehanna basin have occurred in multiple years and multiple sub-watersheds. These observations together with the concurrent observations of intersex and other indicators of contaminant exposure suggest multiple causes contribute to fish mortality and poor health. Findings also suggest that toxic contaminants can influence immunosuppression and making the fish more vulnerable to other factors.

Studies since 2015 continue to suggest that multiple factors affect fish health and mortality. For example, recent studies (2017-18) in the Susquehanna basin identified disease as an important factor leading to fish health problems and mortality. These studies reveal the difficulties in identifying individual stressors or factors, and relating individual contaminants, to causes of degraded fish health and/or morality.

Finally, the appearance of estrogenic hormones, UV filters, and antibiotics in the environment has drawn increasing attention due to potential impacts on human and ecological health. Potential sources of estrogenic hormones and antibiotics include wastewater treatment effluents and animal feeding operations. Ongoing studies by UMBC in the Chesapeake Bay mainstem are examining the occurrence of these toxic compounds in the eastern oyster (Crassostrea virginica), and hooked mussel (Ischadium recurvum). Previous results highlight the ubiquitous bioaccumulation of CECs in aquatic and marine invertebrates.

More recently, the TCW worked with STAC to have a workshop in May 2019 on *Integrating Science and Developing Approaches to Inform Management for Contaminants of Concern in Agricultural and Urban Settings* (hereafter STAC workshop). The workshop included participants from the Bay watershed but also had speakers from other important ecosystems around the Nation. The workshop and associated report summarized some key findings about fish health in urban and agricultural areas. (Majcher and others, 2020; https://www.chesapeake.org/stac/document-library/integrating-science-and-developing-approaches-to-inform-management-for-contaminants-of-concern-in-agricultural-and-urban-settings/).

In urban areas, fish exhibited abnormal tissue growth and reduced reproductive success. Bullhead catfish in the tidal Potomac had liver tumors, with the prevalence in Anacostia some of the highest in N. America and were attributed to contaminants such as PAHs and PCBs (Pinkney and others, 2019: https://www.chesapeakebay.net/channel_files/27647/bullhead_fact_sheet_2018.pdf). The findings did reveal that a monitoring of this species can detect changes in tumors over time and this monitoring will continue in the Anacostia watershed. The reduced reproductive success of yellow perch, which is believed related to combined exposures to legacy (e.g., PCBs) and emerging contaminants, was observed with increased urbanization (Blazer and others, 2013) and is the focus of ongoing work.

In agricultural settings, there have been fish kills and a variety of indicators for poor fish health including low chronic mortality, skin lesions, and reproductive endocrine disruption**.** We learned there is no one culprit for these conditions but exposure to contaminants make the populations more susceptible to infectious agents, parasites, virus, and bacteria.

A study of UV filters, hormones, antibiotics in 14 sites along the eastern shore of the Chesapeake Bay showed ubiquitous presence of UV filters in water, sediment and oyster tissue and long-range transport of contaminants of emerging concern (He and others, 2019; https://www.sciencedirect.com/science/article/pii/S0048969718338944?via%3Dihub). The study demonstrated bioaccumulation of UV filters in oysters and suggests the need for improved CEC removal during municipal wastewater treatment and agricultural waste management within the Chesapeake Bay watershed (He and others, 2019).

The role of contaminants in the health of numerous wildlife species, including birds, amphibians and reptiles in the Chesapeake Bay watershed is not as well documented. Results from the 2013 federal report (Chesapeake Bay Program, 2013) reveal the indications of responses to contaminant exposure have also been found among wildlife in the Chesapeake Bay watershed, primarily wild birds. In a few locations, eggshell thinning associated with p,p'-DDE is apparent, and reproduction may be impaired. In some cases, organochlorine pesticides are found in eggs of predatory birds at concentrations associated with embryo lethality. Several studies are cited in which PCB concentrations in addled bald eagle eggs may have been high enough to contribute to the failure to hatch. Detectable concentrations of PBDEs have been found in eggs of predatory birds that approach the lowest-observed-adverse-effect level for pipping and hatching success. A summary of wildlife issues and toxic contaminants (conducted in 2016) found there was still very limited information to assess effects on wildlife. State wildlife agencies do not regularly participate in the workgroup, and the workgroup didn't establish connection with them during the past cycle; therefore, little progress on this issue can be reported.

Issue: Document the sources, occurrence, and transport of contaminants in different landscape settings

The extent, severity, and sources of ten groups of toxic contaminants in the Bay watershed was previously summarized from existing information (Chesapeake Bay Program, 2013) and are listed in Table 1. Contaminant groups, including PCBs, mercury, polycyclic aromatic hydrocarbons (PAHs), and some pesticides have widespread extent, while the remainder of the groups had localized extent. The findings for severity were based on impairments developed by watershed jurisdictions, which rely on the monitoring of select contaminants in water, sediment and fish tissue. Impairments included human health concerns (e.g., fish consumption advisory), or potential harm to aquatic organisms. During the past two years, there have been studies on sources and occurrence of EDCs, mostly related to pharmaceuticals, pesticides, and biogenic hormones in agricultural areas. These findings will be available in 2021 and improve the certainty for these contaminant groups (figure 1). This issue has evolved to focus more on specific landscape settings that are the primary sources of contaminants: urban (stormwater and WWTPs) and agricultural areas. There will be emphasis on defining the co-occurrence with nutrients and sediment to help take advantage of CBP efforts to improve water quality.

Table 1: Extent and Severity of Contaminant Groups (from Chesapeake Bay Program, 2013)

Contaminant Group	Extent, Severity, and Sources
Polychlorinated biphenyls (PCBs)	PCBs have widespread extent and severity. The severity was based on risk to human health through consumption of contaminated fish with impairments identified in all of the watershed jurisdictions. Some primary sources are contaminated soils, leaks from transformers, and atmospheric deposition.
Mercury	Mercury had both widespread extent and severity. The severity was based on risk to human health through consumption of contaminated fish. The primary source is air emissions from coal-fired power plants.
Polycyclic aromatic hydrocarbons (PAHs)	Widespread extent throughout the Bay watershed. The severity was localized based on impairments for risk to aquatic organisms in a limited number of areas in the watershed. The primary sources are contaminated soils, coal tar sealants, atmospheric deposition, and combustion.
Pesticides	Widespread extent of selected herbicides (primarily atrazine, simazine, metochlor, and their degradation products) and localized extent for some chlorinated insecticides (aldrin, chlordane, dieldrin, DDT/DDE, heptachlor epoxide, mirex). The chlorinated insecticides have localized severity based on risk to aquatic organisms. For many pesticides that had widespread occurrence, water-quality standards were not available to determine impairments. Research shows sublethal effects for some compounds at environmentally relevant concentrations. Primary sources are applications on agricultural and urban lands and legacy residue in soils.
Petroleum hydrocarbons	Localized extent and severity (to aquatic organisms) in a limited number of areas in the watershed.
Dioxins and Furans	Localized extent and severity (to aquatic organisms) in a limited number of areas in the watershed. The primary sources are spills, contaminated soils, and atmospheric deposition.
Metals and Metalloids	Localized extent and severity (to aquatic organisms) of some metals (aluminum, chromium, iron, lead, manganese, zinc) in a limited number of areas in the watershed. The primary sources are spills, industrial processes, and atmospheric deposition.
Pharmaceuticals, Household and Personal Care Products, Flame Retardants, Biogenic Hormones	Information was not adequate to determine extent or severity. However, their use in the watershed suggests widespread extent is possible. Severity was not accessed but research shows sublethal effects to selected aquatic organisms for some compounds at environmentally relevant concentrations. Range of sources from wastewater treatment and septic tanks to animal feeding

Contaminant Group	Extent, Severity, and Sources
	operations. Biogenic hormones assessment was focused on naturally occurring compounds from human or animals.

For urban areas, the STAC workshop and report concluded that the fate and transport of contaminants with suspected fish health effects and their transformation products are largely unknown in urban areas, including degradation characteristics and partitioning (water, sediment preference) of these contaminants under different environmental conditions. For contaminants with known and unknown fish health effects, sources of the contaminants that are the primary risk drivers are largely unknown making selection of appropriate management actions difficult.

For agricultural areas, the sources of contaminants are relatively well defined but detailed information on many CECs is currently limited**.** Primary sources include pesticide use, manure storage/application, biosolid application, irrigation treated wastewater, and septic systems.

The USGS project to assess endocrine-disrupting compounds (EDCs) also provided results on the occurrence of contaminants in the watershed. A paper by McClure and others (2020; link https://www.sciencedirect.com/science/article/pii/S0048969720322828?via%3Dihub) looked for patterns of 28 compounds and estrogenicity in an attempt to better understand the spatiotemporal dynamics of contaminants in surface water. Study highlights include:

- Highest probabilities of occurrence were in the spring and summer months.
- Occurrence of most compounds not strongly linked to stream flow or land use.
- Atrazine, simazine, fipronil and metolachlor co-occurred most often across sites.

Issue: Provide science to help mitigate contaminants and emphasize the co-benefits with nutrients and sediment reductions.

This issue was included in the previous revision to the Research Strategy to provide a scientific basis to help identify and prioritize options for mitigation instead of developing approaches based on the relative risk of different contaminant groups. It was envisioned that this would provide a more streamlined approach for decision makers to develop options for reducing the impacts of contaminants in settings where they are most prevalent and take advantage of nutrient and sediment reductions efforts already underway.

The STAC workshop and report highlighted successful case studies of BMP use for legacy and emerging contaminants in different landscape settings. While studies were limited, examples in both landscape settings were provided. Specifically, in agricultural areas, several BMPs appeared promising, including:

- Adding activated carbon or biochar to established BMPs effectively reduces contaminant transport.
- Retention ponds and vegetative treatment are shown to reduce pesticide loading.
- Finally, manure management (including composting, subsurface application) and buffer strips, were shown to reduce antibiotics.

Likewise, in urban areas, there were several examples at the workshop of studies demonstrating effective management. These included:

- Sediment capture and reactive filter BMPs reduce concentration and toxicity related to urban stormwater runoff.
- Iron-enhanced sand filtration reduces concentrations of pesticides and wastewater indicators.
- In stream innovative treatment using activated carbon with and without bioamendments immobilizes and degrades PCBs.

Issue: Gather information on issues of emerging concern

In the past, issues of emerging concern included contaminant toxicity to pollinators (including neonicotinoids), microplastics, and unconventional oil and gas drilling (known as "fracking"). More recently, additional issues were identified for heightened focus including harmful algal blooms (HABs) and their associated toxins; the potential effects of poly- and perflouroalkyls (PFAS), reducing the effects of road salts, and runoff from coal combustion residual storage facilities and fly ash. Some information was gathered on these topics and they were further prioritized for further exploration.

HABs: Cyanobacterial harmful algal blooms (cyanoHABs) are increasingly a global concern. CyanoHABs can threaten human and aquatic ecosystem health; they can cause major economic damage. The toxins produced by some species of cyanobacteria (called cyanotoxins) cause acute and chronic illnesses in humans. Harmful algal blooms can adversely affect aquatic ecosystem health, both directly through the presence of these toxins and indirectly through the low dissolved oxygen concentrations and changes in aquatic food webs caused by an overabundance of cyanobacteria. USGS scientists are leading a diverse range of studies to address cyanoHAB issues in water bodies throughout the United States, using a combination of traditional methods and emerging technologies in collaboration with numerous partners. However, despite advances in scientific understanding of cyanobacteria and associated compounds, many questions remain unanswered about the occurrence, the environmental triggers for toxicity, and the ability to predict the timing and toxicity of cyanoHABs. (https://www.usgs.gov/news/science-harmful-algae-blooms).

PFAS: PFAS compounds have been manufactured and used in a variety of industries in the United States since the 1940s. Some of the major compounds in this group (e.g., PFOA and PFOS) are no longer produced or in use in the United States; however, they are used internationally and can be introduced to the environment through imported products. These compounds are persistent in the environment and have been shown to have adverse health effects. Recently, New Jersey issued fish consumption guidelines for PFAS compounds (https://www.nj.gov/dep/dsr/). Another primary source of human exposure is drinking water. Little is known about PFAS in the Chesapeake Bay, but due to its wide use in many consumer (food packaging, non-stick cookware, fabric softeners) as well as industrial products (firefighting foams), there is the possibility for widespread extent in surface water.

Chloride from Road Salt: Road salts, when applied in large amounts to reduce ice and snow, affect the quality of streams mainly due to chloride loading. The State of Maryland is working with the State Highway Administration to identify strategies that may reduce impacts to streams without compromising public safety. Further, Maryland is considering a TMDL for chloride to help reduce the impacts of road salts on stream health. Virginia has developed a chloride TMDL for the Accotink Creek watershed. As part of implementing that TMDL and proactively addressing chloride loads throughout Northern Virginia, Virginia is developing a Salt Management Plan that will provide recommendations for best practices, education and outreach, salt tracking and reporting, and monitoring and research.

Coal Ash: Coal combustion residuals (CCRs or fly ash) and their associated storage sites are a large concern due to the potential negative impacts from metals leaching from sites into nearby waters. Several CCR storage sites are located along the rivers in the Potomac and Susquehanna River basins. There are potential beneficial reuses of the CCR material in cement production as an alternative to these riverside disposal sites. More information on current efforts by MD to minimize fly ash disposal in these storage sites is described in the next section.

III. Participating Partners

The following partners participated in the revision of this strategy. A workplan with more details on actions for each partner during for 2018-19 has also been prepared.

Chesapeake Bay Watershed Agreement Signatories

- Maryland Department of the Environment
- Maryland Department of Natural Resources
- Virginia Department of Environmental Quality
- DC Department of the Environment
- Pennsylvania Department of Environmental Protection
- Delaware Department of Natural Resources and Environmental Control
- New York Department of Environmental Conservation
- West Virginia Department of Environmental Protection
- Chesapeake Bay Commission (CBC)
- U.S. Environmental Protection Agency
- U.S. Geological Survey
- U.S. Fish and Wildlife Service
- National Oceanic and Atmospheric Administration

Other Key Participants

- Non-Governmental Organizations
  - Bluewater Baltimore
  - Metropolitan Washington Council of Governments
  - MD Pesticide Network
- Private sector organizations
- University of Maryland, Baltimore County
- Virginia Polytechnic Institute and State University
- Virginia Institute of Marine Science
- CBP Local Government Advisory Committee
- CBP Water Quality Goal Implementation Team Workgroups
- Baltimore Urban Waters Partnership Actionable Science Workgroup

Local Engagement

Most of the actions to plan and complete the actual research are expected to be the responsibility of federal, state and academic entities. In the original strategy, local governments and NGOs were helpful in identifying priorities. In the revised strategy we want to increase communication of science results in order to guide an integrated approach to addressing nutrient and sediment reduction (required under the Bay TMDL) with the potential benefits of concurrent reductions in toxic contaminants. Increasing the awareness of the impacts of toxic contaminants, especially safe consumption of fish and shellfish, will be carried out with local governments and non-governmental organizations. Efforts will be targeted towards areas with diverse and underrepresented populations in the Bay watershed.

IV. Factors Influencing Success

The revised factors for the strategy include:

Understanding and defining sources of contamination leading to fish consumption advisories

Fish consumption advisories are established by the states, based on human health risks from different contaminants. There are resource constraints to collect and analyze fish and associated samples every year to assess attainment of standards and to quantify explicit reductions from targeted management actions.

Multiple factors affecting the health and mortality of fish and wildlife

Studies suggest there are multiple contaminants and additional factors are causing the degradation (and mortality) of fish and wildlife. Therefore, trying to identify specific causes is extremely difficult and complicates developing management options. Lack of interaction with wildlife management agencies limits addressing impacts beyond fisheries.

Lack of data on the occurrence and trends of contaminants

There is no watershed-wide monitoring program on the condition of fish and wildlife that is integrated with water and sediment sampling. There is a lack of consistent information (both spatial and temporal) on the occurrence and concentrations of toxic contaminants. Some of this is due to the high cost of generating new data on toxic contaminants. Additionally, there are few laboratories that have the capabilities to conduct analysis for all the contaminant groups. This limits the ability to understand the extent of contaminants in the watershed and their relation to fish and wildlife.

Limited information of the practices to mitigate contaminants, and their potential co-benefits with nutrients and sediment reductions

More information on the effectiveness of practices to reduce selected contaminants will be needed to take advantage of CBP water-quality models and tools, which are currently focused on nutrients and sediment.

Emerging issues

There is limited knowledge and capacity to assess the state of the science for the numerous emerging issues, their occurrence in the watershed, and the implications (e.g., toxicity effects) of individual emerging issues.

Resource constraints

The ability to improve the understanding of contaminants is constrained by limited resources. The constraints include (1) minimal capacity within the CBP to address contaminants; (2) an emphasis on nutrients and sediment that limits the opportunity for increased CBP focus on toxic contaminants; and (3) minimal funding opportunities to conduct additional studies.

Synthesis

Limited capacity of resource managers and stakeholders in the Chesapeake Bay watershed to review and extract relevant information of from technical articles and reports that can be used for implications for Policy and Prevention.

V. Current Efforts and Gaps

There are ongoing efforts, by multiple organizations in the Bay watershed, to assess toxic contaminants and their effects on fish and wildlife. The types of studies and monitoring include:

- Monitoring to assess water-quality impairments and issue fish consumption advisories in state waters.
- Documenting the extent of degraded fish conditions and wildlife conditions and relation to toxic contaminants and other factors (such as disease). Specific examples include monitoring the prevalence of liver tumors in fish and the linkage with sediment contamination.
- Monitoring and assessment for occurrence and concentrations of selected contaminant groups (such as pesticides) and their relation to different sources and landscapes.
- Research on effectiveness of management practices and mitigation techniques to reduce contaminants, and their potential co-benefits with nutrient and sediment reduction.

A brief description of the current efforts and associated research gaps for the five issues in this strategy are discussed. Efforts to address the research gaps are presented in the management approaches (next section).

Issue: Synthesize information to make fish and shellfish safe for human consumption

- **Current Efforts:** All states and DC, in cooperation with USEPA, have existing monitoring programs to identify impairments in water bodies (303(d) list) and set fish consumption advisories. In most jurisdictions, PCBs and mercury are the primary driver of fish consumption advisories. Jurisdictions have progressed over the past two years in understanding the extent of the PCB impairments in the watershed. Progress to better understand status and investigation of sources of PCBs in the environment has been initiated by jurisdictions implementing approved PCB TMDLs and geographic focused remediation efforts through other regulatory programs. In addition, progress has occurred on the development of regional models such as the James and Elizabeth River and Baltimore Inner Harbor watersheds, that can help with better understanding sources and occurrence of PCBs. Information from these models may help other jurisdictions in the development of other regional models being considered within the watershed.

For mercury, Maryland annually monitors the young of the year fish. To date, there have been no apparent trends in the fish concentrations; however, the sampling will continue, and data will be evaluated annually for trends. USGS, as part of the EDC project, also measured mercury in fish fillets in two locations within the watershed, one in the Potomac and another in the upper Susquehanna.

- **Research Gaps for PCBs:** While progress on PCB source identification has occurred, gaps remain related to approaches to refine sources (including sampling and analysis methodology), status and change in environment, and BMP effectiveness (including co-benefits with nutrients and sediment) for toxic contaminant reduction, and methods and approaches for use of BMP science for PCBs in decision tools.
- **Research Gaps for Mercury:** The pattern of fish mercury concentrations was not consistent with regional patterns in atmospheric mercury wet deposition; for example, mercury deposition is highest in the southern portions of the watershed and lowest in the north, whereas fish mercury concentrations displayed the opposite pattern. This apparent disconnect supports findings elsewhere that biogeochemical and ecological drivers are important determinants for fish mercury bioaccumulation, confounding the linkage with inorganic mercury loading from the atmosphere.
    a. There are limitations with the data for answering broader questions about the factors driving differences in mercury concentrations. The existing data sets were generated by different to address the unique program scopes and goals of each organization. In this context, the authors discuss the limitations of the current data and provide a roadmap for different monitoring program structures that would provide more comparable data among agencies in the watershed. The data from such a monitoring program would better allow agencies to assess changes in mercury due to reductions in air emission,
    b. improve the ability to compare risk of mercury to fisheries and humans through fish consumption advisories
    c. Understand the factors that drive spatial differences in mercury concentrations

Issue: Understand the influence of contaminants degrading the health, and contributing to mortality, of fish and wildlife

- **Current efforts:** Research is ongoing between jurisdictions, federal, and academic partners to better understand the influence of toxic contaminants on the health of fish and wildlife as well as confounding factors that may make them more susceptible to disease in the presence of these contaminants. In the Potomac and Susquehanna basins, studies are also addressing the complex interactions of chemical, pathogens and parasites, and other factors contributing to fish mortalities. Some selected studies are described below.

The USGS completed and is publishing results of a five-year study to better understand the effects of known EDCs and CECs on fish and wildlife within the Chesapeake watershed. The study focused on assessing adverse effects in wild fishes, experimental exposures of key fish species to mixtures based on chemical concentrations measured in affected areas, assessing the role of mercury as an endocrine disruptor, and summarizing existing information on EDC effects on wildlife.

The STAC workshop held by the workgroup in 2019 focused on legacy and emerging contaminants in urban and agricultural areas. In urban areas, researchers reported that fish exhibited abnormal tissue growth and reduced reproductive success as a result of exposures to PAHs and PCBs and other mixed contaminants (Pinkney, Blazer studies, Majcher and others, 2019). Ongoing studies revealed that monitoring of Bullhead catfish species can detect changes in tumors over time and this monitoring continues in the Anacostia River. In agricultural settings, there have been fish kills and a variety of indicators for poor fish health including low chronic mortality, skin lesions, and reproductive endocrine disruption due to toxic contaminant exposure. We learned there is no one culprit for these conditions but exposure to contaminants make the populations more susceptible to infectious agents, parasites, virus, and bacteria.

A study of UV filters, hormones, antibiotics in 14 sites along the eastern shore of the Chesapeake Bay showed ubiquitous presence of UV filters in water, sediment and oyster tissue and long-range transport of contaminants of emerging concern (He and others, 2019; *link* https://www.sciencedirect.com/science/article/pii/S0048969718338944?via%3Dihub). The study demonstrated bioaccumulation of UV filters in oysters and suggests the need for improved CEC removal during municipal wastewater treatment and agricultural waste management within the Chesapeake Bay watershed (He and others, 2019).

State agencies usually have the lead to respond to fish and wildlife kills and determine if the likely cause is a spill or accidental release of petroleum, toxic contaminants, or low dissolved oxygen conditions. Additionally, the NOAA Office of Response and Restoration assesses fish kills due to chemical spills in coordination with the US Coast Guard and state agencies.

- **Research gaps:** Monitoring and research are still needed to further determine the occurrence of fish and wildlife health conditions and their primary causes. Biological monitoring is of fish and wildlife health conditions are not adequate to assess status across the watershed or even in selected landscape settings (agricultural and urban areas), but geographically focused efforts have provided insights for further study. Studies conducted over the past several years have had difficulty defining which contaminants (and mixtures), and factors contribute to 1) causing the greatest degree degradation of the health and reproductive systems of fish and wildlife, (2) compromising the immune systems of fish and making them more susceptible to other environmental stresses, such as pathogens, parasites; and the effects of hypoxia; 3) prevalence of for tumors; and 4) in embryo and larval survival. Therefore, research on the causing degradation of fish and wildlife population is still needed. Some specific gaps identified as part of the STAC workshop (Majcher and others, 2019) included:

a. Evaluate the ways that multiple stressors (both chemical and non-chemical) lead to adverse effects at the individual and population level in both agricultural and urban settings.
b. Establish the linkages between agricultural land use, contaminants, immunosuppression, water quality, and disease in agricultural watersheds.
c. Examine the declines in anadromous and semi-anadromous fish populations associated with urbanization. Such information will help managers focus efforts to minimize these impacts as land use changes throughout the watershed.
d. Determine the sources of the pollutants entering the food chain and the contribution of ongoing inputs on consumption advisories.

Issue: Document the sources, occurrence, concentrations, and transport of contaminants in different landscape settings

Better understanding sources, occurrence and transport of contaminants in different landscape settings helps (1) assess potential effects on fish and other organism (previous issues), and (2) formulate management options (next issue). We have identified the need to address the important link between sources, occurrence, and transport of contaminants in different landscape settings – even if geographically restricted, (figure 4), and their relation to nutrients and sediment.

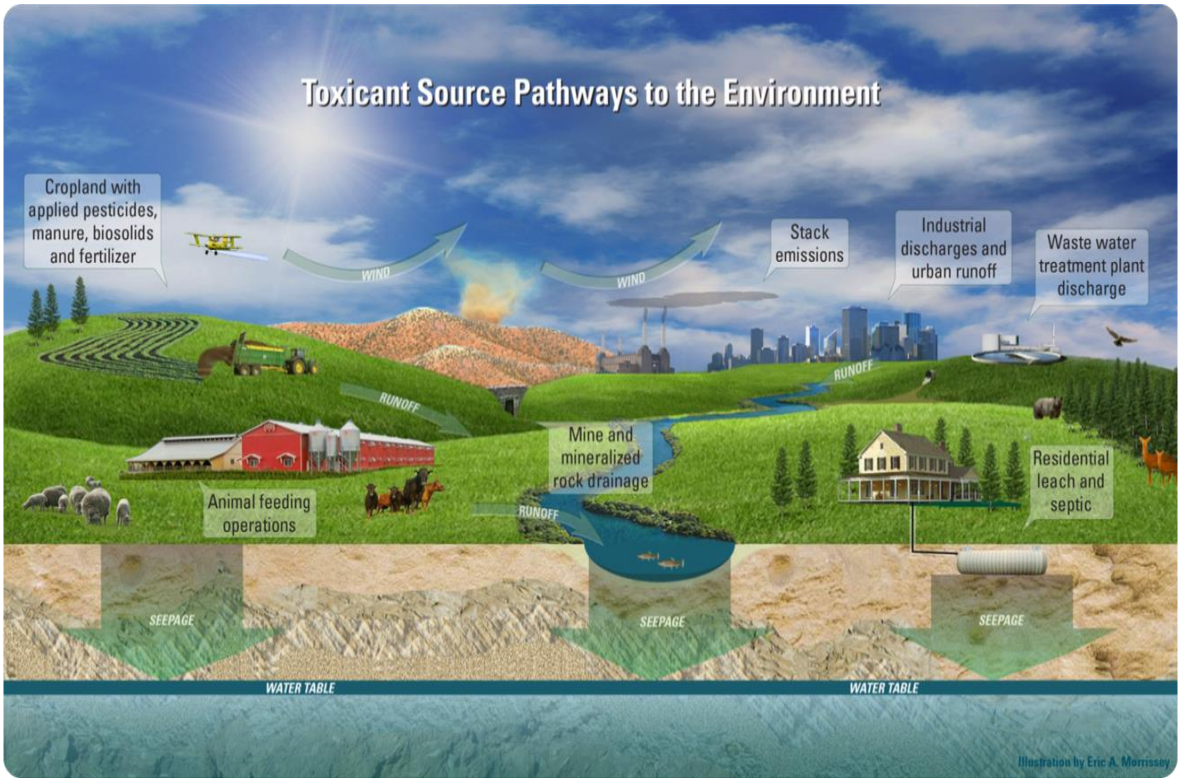


Figure 4: Conceptual diagram of sources, transport pathways of contaminants. Understanding the relation of contaminants with nutrients and sediment will help inform potential for their collective reduction. (from K. Smalling, USGS)

- **Current efforts:** All the states and several federal agencies monitor different types of contaminants but only in selected areas and varying collection frequencies. There have been efforts to summarize the occurrence of selected contaminants in agricultural and urban areas. This was also a major topic of focus at the 2019 workshop, where the report concluded that the fate and transport of contaminants with suspected fish health effects and their transformation products are largely unknown in urban areas. For contaminants with known and unknown fish health effects, sources of the contaminants that are the primary risk drivers are highly site-specific making selection of appropriate management actions difficult. For agricultural areas, the sources of contaminants are relatively well defined, but detailed information on many CECs is currently limited.

  Partners at NOAA published work as part of the National Status and Trends estuarine monitoring program (including sediment, water, and bivalves) that included the Chesapeake Bay. Work has been expanded to included monitoring of pharmaceuticals, personal care

products, current-use pesticides, and other chemicals of emerging concern (CECs) associated with human activities and will be repeated in future years.
. Scientists from NCCOS' Oxford Laboratory and Maryland Department of Natural Resources helped identify suitable survey areas including the Patapsco, Severn, Rhode and Choptank tributaries, which represent a range of land use from heavily urbanized to agriculture. The preliminary results indicate the detection of a number of CECs in both sediments and oyster tissues. Contaminants were detected more frequently in oyster tissue than in sediment (https://coastalscience.noaa.gov/project/mussel-watch-program-assessment-chesapeake-bay-charleston-harbor/). Maximum values of pharmaceutical and personal care products, current use pesticides, flame retardant and persistent organic contaminants were more frequently found in the Patapsco River than the other survey areas (https://coastalscience.noaa.gov/project/mussel-watch-program-assessment-chesapeake-bay-charleston-harbor/). Further studies by NOAA are looking at the linkages between river conditions (including toxic contaminants) and land use. The TCW is examining these results to identify appropriate actions within the watershed.

Researchers from UMBC and the USDA FS are continuing to investigate estrogenic hormones, UV filters, and antibiotics in water, sediment, and bivalves in some tidal and non-tidal portions of the Chesapeake Bay, with different land use settings (both agricultural and urban). Potential sources of estrogenic hormones and antibiotics include wastewater treatment effluents and animal feeding operations. Five UV-filters and three estrogenic hormones were measured in water, sediment and in virile crayfish (Orconectes virilis) tissue to better understand CEC occurrence in urban streams. Methods applied to the crayfish were adapted to test other aquatic and coastal invertebrates from multiple habitats including red swamp crayfish (Procambarus clarkii), eastern oyster (Crassostrea virginica), and hooked mussel (Ischadium recurvum).

Another objective of the USGS EDC project was to better define the sources and occurrence of EDCs and other contaminant groups that affect health of fish and wildlife in agricultural settings in the watershed. Potential hotspots were identified using GIS analysis. McClure and others (2020) looked for patterns of 28 compounds and estrogenicity in an attempt to better understand the spatiotemporal dynamics of contaminants in surface water. Study highlights include:

a. Highest probabilities of occurrence were in the spring and summer months.
b. Occurrence of most compounds not strongly linked to stream flow or land use
c. Atrazine, simazine, fipronil and metolachlor co-occurred most often across sites

Additional legacy and emerging toxic contaminant sampling is ongoing in surface waters of the jurisdictions, such as PA and DE.

- **Research gaps:** There is lack of consistent information (both spatial and temporal) on the occurrence and concentrations of priority toxic contaminants in different landscape settings and their co-occurrence with nutrient and sediment contamination. Additionally, there is no watershed-wide monitoring program on the condition of fish and wildlife that is integrated with nutrient and sediment sampling. Some of these monitoring gaps are due to the high cost of generating new data on toxic contaminants and the design of monitoring programs for purposes other than assessing status and trends. In addition, while jurisdictions, researchers, and federal agencies are initiated monitoring activities for PFAS, status, source, and cooccurrence with landscapes are unknown the Chesapeake watershed. The existing information currently should be summarized to provide an improved understanding of the co-occurrence of prioritized toxic contaminants with nutrients and sediment in different landscape settings, where possible even if geographically limited. The improved understanding will help inform the next issue on options to mitigate contaminants.

Issue: Provide science to help mitigate contaminants and emphasize the co-benefits with nutrients and sediment reductions.

The TCW identified this issue to provide science to help decision makers (CBP Water Quality Goal Team, States, and local jurisdictions) develop and prioritize options to reduce contaminants by taking advantage of nutrient and sediment reduction efforts. The research on the co-occurrence of nutrient, sediment and toxic contaminants, related to their sources, occurrence and transport, will help to better understand mitigation options in different landscape settings. For example, in urban settings, the focus will likely be related to wastewater and stormwater runoff, so states and counties can consider options to both meet the Bay TMDL and reduce toxic contaminants. In agricultural areas, focus will likely be on manure and row crop-related contaminants. The management approach to include summarize existing studies and provide the findings to the CBP source sector work groups and their members as they consider options to improve water quality.

- **Current Efforts:** There are efforts to assess mitigation potential for a limited number of contaminants in the context of TMDL compliance; however, research related to the remediation of toxic contaminants including many listed in Table 1 has advanced in other regulatory programs, such as Superfund, RCRA, and voluntary cleanup. Within the Chesapeake Bay, ongoing work as part of the Anacostia sediment mega-site (DC) and the Middle River (Dark Head Cove) in MD are two examples of many where remediation technologies have been demonstrated at the pilot or full-scale for contaminants of concern to the Chesapeake Bay. Many other state and federal clean-up sites throughout the watershed have demonstrated success meeting site-specific remediation goals for sediment, groundwater, and surface water for toxic contaminants of interest.

  A primary focus of the STAC workshop in 2019 included the use of BMPs for toxic contaminant removal in agricultural and urban areas, as summarized below. Specifically, in agricultural areas, several BMPs appeared promising based on studies from California (Salinas Valley) and within the watershed, including:

  - Adding activated carbon or biochar to established BMPs effectively reduces contaminant transport.
  - Retention ponds and vegetative treatment are shown to reduce pesticide loading.
  - Finally, manure management (including composting, subsurface application) and buffer strips, were shown to reduce antibiotics.

In urban areas, there were several examples at the workshop of studies demonstrating effective management. These included:

- Sediment capture and reactive filter BMPs reduce concentration and toxicity related to urban stormwater runoff.
- Iron-enhanced sand filtration reduces concentrations of pesticides and wastewater indicators.
- In stream innovative treatment using activated carbon with and without bioamendments immobilizes and degrades PCBs.

In the context of TMDL compliance, the ability of BMPs to reduce or meet WLA goals is limited but ongoing. Theoretical assessments of primarily sediment-based BMPs have been completed for toxic contaminants while measurements of actual efficiencies and performance of BMPs for toxic contaminants are underway related to biofiltration and detention basins, but are limited Further, work is ongoing to optimize media used in the construction of stormwater control structures to facilitate or enhance the removal of toxic contaminants. This information is needed to consider adapting decision tools to accommodate toxic contaminants and quantify reductions.

- **Research gaps:** The research gaps include (1) summaries of existing studies on mitigation using BMPs (2) more specific information on effectiveness of specific BMPs to degrade or remove select contaminants, (3) tools that integrate nutrient, sediment, and contaminant BMPs, and (4) interacting with decision makers to apply the findings. These gaps need to be filled in both the urban and agricultural landscape settings. Additional research on mitigation approaches is needed from the perspective of TMDL compliance for local impairments and aligning efforts under the Bay TMDL.

  Several gaps were identified as part of the STAC workshop in agricultural areas including the need to prioritize BMP implementation, the importance of defining the types of contaminants that require reduction (exposure), defining the desired outcome (e.g., improved fish health) and establishing how the BMP functions in relation to this outcome. Further understanding of the co-benefits of nutrient and sediment BMPs is needed to improve water quality (reduce toxic contaminants) and habitat quality and preserve aquatic resources. We need to further develop tools for the management community to identify areas/populations that would benefit from improved BMP implementation and/or monitoring. Finally, we need to build qualitative frameworks to answer questions related to co-benefits for toxic contaminants. Similarly, in urban areas, there is a need to improve information on removal efficiencies for certain BMPs to assess reduction in tools such as CAST. The workgroup was challenged to establish this approach over the last two years. A GIT funded project will to assess the literature and propose approaches to incorporate toxic contaminant reductions into management tools. This project will be critical for any progress on these items over the next two years.

Issue: Gather information on issues of emerging concern

There are numerous issues of emerging concern that are continuously evolving and are relevant to the Research strategy and more specifically understanding how emerging contaminants are impacting surface waters and biological resources of the Chesapeake Bay. While some of the previous issues of emerging concern were retained in the strategy from previous versions, little to no focus was paid to these previous issues (including unconventional oil and gas exploration and drilling, and contaminant toxicity to pollinators) in favor of new issues of concern (including PFAS, road salt, HABs, microplastics and CCRs).

- **Current Efforts:** State of the science updates on the various emerging issues topics were presented to the workgroup over a series of meetings and relevance to the Chesapeake Bay was discussed and prioritized by group members once all presentations were complete (presentations linked here: https://www.chesapeakebay.net/what/event/toxic_contaminants_workgroup_conference_call_november_14_2018 and https://www.chesapeakebay.net/what/event/toxic_contaminants_workgroup_conference_call_february_13_2019). While some priorities varied between stakeholders, PFAS was identified as a priority by most workgroup members, followed by road salts. In addition to the topical TCW meetings, a STAC workshop on microplastics was held and many workgroup members attended the workshop. CBP as a whole has prioritized microplastics with the formation of a microplastics action team, and TCW will participate and engage with the group to bring findings particularly related to the toxicity effects of microplastics on biological resource of the Chesapeake Bay.

- **Research Needs:** With briefings and discussion of many issues over the last several years, there are continuing needs to better understand: (1) toxicity impacts of PFAS on fish and shellfish, and (2) toxicity impacts of microplastics on fish and shellfish, and (3) toxicity effects of road salts.

Actions, Tools and Support to Empower Local Government and Others

- **Current Efforts:** During development of the initial strategy, the TCW has reached out to local organizations within some of the areas of most concern including the Baltimore Harbor and Anacostia watershed. In both the Susquehanna and Shenandoah watersheds, the USGS has been interacting with the respective River Keeper organizations on the fish health studies. As part of the Baltimore Urban Waters Partnership, local governments from MD counties near Baltimore and DC have met with researchers and regulators to discuss new research related to PCBs and stormwater.
- **Research Gaps:** There is an ongoing need to increase interaction with local governments and others who need science to better inform efforts to improve water quality. There is a lack of summary materials and tools to provide information on the potential co-benefits between reduction of toxic contaminants with practices for nutrients and sediment. Local governments could more effectively meet their requirements for the Bay TMDL (for nutrients and sediment) and address local water-quality issues with more integrated information. Also, there is a need to improve information about on the extent of fish consumption advisories, due to toxic contaminants and to better focus efforts to protect diverse communities.

VI. Management Approaches

The Partnership will work together to carry out the following approaches to make progress toward the Toxic Contaminants research outcome. These approaches seek to address the factors affecting our ability to meet the goal and the gaps identified above.

The management approaches address each of the major issues, and associated factors, identified at the beginning of the strategy. The management approaches build from existing research and monitoring efforts to address the research gaps and factors influencing our ability to meet the toxic contaminant goal. The factor of resource constraints applies to, and are discussed, for each management approach. The factor of synthesis is discussed in several management approaches.

Approach: Synthesize information to make fish and shellfish safe for human consumption

This approach will help address the factors and gaps associated with (1) summarizing information on the occurrence of fish consumption advisories and the sources of contamination, (2) resource constraints, and (3) synthesis. This management approach is focused on PCBs and mercury since they are the primary contaminants causing fish consumption advisories. It addresses the factor "**Understanding and defining sources of contamination leading to fish consumption advisories"**.

The **approach for PCBs** includes actions ranging from:

- Refining PCB sources and methods for source identification through both literature and field study communication;
- Taking advantage of existing studies to enhance information on the sources of PCBs in environment. Examples include the Baltimore Areas study (UMBC-USGS) and several studies in the Anacostia and DC. These projects are also looking at sources of PCBs and relation to potential stormwater controls or stream remediation.
- Working toward a hierarchy of PCB monitoring and analytical methods for desired use to promote comparison of data across the watershed for similar needs
- Stay informed on progress of models in James River, Anacostia, upper Potomac, any others as they may inform adaptive management decisions/areas of focus for others in the watershed.

The results will inform the current toxic contaminants prevention and policy management strategy, which is focused on reducing the impacts of PCBs.

The approach for mercury will focus on interaction with the jurisdictions on the opportunity for integrated monitoring of mercury given lack of data to assess effects of atmospheric reductions and other management approaches. The data from such a monitoring program would better allow agencies to (1) assess changes in mercury due to reductions in air emission, (2) improve the ability to compare risk of mercury to fisheries and humans through fish consumption advisories, and (3) better understand the factors that drive spatial differences in mercury concentrations. More details for this management approach, and contributing science partners, are in the Logic and Action Plan.

Approach: Understand the influence of contaminants in degrading the health, and contributing to mortality, of fish and wildlife

The research efforts will provide a better understanding of the factors affecting health of fish, shellfish, and wildlife, with a focus on fisheries. The states in the watershed (as well as DC) have active projects, many in cooperation with USGS, FWS and academic partners, attempting to discern causes of declining fish health, and fish mortality, in their respective drainage areas of the Bay watershed. These efforts will help address the factor **"Multiple factors affecting the health and mortality of fish and wildlife."**

Several efforts will help improve understanding over the next two years, including:

- Assess the effects of contaminants on fish and shellfish in tidal waters. There will be a focus on Anacostia River sediment contaminants effects on fish health by USFWS, and also continue study and evaluate findings from condition of Yellow Perch in urban areas by USFWS, USGS, and UMCP.
- The USGS will continue to generate information to document fish health conditions in the Bay watershed. One effort will initiate studies designed to address temporal and spatial changes in fish health in mixed use watersheds in the freshwater portion of the watershed. The other effort is designed to determine if state collected DELT data can be used to assess how various fish health indicators respond to BMPs and other management actions.
- The USGS will be summarizing and releasing results from its Chesapeake EDC study. Results of fisheries effects will help inform this approach with other results on the sources and pathways will help inform the next management approach.

Approach: Document the sources, occurrence, and transport of contaminants in different landscape settings

This management approach will address the factor, **"Lack of data on the occurrence and trends of toxic contaminants."** This approach is focused on the settings where the sources of the contaminants are expected to have the maximum impact on fish and their opportunities to collectively address contaminants, nutrients, and sediment. These settings include urban and suburban areas, and agricultural lands. In agricultural lands, some of the primary sources to address animal manure, crops where pesticides are applied, and spreading of biosolids. In urban and suburban areas, some of the primary sources to address include aging sewer infrastructure, septic systems, urban runoff, and WWTPs. We will also look at the co-occurrence of contaminants with nutrients and sediment to find opportunities for mitigation options (next approach).

Data inventories revealed conducting regional assessments of trends of contaminants was not possible. Therefore, the approach will evolve to focus on selected geographic areas where data can be used to look at status and change for selected contaminants. Some of actions to support this approach during the next two years include:

- Multiple partners will be working to better define the sources and occurrence of EDCs and other toxic contaminant groups in different landscape settings. Actions will range from (1) continuing Pennsylvania studies on occurrence of pesticides and hormones and other toxic contaminants in surface water (PADEP and USGS), (2) monitoring of sediment, water, and bivalves as part of the regional Mussel Watch program (NOAA), evaluating the relationship between the amount of impervious surface and the impact on fish conditions (MD DNR), (4) publications to inform presence of select UV filters, hormones, and antibiotics in eastern oysters and hooked mussels (UMBC, USFS, USDA).

- The USGS will be summarizing and releasing results from its Chesapeake EDC study on the sources, pathways and effects of these compounds on fish in selected agricultural areas. With the EDC study completed, the USGS is evolving to focus on the relation the occurrence of contaminants in urban areas, including stormwater runoff and WWTPs.
- Have an increased emphasis on PFAS. Work with partners to coordinate PFAS studies of surface water and potential effects on fish and wildlife.

Approach: Provide science to help mitigate contaminants, and emphasize the co-benefits with nutrients and sediment reductions

This management approach will provide science to help the TCW, and other partners including those on the WQ Goal Team, to identify and prioritize mitigation options to help mitigate contaminants and the potential co-benefits with nutrient and sediment reductions. Over the next two years will be focused on generating information on the co-benefits of urban and wastewater practices to remove PCBs and other associated contaminants. There will also be closer interaction between the TCW and Water-Quality Goal Team and their workgroups to apply the results. This approach addresses the factor "**Limited information of the practices to mitigate contaminants, and their potential co-benefits with nutrients and sediment reductions".**

Some of the actions over the next two years for this approach include:

▪ Initiate a GIT funded project to explore approaches for including removal effectives for PCBs and similar contaminants in decision tools. The project will develop methods and provide improved information on the removal efficiencies for select urban contaminant Best Management Practices (BMPs), and contaminant reductions associated with wastewater discharge related to treatment plant and system maintenance improvements, into Chesapeake Assessment Scenario Tool (CAST) and other appropriate management tools in order to better quantify toxic contaminant reduction.

▪ Implement CBP recommendations to the STAC workshop report. These have been reviewed and approved by the TCW, the WQ GIT and the Management Board. The actions include:

CBP Action 1: Enhance Interaction with Stakeholders for Contaminant Information:
The best opportunities are to interact with stakeholders who are implementing practices to reduce nutrients and sediment, so they can consider actions to also mitigate toxic contaminants. The TCW is will increase interaction with jurisdictions, WQ GIT and associated workgroups, and local TMDL implementors.

CBP Action 2: Take advantage of Phase 3 implementation:

The jurisdictions must develop updated lists of nutrient and sediment practices that will be implemented every two years for their WIPs. These 2-year milestones provide opportunities for the TCW to summarize new findings on the co-benefits of toxic contaminant reduction for selected nutrient and sediment BMPs and share them with jurisdictions to consider.

CBP Action 3: Enhance Communication Materials to Inform Decisions:
The TCW will interact with stakeholders on the most useful approaches to provide new findings. In addition to presentations of results, the TCW will discuss opportunities to prepare Fact Sheets and other briefing materials to best communicate results to different stakeholder groups. Preparing communication materials will take additional resources, which could be supported through annual GIT funding proposals.

CBP Action 4: Compile results and expand BMP studies of contaminant mitigation and relation to nutrients and sediment reductions:
Studies of the effectiveness of BMPs designed for nutrient and sediment reduction to mitigate contaminants are currently limited, particularly within the Chesapeake Bay watershed (CBW). However, expanding information about fate of toxic contaminants in BMPs is critical to understand within the current CBP framework of management actions; therefore, several approaches will be emphasized.

CBP Action 5: Include selected BMP results into CBP tools:
Currently management selection and contaminant reduction tools within CBP do not include evaluation of toxic contaminants so opportunities for decision making on co-benefits are extremely limited. Approaches to overcome these limitations include: Populating the Chesapeake Bay Watershed Data Dashboard with selected toxic contaminant monitoring, and executing the GIT-funded project described under action 4 would develop approaches and information for selected BMPs and contaminants in urban areas that could be considered for CAST and other contaminant management models

Approach: Gather information on issues of emerging concern

The TCW kept abreast of several emerging issues over the past two years:: (1) harmful algal blooms and their associated toxins; and (2) the potential effects of poly- and perflouroalkyls (PFASs), (3) coal ash reuse, and (4) reducing the effects of road salts, and (5) microplastics. Over the next two years, the focus will be on support for the microplastics action team, and increased emphasis on PFAS (which is in MA 3). The workgroup will field input from participants of new areas of interest, if any, as they emerge.

Approach: Targeted Local Participation

Scientists from different research efforts will provide findings to local organizations to inform them of ongoing studies. We will also utilize annual workshops put on by several organizations (such as Baltimore Urban Waters Partnership and the MD Pesticide Network) to share findings with local users and organizations. Finally, we will explore opportunities to work through the local government advisory committee to reach local governments and organizations.

Collaboration with other Management Strategies
There is potential cross-collaboration working with WQ Goal Team (to reduce nutrients and sediment); Habitats (improve stream health), and Fisheries (making fish and shellfish safer to eat, and the habitats on which they depend).

VII. Monitoring Progress

The Research Outcome does not have a numerical target so assessing progress is more qualitative. The overarching topic is to "Continually increase our understanding of the impacts and mitigation options for toxic contaminants". There are two supporting items in the outcome to provide a qualitative assessment of progress:

- Further characterize the occurrence, concentrations, sources and effects of mercury, PCBs and other contaminants of emerging and widespread concern.
- Identify which best management practices might provide multiple benefits of reducing nutrient and sediment pollution as well as toxic contaminants in waterways.

Monitoring our progress for these items is based on completion of planned actions and meeting their associated performance targets that are listed in the Logic and Action Plan.

VIII. Assessing Progress

Assessing progress on the actions is the LAP will be done at least annually under the TCW. The reviews will provide opportunities to make adjustments to the biennial workplan can be made to accommodate changing circumstances and availability of resources. Formal review of programmatic progress will be completed through the update of the biennial workplan.

For the previous two year period the qualitative assessment by the TCW was:

• Further characterize the occurrence, concentrations, sources and effects of mercury, PCBs, and other contaminants of emerging and widespread concern. **Progress: Good,** progress has been made on mercury across the watershed and contaminants in local areas, but ability characterize more regional occurrence and concentrations of contaminants has been limited.

• Identify which best management practices might provide multiple benefits of reducing nutrient and sediment pollution as well as toxic contaminants in waterways. **Progress: Fair.** A STAC workshop provided insights of a limited number of BMPs to have co-benefits between nutrient, sediment, and contaminant reductions. However, getting information into CBP decision tools, such as CAST, does not have a clear path forward. Additionally, jurisdictions WIPs don't have much emphasis on addressing co-benefits for contaminant reduction

A similar assessment is expected at the end of 2022.

IX. Adaptively Manage

The Toxic Contaminants Workgroup used the information learned over the past two years to update the management strategy and associated LAP for the Research Outcome. There is interchange between the members of the TCW to discuss evolution of research factors and gaps every two year in alignment with the SRS reviews.

X. Biennial Logic and Action Plan

The Biennial workplan for this research strategy contains actions for 2021-2022.