**Chesapeake Bay Watershed Agreement Management Strategy**

**Toxic Contaminants Goal: Research Outcome**

1. **Executive Summar**y
2. **Outcomes and Baselines**

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, 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 Understanding: The Toxic Contaminant Workgroup (TCW) worked with stakeholders to develop priority issues for this research strategy. These issues are discussed in each of the appropriate sections of the research strategy and include:

* Provide information to make fish and shellfish safer for human consumption.
* Understand the role of contaminants in fish and wildlife kills.
* Identify the influence of contaminants in degrading the health of fish, shellfish and wildlife.
* Document the occurrence, concentrations and sources of contaminants causing fish and wildlife degradation.
* Present issues of emerging concern that should be considered in the future.
* Provide implications for management approaches.

Much of the current baseline information for these issues comes from the report “Extent and Severity of Toxic Contaminants in the Chesapeake Bay Watershed” (Chesapeake Bay Program, 2013). Information from this report and more recent findings was used to discuss the current understanding for each issue in the research strategy.

Issue: Provide information to make fish and shellfish safer for human consumption. Polychlorinated biphenyls (PCBs) and mercury (Hg) 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 Hg that accumulates in fish) is known to cause impaired neurological development.  In addition, both of 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 (e.g., PCB contaminated terrestrial sites, previously contaminated stormwater pipes), and ongoing releases (e.g., wastewater and stormwater releases and atmospheric deposition, especially for Hg).

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 (Agreement) so they are not included in this Toxic Contaminants Research Management Strategy. Many of the human health issues are being addressed by other government agencies and research organizations.

Issue: Understand the role of contaminants in fish and wildlife kills.

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. Fish and wildlife species have been killed by oil spills such as the Colonial Pipeline Spill in a Potomac River tributary and the Chalk Point Oil Spill on the Patuxent River. 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 include the kills of menhaden with ulcerative mycosis in estuarine tributaries. In the case of the menhaden lesions and kills, one pathogen *Aphanomyces invadans,* was consistently observed in the ulcerative lesions. However, the role of toxic contaminants or algal toxins in susceptibility to the pathogens is unknown.
* Fish kills have been associated with immunosuppression influenced by the presence of toxic 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 subwatersheds. These kills are associated with multiple pathogens and parasites. These observations together with the concurrent observations of intersex and other indicators of contaminant exposure suggest a role in toxic contaminants in immunosuppression.

Issue: Identify the influence of contaminants in degrading the health of fish, shellfish 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. These 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 in the watershed. Chemical contaminants, including legacy and chemicals of emerging concern, particularly EDCs have had effects on fish and wildlife populations in the Bay ecosystem.

The role of contaminants in the health of numerous wildlife species, including birds, amphibians and reptiles 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.

There is less evidence linking contaminants to reduced health of effects of toxic impacts on lower trophic levels of the Chesapeake food web, including stream invertebrates and SAV.

Issue: Document the occurrence, concentrations and sources of contaminants causing fish and wildlife degradation.

The current understanding of extent and severity of ten groups of toxic contaminants in the Bay watershed were summarized from existing information (Chesapeake Bay Program, 2013) and are listed in Table 1. These findings showed that a combination of contaminant groups with widespread and local 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.

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| **Table 1: Extent and Severity of Contaminant groups (from Chesapeake Bay Program, 2013)** | |
| **Contaminant Group** | **Extent and Severity** |
| Polychlorinated biphenyls (PBCs) | PBCs 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. |
| Mercury | Mercury had both widespread extent and severity. The severity was based on risk to human health through consumption of contaminated fish. |
| Polycyclic aromatic hydrocarbons (PAHs) | Widespread extent thought the Bay watershed. The severity was localized based on impairments in a limited number of areas in the watershed. |
| 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. 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. |
| Petroleum hydrocarbons | Localized extent and severity in a limited number of areas in the watershed. |
| Dioxins and Furans | Localized extent and severity in a limited number of areas in the watershed. |
| Metals and Metalloids | Localized extent and severity of some metals (aluminum, chromium, iron, lead, manganese, zinc) in a limited number of areas in the watershed. |
| 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 is monitoring data were available. Severity was not accessed but research shows sublethal effects for some compounds at environmentally relevant concentrations. |

Issue: Present issues of emerging concern that should be considered in the future.

Issues of emerging concerns are (1) contaminant toxicity to pollinators, (2) microplastics and (3) antibiotic resistance in gene expression in fish and wildlife. The baseline information on each of these is very limited.

Colony Collapse Disorder (CCD) has taken a significant toll on honey bee hives in much of the US.  While not, as yet, a major problem in the Chesapeake watershed, CCD and declines in other pollinators are topics of growing concern.  Multiple factors, including pesticides (e.g., neonicotinoids and pyrethroids) acting singly or in mixtures have been linked to acute and/or chronic toxicity to honey bees and other pollinators.  Routes of exposure are generally terrestrial and may be through intentional application within hives (e.g., fungicides and miticides) or through dermal contact or ingestion of herbicide or insecticide treated crops.  These pesticides are then returned to the hive where they may poison queens or developing larvae.  Effects may be aggravated by other stressors including travel strain, climate change, and abundant parasites and pathogens.

Additional information microplastics and antibiotic resistance in gene expression in fish and wildlife will be included for the final Research Management Strategy.

Issue: Provide implications for management approaches.

There are existing programs for reducing the effects of different contaminant groups. The Policy and Prevention strategy is focused on reducing the effects of PCBs since they cause many of the fish consumption advisories in the Bay and its watershed. Given the effort to reduce nutrients and sediment in the watershed as part of the Bay TMDL, the research outcome also will focus on providing a better understanding of the potential benefit of nutrient and/or sediment practices for toxic contaminant reduction.

1. **Jurisdictions and agencies participating in the strategy**

The TCW has conducted extensive outreach and engagement of a wide array of stakeholders. The Agreement signatories and stakeholders who have indicated their intention to participate in management strategy development have been identified on the workgroup membership list. The membership of the TCW includes members from the following groups:

* 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
* Federal Agencies: EPA, USGS, FWS, DHS, NOAA
* Non-Governmental Organizations
* Private sector organizations
* Local government organizations
* Academic institutions
* CBP Water Quality Goal Implementation Team Workgroups

3.a **Local Engagement**

Most of the actions to plan and complete the actual research is expected to be the responsibility of federal, state and academic entities. Local governments and NGOs will be helpful in identifying priorities within the research strategy. The TCW expects to maintain active members and to pursue partnerships with local organizations to inform the strategy. The workgroup has made a concerted effort to include representatives from local areas such as the Baltimore Harbor, the Elizabeth River, and the Anacostia River. Increasing the awareness of the impacts of toxic contaminants, especially safe consumption of fish and shellfish, will be carried out with local governments and organizations.

1. **Factors Influencing Ability to Meet Goal**

The primary factors influencing the ability of the research strategy to improve the understanding of the impacts of toxic contaminants are presented in the order of the issues discussed on the baseline section of the report.

* Fish and shellfish consumption advisories. The jurisdictions have different assumptions about human exposure which can limit comparability across the watershed. There are also resource constraints to collect/analyze fish samples every year.
* Ability to identify the multiple factors, including the role of toxic contaminants, contributing to fish and wildlife kills and associated degraded health conditions.
* Ability to determine which pollutants are causing the degradation of fish and wildlife due to wide range and mixtures compounds occurring in the watershed.
* Lack of watershed-wide monitoring programs on the condition of fish and wildlife and occurrence of toxic contaminants. Some of this is due to the high cost of generating new data for on toxic contaminants and associated biological monitoring. Studies are also hindered by not having consolidated information for existing data.
* Limitation of existing funding to address emerging issues and knowledge gaps for other contaminants.
* Lack of toxicity thresholds for many pollutants to allow assessment of their effects on fish and wildlife and development of management targets. A companion factor is the inability to assess risk from mixtures of pollutants.

1. **Current Efforts and Gaps**

There are some ongoing studies in the Bay watershed on 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 advisors in state waters.
* Understanding the role of toxic contaminants and other factors in fish kills in the Bay watershed.
* Documenting the extent of degraded fish conditions in the Potomac and Susquehanna watersheds and relation to toxic contaminants.
* Assessing the effects of endocrine-disrupting compounds on fish and wildlife.
* Monitoring programs for selected contaminant groups (such as pesticides).
* Monitoring the prevalence of liver tumors in several of the Chesapeake Bay Regions of Concern and the linkage with sediment contamination.

For each of the research strategy issues, a brief description of the current efforts and associated research gaps are discussed. Efforts to address the research gaps are presented in the management approaches (next section).

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

*Current efforts:* All states have existing monitoring programs to ensure there are guidelines for safe fish and shellfish consumption through yearly fish monitoring programs.

*Research Gaps:* There is a lack of organized watershed-scale monitoring/modeling effort that can delineate legacy and ongoing sources for these pollutants and determine their relative contributions to fish contamination. This information is critical to the development of appropriate and prioritized mitigation efforts.  Further identification may be needed on contaminant sources and transport to waterways using emerging tools that allow measurement of PCBs and Hg at ultra-low concentrations.

A major focus of PCB monitoring in the Bay watershed has been on fish and shellfish that is critical to the development of fish consumption advisories and protection of human health. However, for PCB source identification, PCB data are needed on the various environmental media that lead to PCB exposure to fish. Past approaches for PCB source identification has involved spatial sampling of air, water, and sediments combined with mass balance modeling to delineate sources, such as the ones carried out in the Great Lakes (e.g., Lake Michigan mass balance study). Such studies can help identify relative loads of PCBs and other pollutants of concern in the watershed from rivers, air deposition and contaminated sediment resuspension. While air and water sampling have been performed in the watershed in the past, there is lack of current data that will be necessary to adequately identify sources at the present time. More specific research needs are:

* Evaluation of the feasibility of mitigation options for sites/sources for which information is available and there is good likelihood of benefit from PCB load reductions to the watershed.
* Synthesis of the information already available and identification of current data gaps that are critical for developing an updated PCB mass balance for the Bay. There has been some ongoing monitoring of PCBs in air, water, and sediments by the different agencies involved in the watershed, but there is a lack of a coordinated Bay-wide synthesis of the data for PCBs.
* Development and implementation of a coordinated monitoring effort to measure atmospheric and water-borne sources of PCBs to the Bay along with measurements of levels in surface sediments. This will include spatially explicit measurements where data are lacking of air, water and sediment samples using latest techniques that allow very low detection limits. For PCBs, the required water quality goals for the protection of human health from fish consumption can be very low (e.g. 0.059 ng/L BAF-based, Target Water Concentration for the tidal Potomac in DC), making it necessary to adopt emerging analytical techniques such as passive sampling (Guidelines for Using Passive Samplers to Monitor Organic Contaminants at Superfund Sediment SitesOSWER Directive 9200.1-110 FS December 2012)
* Development of a PCB mass balance model for the Bay with current data that will allow identification and relative importance of present sources to the Bay.
* Linking the PCB mass balance model with a PCB food chain model for the Bay to determine target water quality criteria based on a desired goal for fish tissue residue in fish (e.g., Striped Bass?). This can lead to the development of management approaches to reduce PCBs in the Bay watershed and will be driven by the goal of reduction of PCB levels in high value fish in the Bay.

Issue: Understand the role of contaminants in fish and wildlife kills.

*Current efforts* Agencies within the watershed jurisdictions have taken the primary role in the first response to the fish and wildlife kills. State agencies are generally the first responders and determine if likely cause is spill or accidental release of chemical, low oxygen or other cause. U.S. Fish and Wildlife Service (FWS) and U.S. Geological Survey (USGS) scientists have assisted in many fish kill investigations when requested, working with state partners in WV, MD, VA and PA to identify pathogens, pathological responses and contributing factors of fish kills.

*Research gaps:* Better understand the role of contaminants in kills of fish or wildlife in the Bay watershed. Contaminants can be directly or indirectly involved in large-scale mortalities. Oil and chemical spills can lead to acute mortalities. More commonly, contaminants may have an indirect effect on mortalities (acute and chronic) through numerous pathways such as modulation of the immune response and disease resistance, tumor induction or promotion, metabolic and endocrine effects. Additionally, there are complex interactions of contaminants (particularly herbicides), nutrients and algal populations that can lead to mortality by algal/cyanobacterial toxins.

Issue: Identify the influence of contaminants in degrading the health of fish, shellfish and wildlife.

*Current efforts:* Research is ongoing in PA, WV and MD to better understand the complex interactions of chemical and algal toxins, pathogens and parasites and water quality on these mortalities. There are ongoing, collaborative studies between these state agencies and USGS in both the Potomac and Susquehanna drainages addressing potential causes of skin lesions and mortalities of bass and sucker species. These include potential roles of algal toxins, a myxozoan parasite in young-of-year smallmouth bass and the invasive species/thiaminase. USGS initiated in 2014 a five year plan to better understand endocrine disruption and effects of chemicals of emerging concern on fish and wildlife within the Chesapeake watershed. This includes adverse effects in wild fishes, experimental exposures of key species to mixtures, based on chemical concentrations measured in affected areas, assessing the role of mercury as an endocrine disruptor, monitoring amphibian populations of adverse effects, as well as exploring the potential for EDCs to be affecting avian and reptile populations.

*Research gaps:* Determine the primary contaminants adversely affecting general as well as reproductive health of fish and wildlife populations within the watershed. Research is needed to identify the primary contaminants (most likely mixtures) contributing to these conditions. A better understanding is needed on 1) role of contaminants in compromising the immune systems of fish and making them more susceptible to other environmental stresses, pathogens and parasites; 2) the effects of hypoxia, other water quality parameters and pathogens/parasites on the response of fish populations to exposure to toxic contaminants; 3) risk factors for tumor production; 4) role of contaminants in reproductive success; 5) role of contaminants in embryo and larval survival; 6) the role of microplastics on health of fish and wildlife.

Understanding the sublethal, cumulative effects of complex mixtures of EDCs and toxic chemicals on reproductive success and general health and survival is necessary in developing management strategies. Identifying factors that influence species’ susceptibility to toxic chemicals and EDC-related effects will identify the most at-risk fish and wildlife populations, as well as guide mitigation efforts to reduce potential impacts on sensitive populations. Integral to mitigation efforts will be identification of sources and transport mechanisms for EDCs. The strategy currently focuses on fish health but we envision some level of effort for addressing the health of shellfish and wildlife to be developed for the final version.

Some of the fish health research needs include:

* Non-neoplastic skin lesions of adult fishes and young of year bass, co-occurring with a high prevalence of intersex. The role of contaminants in production of these lesions needs to be better understood. Questions that need to be addressed: 1) do certain contaminants accumulate in the skin, 2) is suspended sediment a source of these contaminants, 3) are the bacteria observed in some lesions associated with nutrient or other water quality parameters and 4) are other factors such as algal/cyanobacterial toxins involved.
* Skin and internal infections of multiple Mycobacteria species have been identified in striped bass as well as some other species. While considerable research has been directed at identifying the bacterial species, the extent of the problem and the progression of the lesions, studies directed at better understanding the predisposing factors, including exposure to immunosuppressive contaminants is needed.
* A high prevalence of skin and liver tumors of brown bullhead and liver tumors in mummichogs have been documented. While there is good evidence for the role of PAHs in liver carcinogenesis, other factors acting as both promoters and initiators are not well studied. Research is needed on risk factors associated with these tumors.
* The complex interactions between contaminants and infectious disease need to be understood. While contaminants can adversely affect the ability of an organism to resist infectious diseases and parasites, the presence of these biological agents can also affect the ability of an organism to metabolize and otherwise deal with exposure to chemical contaminants.
* Better understand the extent, causes and adverse effects of intersex (testicular oocytes) in bass and potentially other fishes. Considerable research has been directed toward this issue in the Chesapeake watershed. Estrogenic contaminants have been associated with prevalence and severity of intersex in many fish species. However, associations have also been documented in the Potomac drainage with herbicides. The complex interactions of herbicides, phytoestrogens, algal toxins/products and intersex need to be addressed.
* Lack of reproductive success of yellow perch and other anadromous fishes has been documented in certain urban tributaries. A clear relationship between percentage of impervious surface and declining recruitment of yellow perch and river herring has been demonstrated. In yellow perch, effects on egg quality (abnormal yolk, thin chorions) have been observed. A better understanding of the multiple stressors including contaminants, hypoxia, sediment and nutrient loading and changes in salinity is necessary to prevent further declines.
* Neonicotinoid pesticides, which have been implicated in both fish health issues and the decline in pollinators have received little attention to date. They are currently being measured in water and sediment at a few select sites. Monitoring for the presence and adverse effects of these and other emerging pesticide/herbicides (glyphosate, etc.) needs to be implemented.

Issue: Document the occurrence, concentrations and sources of contaminants causing fish and wildlife degradation.

*Current efforts:* The Toxic Summary Report (Chesapeake Bay Program, 2013) provided the most current understanding of 10 contaminant groups within the Bay watershed. Some of these contaminant groups have jurisdictional monitoring programs but many of those of emerging concern do not have any systematic monitoring besides individual studies by some individual federal and academic monitoring efforts.

*Research gaps:* The Toxic Summary Report identified monitoring gaps for: dioxins and furans, petroleum hydrocarbons, some pesticides currently in use (e.g., insecticides and fungicides), pharmaceuticals, household and personal-care products, flame retardants, and biogenic hormones. The information was used to prepare an initial assessment of the level of uncertainty for ten contaminant (Figure 1) with regard to the occurrence, concentrations, sources and effects on fish and wildlife.

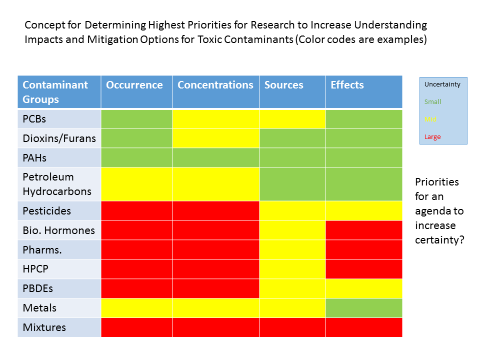


Figure 1: Level of uncertainty for ten contaminant with regard to the occurrence, concentrations, sources and effects on fish and wildlife.

Issue: Present issues of emerging concern that should be considered in the future.

*Current Efforts:* There is very little knowledge within the Bay watershed on (1) contaminant toxicity to pollinators, (2) microplastics, and (3) antibiotic resistance in gene expression in fish and wildlife.

*Research Gaps:* Research gaps on these issues are not provided since they are not being addressed in this management strategy. Under the management approach we will provide a summary paper on each issue be prepared to determine if more research is within the scope of future efforts.

Issue: Provide implications for management approaches.

*Current Efforts:* The current policy and prevention management strategy is focused on reducing the effects of PCBs. The information on sources of PCBs will be enhanced through the research strategy. The new findings will help inform an update the policy and prevention strategy in 2017.

*Research gaps:* The policy and prevention strategy needs additional information on the issues listed in research strategy to consider moving beyond PCBs in the next management strategy. The management approach outlined in the next section of this document will provide an improved understanding of the impacts of toxic contaminants so additional options can be considered to reduce their impacts.

Better understanding and identification and quantification of sources, fate, transport, distribution, and exposure of fish and other organisms to contaminants is a key part of identifying the proper management approach to address these issues. In many cases, current efforts to retain sediment on the landscape through use of management systems in order to retain nutrients and sediments on the landscape and out of the watercourses will result in added benefits of retaining sediment bound contaminants (such as hormones) on the landscape so that they can be degraded and not affect aquatic biota. Additional management strategies that involve applying upgrades or new technology to wastewater treatment (in both centralized and on-site systems) can also be expected to result in reducing the amount of contaminants (such as hormones and other endocrine disrupting compounds) introduced into surface and groundwater, thereby reducing the impact on fish health

5. a **Actions, tools or technical support needed to empower local government and others.**

*Current efforts:* The research workgroup 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 RiverKeeper organizations.

*Research gaps:* There has been limited activity to engage additional local groups about the issues being addressed by the research strategy.

1. **Management Approach**

The management approach addresses each of the major issues identified at the beginning of the strategy. The management approach builds from existing research and monitoring efforts to address the research gaps and factors influencing our ability to meet the toxic contaminant goal.

Since resources are limited some guiding principles for the management approach are to:

* Focus studies on areas where fish and wildlife have been degraded and there are human health concerns.
* Better understand and identify the multiple stressors and mixtures of contaminant groups contributing to degraded fish and wildlife.
* Improve the understanding between sources of these contaminants (and mixtures), their pathways to the environment, and exposures to receptor organisms.

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

The current toxic contaminants prevention and policy strategy is focused on reducing the impacts of PCBs. Additional information will be provided on PCBs sources and transport pathways so the policy and prevention strategy can be improved in 2018. Further information will also be generated for Hg to discern if Chesapeake strategies are needed to supplement National Efforts to reduce its impact on fish and associated consumption advisories.

Existing programs are addressing human exposure to PCBs and Hg primarily through two approaches: 1) monitoring of levels in fish and shellfish and issuing/revising consumption advisories, and 2) moving known contaminated sites towards cleanup both at the State and Federal level. While advisories do not reduce levels of contamination, ongoing cleanup activities should lead to reduction of PCB levels in fish. Better delineation of sources, especially of (1) diffuse sources on land, (2) contribution from biosolids, (3) release from old deposits in stormwater pipes, and (4) atmospheric deposition is needed to refine the management approach and prioritize cleanup efforts on sources that can have the biggest impact on overall reductions in PCB loadings. This will be done through more coordinated monitoring where data gaps exist and begin development of a PCB mass balance model for the Bay that can help delineate and prioritize the current sources that need to be controlled.

Issue: Understand the role of contaminants in fish and wildlife kills.

The management approach will build from ongoing efforts to document the extent and causes of fish and wildlife kills and their relation to toxic contaminants.Active research on fish kills is being conducted by the states of WV, MD and PA to better understand the causes of fish kills. The USGS will enhance efforts in the geographic areas being studied in the Potomac and Shenandoah Basin. Identifying the factors (climatic, invasive species, nutrients) contributing to the proliferation of parasite and opportunistic pathogens associated with mortality of young of year bass by evaluating the distribution of diseased young bass, toxic contaminants that may be passed from mother (egg) to young bass, the proliferation of the benthic worms and snails that are parasite intermediate hosts, and the role of algal toxins.

Issue: Identify the influence of contaminants in degrading the health of fish, shellfish and wildlife.

The research efforts will provide a better understanding of the factors affecting health of fish, shellfish, and wildlife. The states of WV and PA have active projects to attempting to discern causes of declining fish health in their respective drainage areas of the Bay watershed. The USGS has revised its Chesapeake Bay Science Strategy to better support these efforts and put studies into a regional context for the Susquehanna and Potomac watersheds. New USGS activities, working with state partners and FWS include addressing skin lesions, mortalities and reduced reproductive health of adult fishes include identifying the most important causes (pathogens, parasites) and contributing factors (nutrients, toxic/immunosuppressive/endocrine disrupting contaminants), assessing the role of algal/cyanobacteria toxins (microcystin) and other products (phytoestrogens) on general and reproductive health, and developing gene expression markers and molecular pathogen techniques to better understand the mechanisms (disease resistance factors, hormone receptor activation etc.) of observed effects.

To assess the effects of toxic contaminants on wildlife, USGS will summarize existing and work with partners to consider additional research activities. The effects of contaminants on shellfish are being addressed through monitoring and research efforts being conducted by NOAA and they will work with partners to consider additional monitoring and research activities.

Issue: Document the occurrence, concentrations and sources of contaminants causing fish and wildlife degradation.

The management approach will better define the sources and occurrence of EDCs and other contaminant groups that are affecting the health of fish and wildlife. The primary activities will focus on contaminants affecting fish health. These activities, done in collaboration with fish investigators will provide an improved understanding of: (1) the contaminant groups are most likely degrading fish health, (2) their occurrence in the watersheds, and (3) the sources. Sources and occurrence of EDCs and other key contaminant groups that can affect endocrine system and health of fish include pesticides, biogenic and synthetic hormones, and pharmaceuticals. Most of these groups have a large amount of uncertainty about the occurrence and sources (fig 1). Other contaminants, such as neonicitoid pesticides and pharmaceuticals such as antidepressants and antibiotics, may not affect endocrine systems, but can affect other aspects of fish health, including immunosuppression, increased susceptibility to pathogens, changes in fish behavior, and other outcomes.

Identifying the settings where these inputs of these contaminants are expected to have the maximum impact on fish, amphibian, and other biological resources as well as human health are an important factor to consider in assessing the occurrence of these compounds. Sources of EDCs include biosolids, animal manures, aging sewer infrastructure, septic systems, agricultural runoff, urban runoff, and other factors. Important considerations include assessing mixtures of the different type of chemical stressors and understanding how they interact with fish health issues, including, but not limited to endocrine disruption, reproductive changes, increased susceptibility to pathogens.

To meet the needs of assessing the impacts of EDCs, the USGS has developed a National Research Framework for Evaluation of Endocrine Disrupting Chemicals. Although this framework focuses on EDCs, it also offers a way to assess the impact of other chemical stressors on the health of aquatic communities, and so offers a guide to assessing a broader suite of chemical stressors. The USGS National Research Framework for EDCs have been developed to identify priority effects-directed analysis to research will be undertaken to identify the chemical or chemicals responsible for causing endocrine disruption in fish and wildlife inhabiting the Chesapeake Bay watershed. This will be achieved through a series of specific objectives: 1) Develop and validate the appropriate effects measures for direction of the chemical analysis based on the ED concerns in Chesapeake Bay; 2) Develop and validate a complementary chemical fractionation scheme and EDA strategy for the physical separation and testing of chemicals or chemical classes of suspected EDCs based on land-use practices in Chesapeake Bay watersheds; 3) Use the EDA methodology to identify chemicals that cause ED in exposed fish consistent with that observed in Chesapeake Bay. These chemical stressors also include some of the compounds included in the emerging issues such as neonicitoids, which have been identified as causing issues with pollinators in the watershed, and pharmaceuticals, which can affect both fish health and human health. Finally, assessing this broad suite of compounds also helps to meet the need to fill in gaps for assessing mixtures of chemicals.

This approach ensures that the appropriate set of sources, chemicals, and effects can be assessed to insure the integrity of biologic resources in the Chesapeake Bay region.

Issue: Present issues of emerging concern that should be considered in the future.

Summary papers will be prepared on (1) contaminant toxicity to pollinators, (2) microplastics, and (3) antibiotic resistance in gene expression in fish and wildlife. Each issue will be discussed with the TCW and other stakeholders if more research is needed and a policy/prevention strategy should be considered.

Issue: Provide implications for management approaches.

Information generated from the research strategy will be continuous shared with the TCW so they can consider options for mitigation impacts of toxic contaminants. One of the first activities will be assessing the potential for nutrient and sediment management to provide additional benefits to reduce contaminants. The work will be done during 2015 and results available in early 2016. The results will be shared with the CBP Water-Quality Goal Team so they can consider opportunities to emphasize practices that reduce simultaneously reduce nutrient and/or sediment as well as contaminants. For the contaminants found to have the primary effects on fish and wildlife, implications of the findings will be provided to help inform options for policy and prevention.

6.a **Local Engagement**

The research team will work with local organization to inform them of ongoing studies and discuss closer interaction. Potential interactions include have the researchers work with local government and non-profits to identify target locations in watersheds to demo tracking technologies, resulting in actual source-identification and elimination outcomes in targeted jurisdictions, and, at the same time, help to increase technical capacity of local participants.

1. **Monitoring Progress**

Two types of progress monitoring will be pursued:

1. Progress on completion of planned activities for actions not directly under the direction of the Partnership and progress for activities for which the TCW is directly committing to oversight and dedication of resources of the Partnership.
2. Assessment of whether planned actions are resulting in continual improvement of knowledge of occurrence, concentrations, sources and effects for the highest priority pollutants and whether the research agenda outcome is integrated with the policy and prevention outcome in a way that provides the information needed for future prevention strategies (i.e., beyond PCB reductions).
3. **Assessing Progress**

For type 1) progress monitoring as described above, the frequency of assessing progress will be at least annual so that adjustments to the biennial workplan can be made to accommodate changing circumstances and availability of resources. Formal review of type 1) progress data will be completed through the update of the biennial workplan.

Progress assessment based on type 2) monitoring will be conducted at a similar frequency as type 1) recognizing that the planning, completion and publishing of research is usually a multi-year process. Therefore, it is not expected that there will be rapid advancement in gaining more knowledge to reduce uncertainty.

1. **Adaptively Manage**

Adaptive management will focus on whether planned research is on schedule and is being completed (type 1 monitoring above) and whether new information is attained that shifts the TCW’s view on priorities. It is also possible that the needs of the kind of information to use in the policy and prevention outcome will influence adaptation of the research agenda. New technologies to be utilized in research may prompt adaptions to the research agenda.

1. **Biennial Workplan**

summarize the commitments, actions and resources that each jurisdiction, federal agency and partner will take to help achieve each of the outcomes.