Pallid Sturgeon Basin-Wide Contaminants Assessment

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EXECUTIVE SUMMARY

Pallid sturgeon (*Scaphirhynchus albus*), listed as endangered in 1990 under the federal Endangered Species Act (United States Fish and Wildlife Service (USFWS), 1990), have declined due to habitat loss, commercial fishing, and hybridization. Pollution in the Missouri and Mississippi Rivers has to-date only received minor attention as a factor in the on-going decline of wild pallid sturgeon populations (Jacobson et al. 2016a; Bergman 2008). Pallid sturgeon experts and contaminant specialists conceived of the Pallid Sturgeon Basin-Wide Contaminants Assessment (Assessment) to identify potentially harmful contaminants (contaminants of concern), their distribution within pallid sturgeon habitat, and their effects on pallid sturgeon at the landscape level. Extant water quality and analytical chemistry data from samples of river water, sediment, and sturgeon tissues from past studies, assessments, or monitoring activities throughout the species' range were used to establish a list of contaminants. The list includes: metal and non-metal elements, pesticides, organic industrial chemicals, hormones, nutrients, and other potential water quality contaminants. Environmental samples collected from January 1, 2001 through December 31, 2014, when available, were used for all evaluations.

This report is effectively a screening level hazard assessment whereby contituents of concern that may pose a potential harm to pallid sturgeon have been identified. These constituents of concern warrant further examination to determine the level of risk they pose to pallid sturgeon. The Assessment process was one of comparing the existing environmental data for individual constituents to reference values for adverse effects on fish specifically or aquatic life generally. The product of the Assessment is a simplified summary that is geographically organized by pallid sturgeon management unit that generally categorizes each individual contaminant or water quality constituent according to operationally defined levels of concern. This hazard assessment identifies potential constituents of concern to pallid sturgeon and may support prioritization for future data collection and research to enable a quantitative risk assessment.

Regional data density at spatial and temporal scales notwithstanding, the Assessment points to some generalities in contaminant concerns within and across management units. Metals but not pesticides are the predominant contaminant of concern in the Great Plains Management Unit (GPMU). In the Central Lowlands Management Unit (CLMU), selenium exceeds benchmark levels. Triazine herbicides are potentially of concern in all but the GPMU. Concentrations of legacy contaminants such as PCBs and DDT and its metabolites exceeded benchmarks in samples from the CLMU, Interior Highlands Mangement Unit (IHMU), and Coastal Plains Management Unit (CPMU), but local and national trends indicate environmental levels of these contaminants continue to decline. Observed concentrations of nutrients and indicators of nutrient pollution were above benchmark levels throughout the pallid sturgeon's range; however, the significance for pallid sturgeon health specifically is unknown. Almost no information exists on contemporary contaminants of concern such as the natural and synthetic estrogens (estradiol, ethinyl estradiol, and estrone) or polybrominated diphenyls (PBDEs).

There are considerable informational data gaps for contaminants throughout the species' range. Water quality measurements were the most frequent data encountered whereas, sediment and tissue data were orders of magnitude less frequent. The paucity of sediment and tissue concentrations, particularly the latter, prevents any meaningful conclusions regarding adverse effects of these contaminants on the growth and reproduction of pallid sturgeon. However, the

Assessment could form the basis for regional workshops with subject matter specialists to develop plans to evaluate the contaminants most likely to affect pallid sturgeon health.

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DISCLAIMER

This report is intended as an initial hazard assessment by which a variety of chemical contaminants and water quality constituents have been identified as possibly hazardous to pallid sturgeon. Various components of a classical risk assessment are broadly treated in this report, however, our approach does not include a comprehensive literature review nor the necessary probability and uncertainty analyses that distinguish a true risk assessment. Conclusions based on data and information from the various sources used to establish the adverse effects benchmarks must be subjected to further and more rigorous interpretation with the most current information available. Moreover, adverse effects for most contaminants of concern identified on the pallid sturgeon are based on fish species other than pallid sturgeon. The pallid sturgeon may not respond at the benchmark concentrations or in the same manner as other tested fish species. Although our determination of an exceedance of a contaminant benchmark indicates the potential for exposure to a contaminant, and following exposure, the potential for an adverse response by the organism, it is also essential to consider the role of additional site-specific conditions and the life history characteristics of the pallid sturgeon.

INTRODUCTION

Background and Justification

Pallid sturgeon (*Scaphirhynchus albus*) were listed as endangered in 1990 under the federal Endangered Species Act (United States Fish and Wildlife Service (USFWS) 1990, 1993). Habitat loss, commercial fishing, and hybridization have been postulated as the probable reasons for pallid sturgeon population decline (Dryer and Sandvol 1993, Ruelle and Keenlyne 1994, Keenlyne 1997, Campton et al. 2000, Galat et al. 2005, Colombo et al. 2007a, Bettoli et al. 2009). Two decades of conservation efforts to create habitat, manage river flows, and restrict commercial sturgeon harvest have been undertaken to recover the pallid sturgeon. A propagation and stocking program for pallid sturgeon has also been emphasized in order to prevent local extirpation in portions of the pallid sturgeon's range (USFWS 2007). Yet despite these efforts, a notable lack of natural recruitment continues within the Missouri River system and low to no recruitment typifies the Missouri and middle Mississippi Rivers (Jordan et al. 2016).

Pollution in the Missouri and Mississippi Rivers has to-date only received minor attention as a factor in the on-going decline of wild pallid sturgeon populations (Bergman 2008, Blevins 2011; Jacobson et al. 2016a). Water and sediment quality are degraded coincident with much of the pallid sturgeon's range. However, the extent to which the presence of contaminants adversely affects the health of pallid sturgeon and population recovery is unknown (Dryer and Sandvol 1993, USFWS 2007). The recently updated recovery plan addresses the potential threat contamination may pose and provides recommendations to identify, and where possible, remedy sources of detrimental environmental contaminants (USFWS 2014). Anticipating the Pallid Sturgeon Recovery Team's information needs, pallid sturgeon experts and contaminant specialists conceived of the Pallid Sturgeon Basin-Wide Contaminants Assessment (herein referred to as the Assessment): a landscape-level identification of potentially harmful contaminants, their distribution within pallid sturgeon habitat, and their effects on pallid sturgeon. This collaborative project is to our knowledge, the first comprehensive attempt at a basin-wide contaminants assessment for a federally endangered species.

A recent assessment of management options for pallid sturgeon populations in the Missouri River (Missouri River Effects Analysis; https://www.nwo.usace.army.mil/mrrp/effects-analysis/) considered contaminants among many other potential stressors affecting pallid sturgeon populations (Jacobson et al 2016a). The focus of the Effects Analysis was limited to management actions that could be undertaken by the U.S. Army Corps of Engineers (USACE) to avoid jeopardy on the Missouri River mainstem from Fort Peck Dam to the Mississippi River. Although the expert-opinion process used in the Effects Analysiss analysis ranked contaminants high in terms of potential effects, contaminants did not get selected as one of the dominant management hypotheses because of the lack of direct documentation of pallid sturgeon responses and because management of contaminants was considered to be outside of the authorities of the USACE (Jacobson et al, 2015; Jacobson et al 2016b). The Effects Analysis concluded that additional research on contaminants effects was warranted.

The overall goals for this Assessment are to identify contaminants of concern (COCs) within the pallid's range that pose a potential exposure hazard, to describe possible adverse effects on pallid sturgeon from exposure to toxic concentrations of these contaminants, and to identify gaps both in environmental data monitoring and research to understand the effects of COCs on pallid sturgeon. For the purpose of aiding in pallid sturgeon recovery, the Assessment serves as a screening-level hazard assessment by identifying the constituents that pose a potential source of harm to pallid sturgeon to assist in prioritization of data collection that can enable future quantitative risk assessments.

Pallid Sturgeon Vulnerability to Contaminant Exposure

Contaminants are defined here as chemicals within the habitats of the pallid sturgeon. Examples of contaminants include trace elements (e.g., arsenic), heavy metals (e.g., lead), legacy and modern pesticides (e.g., DDT, atrazine), petroleum hydrocarbons, organic chlorinated industrial chemicals (e.g., polychlorinated biphenyls (PCBs)), hormonally active agents (HACs) or endocrine disruptors, and nutrients. These originate from a variety of point and non-point sources including air emissions, industrial and municipal wastewater discharges, accidental chemical spills, and from run-off or drainage of agricultural lands. Legacy organochlorine pesticides and industrial chemicals are now largely banned from use in the United States; however, they degrade very slowly and are still known to occur in the environment at potentially harmful concentrations. Chemical contaminants with hormonal activity include certain household chemicals, pharmaceuticals, personal care products, and new synthetic industrial chemicals that can induce or inhibit normal hormonal activities in animals. Excessive loading of nutrients (e.g., nitrogen and phosphorus) into surface waters is a major cause for water quality impairment in the United States and can result in aquatic habitat degradation through eutrophication thus altering the trophic and physico-chemical composition of aquatic communities with cascading effects to fishes.

Pallid sturgeon life history characteristics make them sensitive to environmental contaminants in their habitats (Ruelle and Keenlyne 1994). As a bottom dwelling species, the pallid sturgeon is in physical contact with contaminated sediments throughout its life (Hurley et al. 2004, Braaten et al. 2011). The pallid sturgeon initially is a benthic feeder and later preys extensively on fish (Gerrity et al. 2006, Grohs et al. 2009). As a top predator, pallid sturgeon are more likely exposed to contaminants that have biomagnified in concentration up the food chain. Pallid sturgeon are long-lived and therefore will accumulate contaminants from the environment over their 30-plus years of life. The high lipid content of the species makes it especially likely to store lipophilic chemicals such as PCBs, dioxins, and organochlorine pesticides (OCPs). The species is both late-maturing and spawns on a multi-year cycle (Jordan et al. 2016), thus, pallid sturgeon may accumulate sufficient contaminants in tissues to maternally transfer toxic concentrations to sensitive developing embryos. Embryos and early-life stages appear to be sensitive to toxicological effects that may include decreased embryo hatching rate, decreased fry survival rates, reduced larval growth, and abnormal larval development (Buckler 2011).

There is growing evidence that pallid sturgeon are exposed to a wide variety of environmental contaminants. Organochlorine pesticides, PCBs, heavy metals, PAHs, and polybrominated diphenyl ethers (PBDEs) have been identified in Lower Missouri River sediments (Echols et al. 2008) and in the water column post-flood (Petty et al. 1995, 1998). Shovelnose sturgeon (*Scaphirhynchus platorynchus)*, commonly used as a surrogate for the pallid sturgeon, have high enough tissue concentrations of many contaminants to elicit consumption advisories for people. Currently, five of the ten states that list them as a sport species have consumption advisories due to elevated chlordane, an OCP, PCBs, and mercury in fillets and roe (Missouri Department of Health and Senior Services 2011). Additionally, a variety of environmental contaminants have been reported in shovelnose sturgeon throughout the Missouri, Mississippi, Platte, and Atchafalaya Rivers (e.g. Allen and Wilson 1991, Welsh and Olson 1992, Ruelle and Henry 1994, Conzelmann et al. 1997, Schwarz et al. 2006, Coffey et al. 2009, Buckler 2011).

High concentrations of contaminants have also previously been detected in wild pallid sturgeon although data on this rare species are scarce (Ruelle and Keenlyne 1993). For example, tissue samples from three Missouri River pallid sturgeon and 13 other pallid sturgeon, mostly collected from the Mississippi River, had heavy metals and trace elements (e.g., mercury, cadmium, and selenium), PCBs, and OCPs (e.g., chlordane, DDT, DDE, and dieldrin) at concentrations of concern (Ruelle and Keenlyne 1993, Ruelle and Henry 1994).

Studies on sturgeon species worldwide have suggested a link between contaminant exposure and adverse health effects for several species (e.g. Linville 1994, Kocan et al. 1996, Kruse 2000, Harshbarger et al. 2000, Coffey et al. 2003, Teh et al. 2003, Feist et al. 2005, Fitzpatrick 2005, Koch et al. 2006, Schwarz et al. 2006, Webb et al. 2006, Hu et al. 2009, Palumbo et al. 2009, Filizadeh and Rajab 2011, Chambers et al. 2012, Heydari et al. 2011, Hedayati and Jahanbakhshi 2012, Little et al. 2012, Vardy et al. 2013, Zahedi et al. 2013, Miandare et al. 2016). The high incidence of reproductive abnormalities (intersex and teratomas) found in both shovelnose and pallid sturgeon in parts of its range may correlate to exposure to endocrine disrupting chemicals (Wildhaber et al. 2007). A sturgeon health evaluation for the lower Platte River identified PCBs, selenium, and atrazine as contaminants that may be adversely affecting pallid sturgeon reproduction (Schwarz et al. 2006). Selenium and total PCBs in shovelnose sturgeon tissues exceeded concentrations known to cause reproductive impairment in some fish species and atrazine was identified in shovelnose sturgeon blood.

Recent studies indicate that point-source discharges may adversely affect pallid sturgeon and their habitat. End-of-pipe wastewater treatment plant (WWTP) effluent can contain hormonally active chemicals, and endocrine disruption in fish exposed to estrogenic substances discharged by WWTPs is well documented (Purdom et al. 1994, Routledge et al. 1998, Cheek et al. 2001, Schultz et al. 2003). Of particular concern are cities that have combined sewer systems (CSS) and do not separate storm-water run-off and sewage. Cities with CSSs are capable of discharging billions of gallons of untreated sewage and storm-water into pallid sturgeon habitats. In addition to WWTPs, drinking water treatment plants are also a concern. In April 2004, several radio-tagged pallid sturgeon were apparently staging at the mouth of the Platte River for a spawning run when they were repelled from the area immediately following a milky discharge from a drinking water treatment facility upstream (Parham et al. 2005). The facility had not been in compliance with its discharge permit that had expired in 1993, and the discharge likely contained several fish irritants including ferric sulfate, calcium oxide, hydrofluorosilicic acid, chlorine, and ammonia. Discharges from these point sources and others such as concentrated animal feeding operations (CAFOs) as well as non-point sources such as agricultural fields can also cause general water chemistry parameters such as dissolved oxygen, excessive nutrients (e.g., nitrogen, phosphorus), pH, ammonia, salinity, turbidity and temperature to vary outside of levels conducive to healthy aquatic organisms (Fontenot et al. 1998, Secor and Niklitschek 2001, Gisbert et al. 2004, USFWS 2005, Kirk et al. 2008, Kappenman et al. 2009, Blevins 2011, Liu et al. 2011, Nonnotte et al. 2017).

Contaminants may adversely affect pallid sturgeon through acute toxicity to the fish, indirectly by altering their habitat and prey base, or both. Short-term (acute) exposures in a large river system are uncommon but may result from an accidental contaminant release or a sudden nutrient-related change that causes depletion of dissolved oxygen, from which the pallid sturgeon may be unable to escape. Acute exposure will often result in immediate high mortality, cessation of feeding or breeding, and life-threatening stress or lesions. Chronic exposure to sub-acute contaminant concentrations over an extended period of time may also have adverse, albeit sublethal, effects on vital functions. Sub-lethal effects include behavioral disorders, abnormal hormone responses, reduced growth, suppressed immune function, chronic stress, and reduced reproductive success.

Population-level effects occur when individual reproductive success is lowered, the rate of survival or fitness of offspring is reduced, critical behaviors are affected, or growth is reduced. Contaminants alone or as an additional factor among the known habitat stressors may have important population-level consequences particularly when numbers of individuals are already severely low. Whether prolonged exposure to contaminants, alone or in addition to other environmental stressors, has affected pallid sturgeon populations is not known. However, examples exist of avian populations that declined to critically low levels from multiple environmental stressors including contaminants (e.g., bald eagles, condors, peregrine falcons).

Assessment Objectives

The objectives of this Assessment are to: 1) identify the COCs and data gaps within the species' range and 2) describe what is currently known about COC effects on sturgeon.

METHODS

Determination and Justification of Contaminants

Extant analytical chemistry data from samples of river water, sediment, and sturgeon tissue (as whole body, fillet, or organs) resulting from past studies, assessments, or monitoring activities throughout the species' range were used to establish the list of contaminants. The list includes: metal and non-metal elements, pesticides, organic industrial chemicals, hormones, nutrients, and other potential water quality constituents (Table 1).

Data Sources

Environmental samples collected from January 1, 2001 through December 31, 2014 were sought for all evaluations. Many of the sampling locations used in this Assessment were sampled repeatedly at different times of the year or over different years. In a few instances, there were insufficient data within this time frame, and therefore data from other time periods were used. Data for chemical concentrations in sturgeon tissues were especially scarce, and therefore, in some instances, data were augmented with information from other fish species. These exceptions are justified in the Assessment text.

The two principal databases used to compile the water chemistry data were the U.S. Environmental Protection Agency's (EPA) STORET (EPA 2011a) and the U.S. Geological Survey's (USGS) National Water Information System (NWIS) (USGS 2011a). Unfiltered values were used if available otherwise values are of filtered samples. The NWIS database and the sediment chemistry database from the USGS's Upper Mississippi River Sediment Quality Database provided sediment chemistry data (USGS 2011b). Additional sources of water and sediment chemistry data included tribal, government, and university data published in reports or the scientific literature. Three fish tissue residue databases were queried: the National Contaminants Biomonitoring Program database (USGS 2011c), the 1995 Biomonitoring of Environmental Status and Trends database (USGS 2011d), and the USFWS's Environmental Contaminants Data Management System (ECDMS) (USFWS 2011). However, only the USFWS database contained sturgeon tissue data. Other sources of information about contaminant concentrations found in fish tissues included government and university data published in reports or the scientific literature. Original data for this Assessment are provided in Appendix (A).

Data Organization and Presentation

The historic range of pallid sturgeon comprised more than 6,000 km of free-flowing river extending along a north-south latitudinal gradient from near the border between the United States and Canada to the Gulf of Mexico. Historic geographic separation and recent isolation because of dams has resulted in complex genetic groups or stocks (Schrey and Heist 2007). Thus, in order to maintain the greatest genetic diversity and because of distinct landscape differences, the USFWS divides the pallid sturgeon's range into four separate management units (Bergman 2008). The management units include, from upstream to downstream, the Great Plains (GPMU), Central Lowlands (CLMU), Interior Highlands (IHMU), and the Coastal Plains (CPMU; Figure 1). We have characterized and reported the contaminant concentration data in this Assessment according to these management units to better serve the pallid sturgeon recovery objectives to identify and reduce the greatest threats within each management unit (USFWS 2007, 2014).

Benchmark Identification

The compiled contaminant concentration data in the various media (water, sediment, and tissue) are compared to benchmark values. A contaminant benchmark, as defined for the purposes of this Assessment, is the concentration of a chemical or pollutant above which adverse effects, to fish specifically or aquatic life generally, may occur based on best available laboratory and or field studies.

The benchmark values and the specific sources for each benchmark are provided in Table 1. Benchmark values are also cited in individual tables. A variety of source materials were reviewed in order to compile the benchmarks for each of the contaminants. Water benchmarks were derived from water quality standards, surface water screening values developed by Region

IV of the EPA (EPA 2011b), screening values compiled by the National Oceanic and Atmospheric Agency (NOAA) in the Screening Quick Reference Tables (SQuiRT) (Buchman 2008) among others (see citations in Table 1). Sediment benchmarks were derived from consensus-based effects thresholds by Ingersoll et al. (2000), screening values by Region IV of the EPA (EPA 2011b), screening values in SQuiRT (Buchman 2008), and from the Oak Ridge National Laboratory Energy Systems and Environmental Restoration Program (ORNL 1997) (Table 1). Tissue benchmarks were based on critical-tissue-residue benchmark values from the U.S. Army Corp of Engineers' Environmental Residue Effects Database (ERED 2011) and the Linkage of Effects to Tissues Residues Database (Jarvinen and Ankley 1999) (Table 1). Benchmarks for some contaminants were established based on the best available science published in the peer-reviewed literature. When multiple benchmarks were possible, the lowest warm water fish critical-tissue-residue value was selected. No uncertainty or safety factors were used to adjust the critical-tissue-residue benchmarks.

Data Classification Relative to Benchmarks

A contaminant was identified as a COC if the environmental concentration was equal to or exceeded at least one benchmark either for water or sediment or tissue. A contaminant would also be classified as a COC if that particular contaminant had resulted in a contaminant regulatory action (e.g., an impaired water listing) within the management unit regardless of whether or not a benchmark exceedance was identified. The number of environmental samples that exceeded a benchmark per the total number of samples analyzed is reported for each chemical, for each medium (water, sediment, tissue), for each management unit (Tables 3 through 18). The rate of COC exceedances are not directly comparable within or across management units because of disparities in the number of samples collected, and therefore data available, within a management unit.

Contaminants that did not receive a COC designation were assigned to one of three categories. Contaminants that were not likely to occur because of temporal and spatial distribution or because of inherent chemical properties were identified as Not Likely (NL) of concern. Contaminants not of concern (NC) were identified as those contaminants for which there were adequate data available to assess that it did not exceed the benchmark. In many cases, a contaminant was suspected or likely to occur in a management unit, but no data were available to assess its status. These contaminants were classified as Data Gaps (DG).

A hazard quotient (HQ; https://www.chemsafetypro.com/Topics/CRA/How_to_Calculate_Hazard_Quotients_(HQ)_and_Risk_Quotients_(RQ).html) was also calculated for the subset of observations that exceeded a benchmark. The HQ is a value that is commonly used in Hazard Assessments in order to compare and prioritize among contaminants. The HQ was derived by calculating the geometric mean of the concentrations (only those greater or equal to the benchmark) and dividing this quantity by the benchmark.

Preliminary Hazard Conclusions

In addition to the individual tables for each media, a table summarizing the results for each chemical for the three media (sediment, water, tissue) and a Preliminary Hazard Conclusion is provided for each manangement unit. The four possible preliminary hazard conclusions paralleled the categories used for the individual medium: COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample in any media; NC = contaminant not of concern, contaminant for which there are adequate data available to assess that it does not exceed the benchmarks for any media; DG = data gap, contaminant that is likely to occur in the management unit, but its status was not evaluated because there were insufficient contaminant exposure data, limited spatial data collected, and/or a benchmark value could not be established; NL= not likely, contaminant that is not likely to occur because of the location in the basin. The identification of COCs is meant to infer potential hazard. Identification of COCs provides a list of contaminants for which further evaluation may be warranted and is an initial step in a precautionary approach to evaluate the impact of environmental quality on recovery of pallid sturgeon. A more rigorous evaluation of COC exposure and effects for pallid sturgeon would include evaluation of the timing and duration of exposure, bioavailability and metabolic detoxification, chemical mixture interactions, and species-specific differences in contaminant sensitivity between pallid sturgeon and the species used to establish the benchmarks.

The preliminary hazard conclusions developed in this Assessment may only be considered as the product of an initial screening because of the stated uncertainties inherent to this assessment (see Disclaimer). Screening level assessments are commonly undertaken as an initial step in risk analysis (e.g., EPA 2001). A conclusion of preliminary hazard indicates that potential adverse effects for a certain contaminant may occur or may be occurring based on available data. Additional data will be needed to evaluate the degree of risk (e.g. minimal, low, moderate, or high). Nevertheless, the identification of a set of COCs and discussion of those COCs that may be most detrimental to pallid sturgeon will be useful to direct future studies and to inform endangered species conservation practices.

RESULTS AND DISCUSSION

A total of 603 locations and 61,108 observations were evaluated over an estimated 2,884 miles of river habitat for pallid sturgeon (Table 2). Within each management unit the total number of locations and observations differed considerably however, the number per river mile was similar across management units. Years with available data varied greatly among management units and media. The IHMU and the CPMU had the most years with data and the CLMU and GPMU had the least. The greatest number of observations were for water and the fewest for tissue. There were no tissue data within the selected timeframe for the CPMU and GPMU, therefore, data from the early 1990's were used. The number of analytical results for water was greatest during 2007 (7,296 observations) and declined every year thereafter falling to only 186 observations in 2014 (Figure 2). The greatest number of observations for sediment was in 2004 (980 observations) declining thereafter. Two years, 2011 and 2014, there were no observations. There were no tissue observations for five of the 15 years from 2001 to 2014. Tissue observations were greatest in 2002 (518 observations) then varied between zero and 265 through 2010 after which there were no more tissue results available.

Great Plains Management Unit

Characterized contaminants in the GPMU are in Table 3 for sediment, Table 4 for water, and Table 5 for tissue. Sixteen COCs were identified as part of the preliminary hazard conclusion (Table 6). These include all the elements, except boron, PCBs, and all the nutrient and physical water quality indicators. Boron was identified as NC, and data gaps were identified for the remaining eighteen constituents that include all of the pesticides, the industrial organics other than PCBs, and all of the estrogens.

Elements. There were 530 surface water samples available for screening arsenic collected from numerous locations along the Missouri and Yellowstone Rivers, as well as some tributaries to those rivers. Of those samples, there were 116 exceedances (22%) of the water arsenic benchmark with an HQ of 1.9 (Tables 4 and 6). There were 51 arsenic sediment samples available. Exceedances of the arsenic sediment benchmark were observed in eight (16% with an HQ = 1.5) of the samples from five locations that included two locations on the Missouri River near Culbertson, MT, the Missouri River near Coal Banks Landing, the Milk River near Nashua, MT, and the Yellowstone River near Forsythe, MT. Of these locations sediment arsenic exceedances were most frequently observed at the Missouri River sites near Culbertson, MT. Only two values, reported in 1988 were found for arsenic in fish from the GPMU and neither exceed the benchmark for whole body tissue.

There were 101 surface water samples available for beryllium from numerous locations within the GPMU, although there were no samples available from the Missouri River. Of those samples, there were a total of two exceedances observed from the sampling sites on the Tongue River near Miles City, MT and Rosebud Creek, a tributary to the Yellowstone River near Rosebud, MT. Although only 2% of samples exceeded benchmark, the HQ was 4.1 (Table 6). A total of 10 sediment samples were available from a few different locations, but benchmarks were not established for sediments.

There were 284 surface water samples for cadmium available for screening from numerous locations along the Missouri and Yellowstone Rivers, as well as some tributaries to those rivers. There were 29 exceedances of the water cadmium benchmark (Table 4) for some of the samples from the Milk River near Nashua, MT; Missouri River near Wolf Point, MT; Tongue River near Mile City, MT; and the Powder River near Locate Creek. The majority of exceedances were from Powder River samples. The samples with exceedances were 10% of the total with an HQ of 3.1(Table 6). Fifty-one sediment samples were screened for cadmium from sites along the Missouri and Yellowstone Rivers, as well as some tributaries to those rivers; there were no exceedances. The only fish tissue data available for the screening were for sturgeon from 1983, 1988, 1992, and 1994. Of these, two whole body samples that exceeded the cadmium benchmark (HQ = 2.1; Table 6) were observed from the Missouri River immediately below the Yellowstone River and on the Yellowstone River immediately above the confluence with the Missouri River. Compared to known effects levels in other species, exceedances for cadmium in liver, kidney, and muscle tissues were also observed in samples collected from the Missouri River (not reported in Table 5). However, livers from two pallid sturgeon (1983) from the Missouri River in North Dakota were among three samples that did not exceed the effects level for liver cadmium.

There were 287 water samples and 54 exceedances (19% of samples and HQ = 2.6; Tables 4 and 6) for chromium from numerous locations along the Missouri and Yellowstone Rivers including from the Milk River near Nashua, MT; Missouri River near Wolf Point, MT and Coal Banks Landing; Tongue River at Miles City, MT; Powder River near Locate Creek; Rosebud Creek near Rosebud, MT; Yellowstone River near Sidney, MT; and Sears Creek near Crane, MT. Of these locations, the highest rates of exceedances were seen at the Powder River and Milk River locations near Locate Creek and Nashua, MT, respectively. There were no exceedances in the 51 chromium sediment samples, although there were exceedances for earlier time points outside of this Assessment. There were no chromium tissue data.

For copper, there were 391 water samples available from numerous locations with 42 exceedances (11% of samples and HQ = 3.1; Tables 4 and 6) of the water copper benchmark from locations on the Missouri River near Wolf Point, MT and Coal Banks Landing; Yellowstone River near Sidney, MT; Milk River near Nashua, MT; Tongue River near Miles City, MT; Powder River near Locate Creek and the confluence with the Yellowstone River; and Missouri River near Coal Banks Landing and just below the confluence with the Milk River. The greatest number of samples with exceedances came from the Powder River. There were no copper sediment exceedances. Historic pallid (1983 and 1988) and shovelnose sturgeon (1988, 1992 and 1994) tissue samples were available that included whole body (n = 2), kidney (n = 2), liver (n = 37), and muscle (n = 2) samples. The two whole body shovelnose sturgeon evaluated for this Assessment were from 1988 and did not exceed the benchmark. Compared to known effects levels in other species, exceedances for cadmium in liver, kidney, and muscle tissues were also observed (not reported in Table 5).

There were 55 exceedances of the benchmark for lead in 395 water samples (14% of samples; Table 4) collected from the Milk River near Nashua, MT; Missouri River near Wolf Point, MT and Coal Banks Landing; Tongue River near Miles City, MT; Powder River near Locate Creek; and Yellowstone River near Sidney, MT. The majority of the exceedances were seen in samples collected from the Tongue and Powder River locations. There were no lead sediment sample exceedances (Table 3). Historic (1988) whole body shovelnose sturgeon composite samples (n = 2) from one location on the Yellowstone River and one on the Missouri River exceeded the benchmark. Lead HQ was high for water (3.9) and also for tissue (19; Table 6).

There were 215 water samples and 41 sediment samples reviewed for mercury but no exceedances of the benchmarks. Historic (1988) whole body shovelnose sturgeon composite samples (n = 2) were available from single locations on the Yellowstone and Missouri Rivers.

Mercury exceeded the benchmark in each of these tissue samples. The HQ for these samples was 1.8 (Table 6).

There were 403 water samples for nickel with nine exceedances (2% of samples and HQ = 2.2; Tables 4 and 6) for some samples collected from the Tongue River near Miles City, MT; Powder River near Locate Creek; Rosebud Creek near Rosebud, MT; and Missouri River just below the confluence of the Milk River. Half of the 10 nickel sediment samples available had exceedances and an HQ of 1.1 (Tables 3 and 6).

There were 496 surface water selenium samples with 53 exceedances (11% of samples with HQ = 1.6; Tables 4 and 6) observed from the Tongue River near Miles City, MT; Powder River near Locate Creek; Yellowstone River near Sidney, MT; Missouri River near Coal Banks Landing; the Missouri River tributary Hardscrabble Creek near Culbertson, MT; and the Yellowstone River tributary O'Brian Creek located between Crane and Sidney, MT. Most of the surface water exceedances occurred in samples collected from the Powder River. There were no exceedances of the sediment samples nor the whole body shovelnose sturgeon tissue collected in 1988.

There were 471 surface water zinc samples and 94 surface exceedances observed from sites on the Milk River near Nashua, MT; Missouri River near Wolf Point, MT, Culbertson, MT and Coal Banks Landing; Tongue River at Miles City, MT; Powder River near Locate Creek; Yellowstone River near Sidney, MT; Marias River near Loma, MT; the Missouri River tributary Eagle Creek; Poplar River near Poplar, MT; and the Yellowstone River tributaries Rosebud and Sears Creeks. Most of the surface water exceedances were seen in samples collected from the Powder River. Two of 52 zinc sediment samples collected from the Marias River near Loma, MT exceeded the benchmark. Both water and sediment HQs were elevated at 3.3 and 3.6, respectively (Table 6).

Over 300 surface water boron samples were available for screening, but no exceedances occurred. Sediment and tissue data was not available for boron, nor were boron benchmarks established in those matrices. Regardless, boron was identified as NC due to the widespread availability of surface water screening data and lack of associated exceedances.

All of the elements identified as COCs within GPMU are naturally occurring, although numerous anthropogenic activities may also mobilize or release these elements and thus lead to their increase in concentration above expected background levels. Geothermal activity in Yellowstone National Park has been identified as a source of arsenic to the upper Missouri River, and naturally elevated arsenic concentrations also occur in late Wisconsin-aged glacial till deposits, a common geological feature for parts of the GPMU (Nimick et al 1998, Fullerton et al. 2004, Erickson and Barnes 2005). Numerous seleniferous geologic units are found within the GPMU that include upper cretaceous marine sedimentary rocks and tertiary continental sedimentary deposits. These deposits likely contribute some background selenium load to waterbodies within the GPMU, but anthropogenic activities like the application of phosphate fertilizers and land irrigation may mobilize arsenic and selenium, respectively, increasing the concentrations of these COCs to levels of concern (Seiler et al. 1999, Welch et al. 2000). Further, Seiler et al. (1999) identified areas susceptible to irrigation-induced selenium contamination in the western United States, some of which occur within the GPMU.

Current and historic mining operations and energy extraction activities are likely sources for all of the identified element COCs within the GPMU and are some of the largest current producers for chromium, copper, and lead within the management unit (Zelt et al. 1998, USGS 2006, EPA 2016a). Electricity generation, particularly from coal-fired power plants, and petroleum refining are also large producers of these COCs within the GPMU (EPA 2016a). Numerous other known current and historic sources of elements exist within the GPMU that do not necessarily report quantities produced or released. These include the dumping or application of sewage sludge on lands, smelting, stormwater runoff, and wastewater discharge (Nriagu and Pacyna 1988, Karvelas et al. 2003). Some fertilizers, pesticides, and agricultural practices may be a significant source of copper within the GPMU in addition to selenium and arsenic (Eisler 1998, Kilbride et al. 1998). Long range atmospheric transport and deposition of lead and mercury is a likely source of lead and mercury contamination to the GPMU. Local emission sources also exist that include aircrafts, locomotives, and coal-fired power that contribute lead and mercury (EPA 2014, EPA 2016a). In addition to coal-fired power plants, waste incineration, forest fires, and leaching of mercury-containing waste are additional sources of mercury within the GPMU.

Some of the COCs were also identified by Montana Department of Environmental Quality as contributing causes of impairments under the Clean Water Act to some of the waterbodies found within the GPMU. Some of the stretches of the Missouri River above Fort Peck Reservoir were identified as impaired on the 2016 303(d) list with arsenic, copper, and lead as three of the contributing causes. The source of the arsenic and copper was attributed to impacts from abandoned mines, while the source of the lead was unidentified. Portions of the lower Yellowstone River were included on the 2016 303 (d) list of impaired waters with chromium, copper, and lead as some of the contributing causes. The sources of chromium, copper, and lead to the Yellowstone River were unidentified. Sites on the Powder River consistently had exceedances of surface water and sediment benchmarks. The Powder River Basin is a highly productive area for coal bed methane, coal, petroleum, conventional natural gas, and uranium. These activities, particularly those in the upper basin, may contribute to some of the elevated elements detected in the Powder River sampling sites (Dreher and Finkelman 1992, Zelt et al. 1998, Ramirez et al. 2005).

Pesticides. The preliminary hazard conclusion for all of the GPMU pesticides were data gaps (Table 6). This is mainly due to limited sampling locations within the GPMU, limited or lack of sediment data, lack of understanding of sediment effects associated with some of the pesticides, and potential for effects due to the mixture of two or more pesticides. Surface water data was available for all of the pesticides, although data was limited for 2,4-D, chlordane, DDT, and DDD. For the remaining pesticides, more than 100 samples were available for each of those pesticides that represent collections made in the Missouri and Yellowstone Rivers, as well as some of their tributaries. The concentrations for carbaryl, chlorpyrifos, diazinon, and dieldrin were all less than the reporting limit, and there were no exceedances of any surface water pesticide benchmarks. It should be noted that for surface water screening of most of the pesticides, there was only a single sample location available for the Missouri River that was located near Culbertson, MT. Within the GPMU, there is a higher density of agriculture found within many of the watersheds draining to the Missouri River, particularly below Fort Peck reservoir compared to those watersheds draining to the Yellowstone River; this suggests that sections of the Missouri River may be more susceptible to pesticide runoff from upland agricultural operations. Therefore, data gaps remain for all of the pesticides based on limited surface water sampling locations.

Only three sediment samples from 1998 were available for sediment screening that quantified chlordane, dieldrin, DDD, and DDE concentrations, and these were collected from locations on the Yellowstone and Powder Rivers. Of those samples, there were no exceedances (Table 3). Whole body tissue concentrations were available for chlordane, dieldrin, DDT, DDD, and DDE based on two composite samples of shovelnose sturgeon collected in the Missouri and Yellowstone Rivers in 1988, but no exceedances occurred. Data gaps remain for sediment and tissue pesticide concentrations due to the limited or complete lack of available screening data.

Data gaps remain for all of the pesticides in the GPMU due to a lack of understanding of sediment effects for some of the pesticides, and the potential for additive or synergistic effects due to the interactions among certain pesticides. The 2,4-D, carbaryl, chlopyrifos, diazinon, metolachlor, and triazine herbicides are used throughout the GPMU, and many have been detected in the GPMU groundwater (Schmidt 2008). Miller et al. (2004) reported that in the Yellowstone River Basin, atrazine and its degradation products are the most commonly detected herbicides, chlorpyrifos is the most commonly detected insecticide, and a mixture of two or more pesticides was detected in 75% of the samples tested. The North Dakota Department of Agriculture reported that 2,4-D was the most frequently detected pesticide in the Yellowstone River in North Dakota in 2009, although concentrations were below the surface water benchmark for 2,4-D (Johnson 2012). In addition to 2,4-D, various other pesticides not considered in this report were also detected (Johnson 2012). The persistent and hydrophobic nature of some of the legacy pesticides such as chlordane, DDT and its degradation products, and dieldrin means that these compounds will likely accumulate in sediments and tissues. Additional sediment and tissue samples would be necessary to properly characterize their hazard within the GPMU.

Industrial Organics. PCBs were identified as a COC within the GPMU (Table 6). Data gaps were identified for all of the other industrial organics due to the lack of available screening data or limited data. Within the GPMU, there were no data available for dioxins/furans, nonylphenol, and PBDEs, and only limited screening data was available for total PAHs and PCBs. Dioxins/furans are by-products created during pesticide manufacturing and pulp and paper bleaching. Further, they can be released to the environment during the combustion process that can include activities like waste incineration and wildland fires. Pesticide manufacturing and pulp and paper bleaching are limited within the GPMU, however, waste incineration and wildland fires occur throughout the management unit. Nonylphenol is an endocrine disruptor that is a degradation product of detergents. As such, it is often detected in wastewater treatment plant effluent. Many treatment plants are located throughout the GPMU that may serve as a source of nonylphenol to this management unit. Similarly, PBDEs are a group of flame-retardant compounds that are also detected in the effluent of wastewater treatment plants.

Three total PAH sediment samples were collected from the Yellowstone and Powder Rivers in 1998. No exceedances were observed at these three sites, but the potential for PAH contamination is great due to the large number of potential sources located throughout the GPMU that include industrial and municipal discharges, road and other impervious surface runoff, and recreational watercraft use. Further, major oil spills have occurred within the GPMU that have resulted in detectable levels of PAHs in tissues and documented injury in certain fish species (FWP 2015; DOI 2017). Spills will likely continue within the GPMU due to ongoing oil activity present within the management unit, specifically the oil production targeting the Bakken Formation and Williston Basin, and the transportation network that exists within the GPMU that carries oil and other products that often intersect with pallid sturgeon habitat. Therefore, PAHs are considered a data gap because the three samples available for this assessment are not enough to fully characterize the hazard of these compounds throughout the entire management unit.

Only two tissue samples were available for screening of PCBs within the GPMU. These samples were composite whole body shovelnose sturgeon samples that were collected from the Missouri and Yellowstone Rivers near their confluence. Of these two composite samples, there was one PCB exceedance (HQ = 1.9; Table 6) observed in the Missouri River sample. The PCBs are persistent hydrophobic compounds that readily bioaccumulate within organisms. Although PCBs are no longer manufactured, they are found ubiquitously throughout the environment and may be transported great distances through the atmosphere. Due to the exceedance observed in the one tissue sample, PCBs are considered a COC for the GPMU. Additional sampling to expand the spatial coverage and media sampled is required to improve the understanding of potential impacts of PCBs within this management unit.

Nutrients, Chlorophyll a, and pH. Ammonia, total nitrogen, and total phosphorus were all identified as COCs for the GPMU (Table 6). Of the 493 surface water samples available for ammonia that were collected from sites in the Missouri and Yellowstone Rivers, as well as some tributaries to those rivers, there only were 3 exceedances (Table 4), but there is an elevated HQ of 5.7 (Table 6). These exceedances occurred in the Poplar River and Arrow Creek, both tributaries to the Missouri River. There were 350 total nitrogen surface water samples available for screening that were collected from numerous locations within the GPMU that included sites along the Missouri and Yellowstone Rivers, as well as some tributaries to those rivers. There were 178 surface water exceedances (51% of samples, HQ = 2.1; Tables 4 and 6) for total nitrogen observed within the GPMU that included samples collected from the Milk River, Missouri River, Yellowstone River, Tongue River, and Powder River. For total phosphorus, there were 690 surface water samples available for screening that were collected from numerous locations within the GPMU that included sites along the Missouri and Yellowstone Rivers, as well as some tributaries to those rivers. There were 584 total phosphorus surface water benchmark exceedances (85% of samples, HQ = 3.1; Tables 4 and 6) that were widespread and occurred at most sites within the GPMU where a total phosphorus sample was collected.

Chlorophyll a and pH were also identified as a COCs within the GPMU. Of the 150 chlorophyll a surface water samples available for screening, which included samples taken from the Missouri, Yellowstone, and Powder Rivers, there were 35 exceedances (23 % of samples, HQ = 1.8; Tables 4 and 6) observed from samples collected from the Missouri and Yellowstone Rivers. Data for pH was available for surface water at almost every site assessed across the GPMU that included locations on the Missouri, Powder, Marias, Milk, Tongue, and Yellowstone Rivers, as well as many of the smaller tributaries to the Yellowstone and Missouri Rivers. Of the data available, there were two exceedances observed. These exceedances occurred in a single sample from the Missouri River near Culbertson, MT and Shadwell Creek, a small tributary to the Yellowstone River near Crane, MT. Based on these exceedances, pH was designated as a COC for the GPMU.

In February 2015, the Montana Department of Environmental Quality received a letter of approval from EPA for their proposed numeric water quality criteria intended to control excessive nutrient (nitrogen and phosphorus) pollution in Montana's streams, rivers, and lakes. To date, nutrient criteria have only been developed for the lower Yellowstone River and wadeable streams; criteria have not been developed for the Missouri River. The new nutrient criteria for the Yellowstone River are separated by river reach; one reach being the confluence of the Big Horn River to the Powder River confluence and the other being the Powder River confluence to the state line. For the Big Horn River confluence to the Powder River confluence segment, total phosphorus and total nitrogen criteria are 90 µg/L and 700 µg/L, respectively. For the Powder River confluence to the state line segment, total phosphorus and total nitrogen criteria are 140 µg/L and 1000 µg/L, respectively. This compares to the total phosphorus and total nitrogen benchmarks 90 µg/L and 700 µg/L, respectively, which were used for this analysis and were based on EPA Ecoregional Recommended Nutrient Criteria for rivers and streams. Although Montana's new suggested criteria are higher compared to the benchmarks used for this analysis, exceedances still occurred at most sites in the Yellowstone River when surface water total nitrogen and total phosphorus data were compared to the new criteria.

Nutrient sources within the GPMU are numerous and include both non-point and point sources. This includes natural sources, such as nitrogen and phosphorus found in soils that may be transported to rivers via some natural or anthropogenic process and other anthropogenic sources, such as the application of fertilizer or livestock waste. Point sources, such as discharges at wastewater treatment plants and concentrated animal feeding operations, are also found throughout the GPMU. Furthermore, atmospheric deposition is another source that is likely contributing nutrients to the GPMU. Although nutrients are not listed as potential causes of some of the impairments identified in the Yellowstone and Missouri Rivers under Section 303 (d) of the Clean Water Act, many of the smaller tributaries to those rivers have nitrogen and phosphorus listed as probable causes of impairments in those waterbodies.

Based on the pH measurements taken across the GPMU, the waterbodies within the management unit are typically neutral to alkaline (pH 7 to pH 8). The two pH exceedances were 9.45 and 9.51. Numerous natural factors can affect the pH of water including local geology, precipitation, climate, and photosynthesis and respiration by aquatic plants. Humans can also influence the pH of water by various actions that can include the modification of the surrounding land cover or land use or through the discharge or release of various industrial pollutants.

Estrogens. Estrogen data was not available for screening within the GPMU; therefore all of the estrogens are considered data gaps. Numerous potential sources of estrogens are located within the GPMU that include wastewater treatment plants, septic tanks, and concentrated animal feeding operations. Additional information is required to characterize the potential hazard of estrogens to pallid sturgeon within the GPMU.

Central Lowlands Management Unit

Characterized contaminants in the CLMU are in Table 7 for sediment, Table 8 for water, and Table 9 for tissue. The majority of the available data are for elements and pesticides in water. Sixteen COCs were identified for the preliminary hazard conclusion (Table 10). These included arsenic, cadmium, copper, lead, mercury, nickel, selenium, chlorpyrifos, DDT, triazine herbicides, PCBs, pH, nitrogen, phosphorus, ammonia, and chlorophyll a. Boron is not of concern and beryllium is not likely of concern due to the lack of exceedances observed throughout the CLMU and expected low likelihood of exposure. The remaining 17 contaminants were classified as having data gaps.

Elements. Benchmark values for elements in the CLMU were exceeded more often in tissue and sediment (arsenic, copper, cadmium, lead, mercury, nickel, and selenium) than in water. In the Lower Platte River, where pallid sturgeon have been observed in recent years, selenium water concentrations were greater than 2 µg/L and whole body concentrations were as high as 9 mg/kg dw. However, excess selenium in this system has been determined to be due to the natural geology of the area (Nebraska Department of Environmental Quality 2014). Also, Papoulias et al. (https://ecos.fws.gov/ServCat/DownloadFile/21408?Reference=22888) found that early life stage *Scaphirhynchus* sturgeons did not show adverse effects at egg concentrations less than 12 µg/g dw of selenium, three times higher than benchmark, suggesting they may have developed some tolerance to selenium in this system. Only selenium exceeded benchmarks across media. Nickel exceeded benchmarks in only a few sediment samples from the Missouri

River. Chromium and zinc did not exceed any benchmarks, but because so few sediment samples were analyzed, it was considered a data gap. The HQ was greatest for sediment selenium (3.2; Tables 7 and 10) however, only 6% of samples exceeded the benchmark. Over 50% of water and tissue samples exceeded selenium benchmarks with HQs of 1.4 and 1.3, respectively (Tables 7, 8, and 10). Cadmium, lead, and mercury were slightly greater than twice benchmarks for tissue with 15-30% of samples exceeding (Table 9). Arsenic in water and sediment had similar HQs of 1.3 and 1.2, respectively (Tables 7, 8, and 10).

Pesticides. Pesticides were not sampled very often in sediments or tissues where they are likely to accumulate and for this reason the majority of the pesticides were designated as data gaps. One of 24 sediment samples exceeded the DDT benchmark in the Missouri River near RM 490. The triazine herbicides and chlorpyrifos were the only contaminants of concern identified in the several hundred water samples analyzed in the CLMU (Table 8). Chlorpyrifos was designated a COC because it exceeded the benchmark in one water sample of 281 (0.062 µg/L) from the Big Sioux near Akron, IA (Table 8). Triazines, in contrast to most of the other pesticides evaluated for this assessment, are quite water soluble and currently in heavy use in the Midwest around the Missouri River and its tributaries (https://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=2012&map=ATRAZINE&hilo=L&disp=Atrazine); 16% of samples were above benchmark (Table 8). The Elkhorn River, a major tributary to the Platte River, tended to have the highest concentrations of triazines from the sources examined for this review. The HQ for triazine herbicides (4.1) in water was the highest of the three COC pesticides (Table 10).

Industrial Organics. Very few data were found for the chemicals associated with industrial activities. Dioxins/furans, nonylphenol, PAHs and PBDEs were all identified as having data gaps (Table 10). Polybrominated biphenyls were measured in 60 sediment samples (concentration < 1 part per billion), but there is no sediment benchmark (Table 7). The presence of PBDEs in sediment and the current understanding of these compounds' distribution, persistence, and effects in fishes make PBDEs a concern and therefore a priority data gap to address relative to exposure to sturgeon in the CLMU. The PCBs were a COC in this management unit and exceeded the tissue benchmark in 5 of 10 samples with an HQ of 2.7 (Tables 9 and 10).

Nutrients, Chlorophyll a, and pH. The general water quality indicators of ammonia, chlorophyll a, nitrogen, and phosphorus all had numerous exceedances over benchmark values and are identified as COCs in the CLMU (Tables 8 and 10). In a few cases, pH was also either above or below threshold. Among these constituents, HQ for chlorophyll a was highest at 14.6 followed by phosphorus at 3.1 (Table 10). Run-off from agricultural lands and confined animal feeding operations (CAFOs) are the most likely sources given that these are principal land use activities in Nebraska, Iowa, and South Dakota (Soto et al., 2004, Wright and Wimberly 2013). The amount by which concentrations of nitrogen and phosphorus have exceeded the benchmark has been increasing over time consistent with changing land use patterns (Wright and Wimberly 2013).

Estrogens. No data were available on estrogens in the CLMU, therefore estradiol, ethinyl estradiol, and estrone were identified as having data gaps.

Interior Highlands Management Unit

Categorization of the general list of contaminants to be evaluated for the IHMU may be found in Table 11 for sediment, Table 12 for water, and Table 13 for tissue. Twenty COCs were identified for the preliminary hazard conclusion (Table 14). These include the elements arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc; the pesticides chlordane, chlorpyrifos, dieldrin, DDE, DDT, and triazine herbicides; the industrial organic PCBs; the nutrients nitrogen, phosphorus, ammonia, and chlorophyll a. Four contaminants were classified as not likely to be of concern and no contaminants were considered as not of concern. An additional eleven were identified as having data gaps.

Elements. Heavy metals are predominantly associated with water and sediments but were measurable in water, sediment, and tissues in the IHMU. There were nine elements identified as COCs within the IHMU (Table 14).

Neither sediment nor water samples exceeded the benchmark for mercury. However, shovelnose sturgeon tissue samples exceeded the benchmark for mercury in 58% of samples analyzed with a calculated HQ of 2.0 (Tables 13 and 14). These exceedances occurred in both the Missouri River near Mokane, MO and Weldon Spring, MO and in the Mississippi River near Crystal City, MO and Cape Girardeau, MO.

Arsenic, cadmium, chromium, copper, lead, and zinc are considered COCs for the pallid sturgeon in the IHMU in both surface water and exposure to contaminated sediment. Surface water exceedances all occurred in the Missouri River near Chesterfield, MO and St. Charles, MO. There was only one exceedance recorded in the Mississippi River portion of the IHMU for surface water and that was for lead and arsenic near St. Louis, MO. Exceedances in sediments for the six elements occurred in both the Missouri River at Hermann, MO and in the Mississippi River at Thebes, IL. Cadmium, copper, lead and zinc also exceeded the benchmark in samples taken from the Mississippi River at river mile 152 near Herculaneum, MO. Arsenic was above benchmark in sediments from several additional sites in the Mississippi River. No exceedances of cadmium or lead were found for fish tissue in approximately 40 fish analyzed. No current fish tissue data were available for chromium, copper, or zinc.

Selenium in surface water is considered a COC for the pallid sturgeon in the IHMU. Surface water samples exceeded the benchmark in 28 of 302 samples analyzed for selenium. These exceedances occurred in both the Missouri River near Hermann, MO, Chesterfield, MO, and St. Charles, MO, and in the Mississippi River near Oakville, MO. A data gap exists as to whether selenium in sediment and tissue is considered a COC in the IHMU.

Nickel is considered to be a contaminant of concern for the pallid sturgeon in the IHMU only through exposure to contaminated sediment. These exceedances were found in both the Missouri River at Hermann, MO and in the Mississippi River at Thebes, IL. No detections were made above the benchmark in 151 surface water samples analyzed for nickel. A lack of tissue data is considered a data gap for nickel.

Beryllium and boron are considered not likely to be contaminants of concern for the pallid sturgeon in the IHMU. The only boron data available for review was for surface water. Neither beryllium nor boron had exceedances of their water benchmarks. Beryllium was measured in six sediment samples and averaged 1.5 mg/kg but there is no benchmark for evaluation. No data existed for fish tissue samples.

Zinc and lead in sediments had the highest HQs at 40.7 and 23.4, respectively although less than 5% of samples exceeded benchmarks. Mercury is notable in that 56% of samples averaged twice as much as the benchmark.

Major sources of arsenic, cadmium, chromium, copper, and nickel are municipal and industrial wastewaters, and stormwater run-off. Selenium and mercury are contaminants in some types of coal used in Missouri and are distributed into the air as coal is burned, as leachate from coal ash pits, and when used on roadways for ice. There are approximately five coal burning power plants within the IHMU. Selenium and arsenic are also commonly found in agricultural runoff. One of the world's largest lead-zinc mining areas, southeastern Missouri's New Lead Belt, is in the drainage of the IHMU.

Pesticides. There were five pesticides identified as COCs within the IHMU. Of these identified pesticide COCs, one is considered as COCs in water, and four are considered a COC in fish tissue. Current data were limited for several of the pesticides, and because of this, several data gaps exist for the IHMU in this contaminant class. Pesticides of concern in the IHMU include: chlordane, chlorpyrifos, dieldrin, triazine herbicides, DDE, and DDT (Table 14).

Triazine herbicides are considered contaminants of concern for pallid sturgeon in the IHMU in surface water with exceedences observed in 34% (HQ = 1.4) of samples analyzed. These triazine herbicide exceedances were recorded in both the Missouri River near Boonville and Hermann, MO and in the Mississippi River near Thebes, IL. Triazine herbicides, in particular atrazine, are used heavily on crops throughout the IHMU and on lands draining into the upper Mississippi River. Tissue exceedances for DDT and DDE were similar occurring in 14% and 19%, respectively, of samples (HQ $\geq$ 2.0) analyzed (Tables 13 and 14). Chlordane exceeded the tissue benchmark in 21% of the samples (HQ = 1.7) and dieldrin in 10% of samples (HQ = 1.8; Tables 13 and 14). The shovelnose sturgeon exhibiting these exceedances were collected in the Missouri River near Hartsburg, MO and in the Mississippi River at river mile 89, Cape Girardeau and Crystal City. Only five sediment samples were analyzed for these two constituents with no exceedances.

The organochlorine pesticides chlordane and DDT were banned in the USA in 1983 and 1972, respectively, and dieldrin was voluntarily removed from the market in 1987. The temporal trend in concentration of these chemicals in the IHMU reflects the nationally decreasing trend in riverine systems. However, because of their environmental persistence, elevated concentrations are still found today in sediments and biota even without new inputs to the river.

Two-hundred fifteen water samples in the IHMU were available with no exceedance of the metolachlor water benchmark. However, no data were found for sediment or in tissue. Since no metolachlor data were available for these media, data for sediments and tissue were identified as data gaps. Similarily carbaryl, with 110 water samples but no tissue or sediment samples, was viewed as a data gap that would need to be filled before an assessment could be completed. In addition, 2,4-D, carbaryl, diazinon, and metalochlor were identified as data gaps for this assessment because insufficient data were available. Residential use of chlorpyrifos was cancelled in 2001, and although it is still used on crops in the IHMU, trends show a reduction of use and concentrations in water bodies (Sullivan et al. 2009). Only one of 206 water samples exceeded the benchmark (Table 12).

Industrial Organics. Pallid sturgeon are exposed to industrial organics in the IHMU portions of the Missouri and Mississippi Rivers. Tissue concentrations of PCBs have been documented in shovelnose sturgeon and other fish species and were found to exceed the effects threshold in nearly 94% of samples with an HQ of 5.7 (Tables 13 and 14). Fish fillet tissue PCB concentrations suggest that PCB contamination is widespread in both the Missouri and Mississippi Rivers, with concentrations being somewhat elevated below major urban centers (Kansas City and St. Louis). Exceedances were also found in all of four egg samples taken throughout the IHMU and all eight testicular samples taken from the Missouri River at Boonville, MO.

Today, the most likely sources for PCBs to enter and persist in aquatic systems are unreclaimed waste sites, sediment transport, and trophic cycling (WHO 1992, Hooper and McDonald 2000). Although PCBs are rarely detected in water samples, passive sampler data showed spikes in PCBs after the 1993 floods of the Missouri River indicating PCBs persist in depositional sediments and soils of the flood plain (Petty et al. 1995, 1998). PCBs are regularly found in fish tissues in the IHMU, and as a result, Missouri has issued fish consumption advisories for shovelnose sturgeon as well as catfish and carp in the Missouri and Mississippi Rivers (Missouri Department of Health and Senior Services, 2012).

PCBs are suspected of originally entering the Missouri and Mississippi Rivers from several sources. The Monsanto company produced PCBs from the 1930s to the 1970s at its plant in the village of Sauget, IL near the Mississippi River across from St. Louis, MO. The plant and a tributary of the Mississippi River, Dead Creek, are EPA superfund sites. Gavins Point Dam, SD and NE, is a hydroelectric plant built in the 1950s that likely used PCBs in equipment for electricity generation.

Dioxins/furans and PBDEs are also detected in fish tissues, generally co-occurring with PCBs (Buckler 2011). Analysis of tissue samples from the IHMU found 95 measurements of PBDEs (highest concentration was 2.9 mg/kg), but no measurements were available for dioxins and furans (Table 13). The PBDE compounds are of concern, however, no exceedances could be determined lacking a benchmark value. Measurement of PAHs and nonylphenol in the IHMU has been infrequent. Sediment data indicate that most concentrations of PAHs measured are below probable effects levels (Echols et al. 2008). Water concentrations of PAHs were detected at relatively low concentrations by Petty et al. (2004) near Columbia, MO using a passive sampling device. Similarly, nonylphenol was detected but not quantified in passive samplers (Petty et al. 2004).

Dioxins/furans, nonylphenols, and PBDEs are known to occur in the IHMU environmental media but insufficient data were available to assess exposure. In addition, insufficient information was available to establish benchmarks for nonylphenol and PBDEs in tissue. Therefore, these three industrial organic compounds were identified as data gaps for this assessment.

Nutrients, Chlorophyll a, and pH. Nutrient pollution is a concern in the IHMU. Total nitrogen and phosphorus exceeded the benchmark for 66% (HQ = 1.3) and 92% (HQ = 4.8) of samples analyzed, respectively, for surface water (Tables 12 and 14). Ammonia (2% of the samples with average HQ of 1.2) and chlorophyll a (33% of samples with average HQ of 5.4) exceeded the benchmark for surface water but in fewer samples (Tables 12 and 14). All exceedances occurred in both the Missouri River near Hamburg and Hermann, MO and in the Mississippi River near Thebes, IL. Ammonia enters the Missouri River IHMU primarily through municipal wastewater and storm water runoff. Confined animal feeding operations can be a source of ammonia, but their contribution to the Missouri River in the IHMU is not known. Water pH outside of healthy temperate river values (6.5 - 9.0) is not likely of concern with over 400 measurements and no benchmark exceedances (Tables 12 and 14).

Estrogens. Estrogens also enter the Missouri River IHMU through municipal wastewater, storm water runoff, and CAFOs. Concentrated phytoestrogens may be problematic where ethanol plants discharge wastes (Lundgren and Novak 2009). Very little sampling has occurred in this reach of the river for estrogenic compounds and can be considered a data gap for the IHMU. However, Petty et al. (2004) using POCIS extracts in the YES assay estimated the surface water near Columbia, MO had estrogenic activity equivalent to 1 nM of 17β-estradiol.

Coastal Plains Management Unit

Categorization of the general list of contaminants to be evaluated for the CPMU may be found in Table 15 for sediment, Table 16 for water, and Table 17 for tissue. Twenty three COCs were identified for the preliminary hazard conclusions (Table 18). Existing fish consumption advisories within the CPMU include a 31-mile reach of the mainstem Mississippi River at Memphis, Shelby County, TN and segments of major tributaries and back channels (i.e., Wolf River, Loosahatchie River, Nonconnah Creek, and McKellar Lake) within that municipality.

It should be noted that pollution monitoring and control efforts are inconsistent within the CPMU, and all of the load allocation controls stipulated in TMDLs related to non-point sources are voluntary. There are also differences among the approaches taken by and available resources of management agencies responsible for the individual state water quality monitoring and enforcement programs. Current use pesticides, as well as legacy organochlorines, are not routinely monitored in the CPMU, and many have no applicable water quality criteria.

Elements. There were 10 elements identified as COCs within the CPMU. Boron was not of concern (Table 18). Of these, nine are considered a COC in sediment, the same nine are COCs in water, and four are a COC in fish tissue. Elements of concern in the CPMU include: arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc. Arsenic, cadmium, lead, and mercury had exceedances for the three matrices (Table 18).

Arsenic is implicated in designated water quality use impairments under Section 303(d) in the CPMU. There were numerous cadmium and lead exceedances at the Iberville Parish, Plaquemine, and Pointe Coupee Parish, and Louisiana stations. Lead concentrations above the benchmark value were also observed in the Lower Hatchie River watershed and the Wolf River in Memphis, TN. Exceedances of copper were noted in the Lower Hatchie River watershed in

Tennessee and at the Pointe Coupee Parish and Plaquemine stations in the Atchafalaya River.

Exceedances of mercury for all matrices were noted from tributaries of the Mississippi River in Kentucky and Tennessee. Atmospheric deposition of mercury, primarily from fossil fuel power plants, is the primary source of mercury contamination in the management unit. Although relatively minor, there are also industrial point source discharges that still contain mercury in the CPMU. These observed exceedances may also be attributable to fertilizers and/or natural salts in highly erodible soils. Historical records (early1990s) for tissue samples collected from both shovelnose and pallid sturgeon also indicated exceedances of the benchmarks for mercury in shovelnose whole-body samples and pallid sturgeon muscle tissue samples. Exceedances of human health risk-based concentrations for mercury have resulted in waterbody use impairments in numerous locations throughout the lower Mississippi River basin. The HQs for the elements spanned an order of magnitude from 1.0 for sediment selenium to 25.6 for surface water selenium (Table 15, 16, and18). The next highest HQ was for mercury at 4.2 for 23% of water samples and 3.5 for 85% of fish tissues. Seventy-five percent of tissue samples had a calculated HQ of 2.3 for lead (Tables 17 and 18). Greater than 90% of chromium and nickel sediment samples exceeded the benchmark but HQs were 1.6 and 1.7, respectively (Tables 15 and 18).

Pesticides. There were seven pesticides identified as COCs within the CPMU. Of these, one is considered a COC in sediment, three are a COC in water, and four are a COC in fish tissue. Pesticides of concern in the CPMU include: chlopyrifos, diazinon, dieldrin, DDD, DDE, DDT, and triazine herbicides. Pesticides classified as DG within the management unit include: 2,4-D, carbaryl, chlordane, and metalochlor. Chlorpyrifos had the highest HQ (4.9) of the pesticides but accounted for less than 1% of the water samples (Tables 16 and 18). By contrast, 22% of tissue samples analyzed for DDT exceeded the benchmark with an HQ of 3.5 (Tables

17 and 18). Triazine herbicides had an HQ of 2.2 for 18% of samples in surface water (Tables 16 and 18).

Discharges in the lower Mississippi River heavily influence ambient water quality conditions, and there are significant seasonal fluxes of pesticides in the mainstem. Dieldrin exceedance was noted at St. Francisville. Numerous atrazine exceedances were observed above Vicksburg, St. Francisville, Baton Rouge, Belle Chasse, Luling, and Venice. Numerous atrazine exceedances were also observed in the Atchafalaya River at Melville, LA. The level of atrazine in one surface water sample approached the benchmark value at Tiptonville, TN.

Limited sediment data for current use pesticides were available at only one site at Tiptonville, TN. All except DDE were below the analytical method detection limits (Tables 15 and 18). DDT, its metabolites, and dieldrin exceeded tissue benchmarks (Tables 17 and 18).

Industrial Organics. PCBs were identified as COCs within the CPMU. An HQ of 5.7 was derived for 55% of the tissue samples (Tables 17 and 18). The remainder of the industrial organics were classified as data gaps for lack of data.

Industrial organics are associated with historical and current industrial point source discharges. These contaminants have contributed to impairments of the river's designated uses under Section 303(d) of the Clean Water Act. In the absence of contemporary data, historical records for tissue samples (1990s) indicated exceedances of the benchmarks for PCB Aroclors 1242, 1248, 1254 and 1260 in pallid sturgeon gonadal, liver, and muscle tissue.

The PAHs pose a potential hazard to aquatic habitats in areas where significant petroleum refining and petrochemical operations are occurring in the CPMU. There's also a growing body of biological exposure and effect data related to higher molecular weight PAHs and aliphatic hydrocarbons in storm water runoff in urbanized areas; however, these compounds are not routinely monitored in the management unit.

Nutrients, Chlorophyll a, and pH. All five constituents in this group were identified as COCs within the CPMU (Table 16 and 18). Although ammonia may be expected as a concern in oxbow and back channel habitats, as well as smaller tributaries, one exceedance was noted in the mainstem at Baton Rouge. Greater than 80% of nitrogen, phosphorus, and chlorophyll samples exceeded bencmarks with HQ ranging from 1.4 to 2.0 (Tables 16 and 18).

Estrogens. There were no data available for estradiol, ethinyl estradiol, and estrone within the CPMU. These three constituents are classified as DG (Table 18).

SUMMARY

This Assessment has identified several contaminants of concern at sufficiently high concentrations to be possible hazards for pallid sturgeon. These constituents were present in water and sediment through the pallid's range and found in the tissues of pallid and shovelnose sturgeon.

The suite of COCs identified for each management unit was generally consistent with the landuse in the watershed of that stretch of river. The GPMU was characterized by elemental COCs in water: arsenic, beryllium cadmium, chromium, copper, lead, nickel, selenium, and zinc. Only arsenic, nickel, and zinc were also COCs in sediments. These reflect the minerals in the soils and mining activity in the upper basin. Fewer elements were identified as COCs for the CLMU and the IHMU, however, the waters of the CPMU again show the same suite of COC elements as the GPMU with the difference that they were also COCs in sediments. The CPMU as the last stretch of river might be expected to be a sink for many contaminants. Mercury was a COC in all three matrices in the CPMU but only so in tissues of the other three upstream management units indicative of its potential for bioaccumulation and biomagnification. Arsenic was also ubiquitous in water and sediment throughout the range, but not found in tissues. Selenium was a COC in all matrices in the CLMU owing to the presence of seleniferous soils in this region. Triazine herbicides first appear as a COC in the CLMU which coincides with the corn belt. Triazines are found downstream but at lower concentrations. Beginning with the IHMU through the CPMU the number of COCs for the pesticide and industrial organics categories increases especially in sediments and tissue. Nutrients and general water quality indicators were COCs in water throughout the range.

There were no contaminants that were not of concern throughout the pallid sturgeon's range. However, boron was not of concern in all but the IHMU, where it was classified as not likely of concern. Metalochlor, dioxins/furans, nonylphenol, PAHs, PBDEs, and the estrogens (estradiol, ethinyl estradiol, and estrone) were found to be data gaps in all management units. The contaminants identified through a screening level hazard assessment such as was conducted here are assumed to be causing harm until further evaluation proves differently. The overriding purpose of the Assessment was therefore to catch all actual COC's, even at the expense of catching some false COC's that will ultimately be released later after further evaluation.

A glaring result of this Assessment is the lack of information available for sediments and tissues particularly in as much as these data are the most useful in evaluating adverse effects on pallid sturgeon and other species of concern. Data gaps are also notable for the contemporary contaminants of concern such as PBDEs, estrogens, nonyphenol and others that are known chemical contaminants in residential and municipal waste streams. This Assessment also highlights that evaluation of contaminants and water quality in the Missouri and Mississippi Rivers has tended to decrease over the years perhaps reflecting the defunding of USGS river monitoring stations and discontinuation of programs such as the National Contaminants Biomonitoring Program, which periodically evaluated contaminants in the nation's large river systems, and the USFWS Environmental Contaminants Program, a formerly good source of tissue data for trust species. The Missouri and Mississippi Rivers are arguably dynamic sinks for chemicals that move off and out of the watershed. Although many of these chemicals will eventually move into the Gulf of Mexico, during their long residence time in the riverine environment, they may be a hazard for the pallid sturgeon. This Assessment identifies those potential chemical hazards and underscores the need for more monitoring and research before an adequate evaluation of the risk that chemical contaminants pose for the endangered pallid sturgeon.

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Great Plains Management Unit

Central Lowlands Management Unit

Interior Highlands Management Unit

Coastal Plains Management Unit

Figure 1. Map of pallid sturgeon range with management units identified.

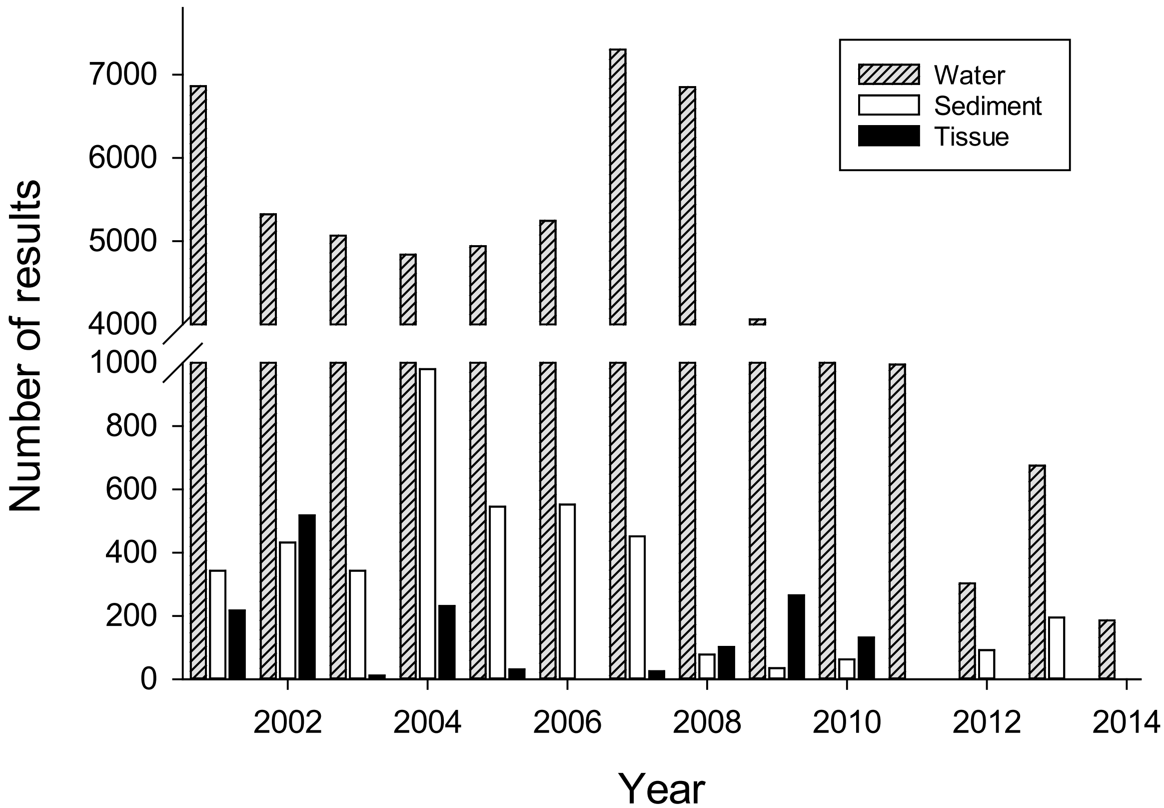

Figure 2. The number of individual constituent results found for each year from 2001 through 2014 for water, sediment, and tissue within the geographic range of pallid sturgeon habitat.

Table 1. Benchmarks established for this assessment to protect fish and their habitat from select contaminants in water, sediment and fish tissue. NA = not applicable.

Contaminants Evaluated	**Effects to Fish**	**Benchmarks*** **			**References**
Elements		Water (µg/L)	Sediment (mg/kg)	Tissue** (mg/kg)	
Arsenic (total)	Fin and head deformities, liver damage, decreased growth and survival	5	9.8	2	EPA 2006, USDOI 1998, Jarvinen and Ankley 1999, MacDonald et al. 2000, Kumari et al. 2017
Beryllium	Gill damage, indirect effects based on decreased invertebrate prey	5.3	No Benchmark	No Benchmark	EPA 1980, Jargo et al. 2002
Boron	Early life stage mortality.	1500	No Benchmark	No Benchmark	CCME 2009
Cadmium	Decreased growth and survival.	0.25*	1.0	0.11	Jarvinen and Ankley 1999, MacDonald et al. 2000, EPA 2016b
Chromium (total)	Decreased mass, reproduction, dcreased invertebrate prey.	11	43	No Benchmark	MacDonald et al. 2000
Copper	Growth and reproductive effects (spawning failure, decreased egg size)	9*	32	10.56	Jarvinen and Ankley 1999, MacDonald et al. 2000

Lead	Developmental deformities, decreased growth and survival.	3.0*	36	0.34	Jarvinen and Ankley 1999, MacDonald et al. 2000
Mercury	Adverse effects on survival, growth, reproduction, behavior.	0.7	0.18	0.04	Jarvinen and Ankley 1999, MacDonald et al. 2000, Sandheinrich and Wiener 2011
Nickel	Gill damage, embryo mortality, behaviorial effects.	52 *	23	No Benchmark	Eisler 1998, MacDonald et al. 2000
Selenium	Deformites, larvae and juvenile mortality, reproductive failure.	2.0	2.0	4 dw	Henderson et al. 1995, Lemley 1996, Stephens et al. 1997, Seiler et al. 2003
Zinc	Avoidance, decreased reproduction, habitat modification.	30	121	No Benchmark	Suter and Tsao 1996, MacDonald et al. 2000, Woodward et a. l 1997, Brungs 1969
Pesticides					
2,4-D	Habitat altered by herbicide action, direct toxic effects at higher concentrations	70	No Benchmark	No Benchmark	EPA 2009

Carbaryl	Delayed hatching, altered behavior, decreased invertebrate prey.	0.5	No Benchmark	No Benchmark	EPA 2008a, HSDB 2012
Chlordane	Hyperexcitability, increased respiration, reduced survival and reproduction.	0.00215	0.0017	0.6	Eisler 1990
Chlorpyrifos	Incoordination, delayed maturation and growth, reduced reproduction.	0.041	No Benchmark	No Benchmark	Eisler 1988
Diazinon	Reduced growth, survival and reproduction. Decreased invertebrate prey.	0.17	No Benchmark	No Benchmark	Eisler 1986, EPA 2008b
Dieldrin	Endocrine disruption, reduced survival, growth.	0.056	0.0019	0.11	EPA 1995 , Becvar and Lotufo 2011
DDD	Interrenal function and cortisol metabolism.	0.0064	0.0033	0.6	Lacroix and Hontela, 2003
DDE	Endocrine disruption, reproductive and	10.5	0.00142	0.29	EPA 2001, Becvar and Lotufo 2011

	behavior effects, mortality.				
DDT	Endocrine disruption, reproductive and behavior effects, mortality.	0.0005	0.00119	0.0256	Buchman 2008, Becvar and Lotufo 2011
Metolachlor	Endocrine disruption, habitat alteration from herbicide action.	100	No Benchmark	No Benchmark	Yuanxiang et al. 2011
Triazine herbicides (atrazine,simazine, propazine)	Endocrine disruption, reduced growth and reprodution, habitat alteration.	0.5	No Benchmark	No Benchmark	Moore and Waring 1998; Moore and Lower 2001; Papoulias et al. 2006; Suzawa and Ingraham 2008
Industrial Organics					
Dioxins/Furans	Deformities, impaired reproduction and growth, ealrly life stage mortality.	0.00001	0.00000085	0.0021	Wenning et al. 2011
Nonylphenols	Endocrine disruption, decreased reproduction.	5.0	No Benchmark	No Benchmark	Ishibashi et al. 2006; Kurihara et al. 2007; Brian et al. 2005; Schoenfuss et al. 2008
PAHs	Wide range of effects: narcosis, mortality all life	No Benchmark	1.61	No Benchmark	Logan 2007

	stages, decreased growth, lower condition factor, edema, cardiac dysfunction, deformities, skin and liver lesions and tumors, cataracts, damaged immune systems, estrogenic effects.				
PBDE	Thyroid system toxicity and direct or indirect effects on reproduction	No Benchmark	No Benchmark	No Benchmark	Yu et al. 2015
PCBs	Endocrine disruption, impaired growth and reproduction, altered behavior.	0.014	0.0227	0.15	Wenning et al 2011
Nutrients, Chlorophyll a, and pH					
Total Nitrogen	Habitat and prey altered by eutrophication, decreased dissolved oxygen	310 - 2180	NA	NA	EPA Ecoregional Nutrient Criteria Documents (http://www.epa.gov/waterscience/

					criteria/nutrient/ ecoregions/rivers/index.html)
Ammonia	Loss of equilibrium, hyper-excitability, increased respiration, loss of prey	300 at pH 8, Temp at 25^{0}C	NA	NA	Augspurger et al. 2003
Total Phosphorus	Habitat and prey altered by eutrophication, decreased dissolved oxygen	10 - 128	NA	NA	EPA Ecoregional Nutrient Criteria Documents (http://www.epa.gov/ waterscience/ criteria/nutrient/ ecoregions/rivers/index.html)
Chlorophyll a	Bioindicator of eutrophication and altered fish habitat	0.93 - 3.00	NA	NA	EPA Ecoregional Nutrient Criteria Documents (http: //www. epa.gov/ waterscience/criteria/ nutrient/ ecoregions/ rivers /index.html)
pH	Physiological effects, damage to gills, eyes, and skin	6.5 – 9.0	NA	NA	EPA 1976
Estrogens					
Estradiol	Endocrine disruption, decreased reproduction	5 ng/L	NA	NA	Brian et al. 2005; Thorpe et al. 2001

Ethinyl estradiol	Endocrine disruption, decreased reproduction	3 ng/L	NA	NA	Brian et al. 2005; Thorpe et al. 2001
Estrone	Endocrine disruption, decreased reproduction	50 ng/L	NA	NA	Thorpe et al. 2001

Note: Reference citations available in References Section,
NA = not available
* Benchmark values require conversions based on hardness.
** = whole body wet weight unless otherwise noted, more stringent benchmarks were also evaluated based on concentrations in tissues other than whole body and are explained in the results.
***Screening level benchmark and does not necessarily correspond to all the effects on fish that are listed.

Table 2. Description and indicators of relative availability of data by management unit. No. = number.

Management unit	Approx river miles (RM)	No. Locations	No. locations per RM	Years Data Available						Total observations	No. observations per RM
				No.	Tissue Years	No.	Sediment Years	No.	Water Years		
Coastal Plains	1,250	318	*0.25*	*3*	[1991-1993]	*10*	2001-2010	*13*	2001-2013	38,775	*31*
Interior Highlands	250	49	*0.20*	*8*	2001-2005, 2007-2009	*7*	2001-2004, 2008-2010	*11*	2001-2008 2010-2012	6,482	*26*
Central Lowlands	453	69	*0.15*	*1*	2002	*4*	2002, 2004-2006	*13*	2001-2013	7,339	*16*
Great Plains	931	167	*0.18*	*2*	[1992, 1994]	*3*	2001, 2012-2013	*14*	2001-2014	8,512	*9*
Totals	2,884	603	*0.21*	*14*		*24*		*51*		61,108	*21*

Table 3. Categorization of the general list of the contaminants of concern for **sediment** in the **Great Plains Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples (N) available to evaluate the constituent is listed. NA = Not Applicable. * = total number of data points available.

Contaminant	**Benchmark (mg/kg)**	**# Exceedances of N**	**Hazard Quotient**	**Decision**
Trace Elements				
Arsenic	9.8	8 of 51	1.5	COC
Beryllium	No Benchmark	*10	NA	DG
Boron	No Benchmark	No Data	NA	NL
Cadmium	1	0 of 51	NA	NL
Total Chromium	43	0 of 51	NA	NL
Copper	32	0 of 10	NA	NL
Lead	36	0 of 50	NA	NL
Mercury	0.18	0 of 41	NA	NL
Nickel	23	5 of 10	1.1	COC
Selenium	2	0 of 10	NA	DG
Zinc	121	2 of 52	3.6	COC
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.0017	No Data	NA	DG
Chlorpyrifos	No Benchmark	No Data	NA	DG
Diazinon	No Benchmark	No Data	NA	DG
Dieldrin	0.0019	No Data	NA	DG
DDT	0.00119	No Data	NA	DG
DDD	0.0033	No Data	NA	DG
DDE	0.00142	No Data	NA	DG
Metolachlor	No Benchmark	No Data	NA	DG
Triazine herbicides	No Benchmark	No Data	NA	DG
Industrial Organics				
Dioxins/Furans	8.5×10^{-7}	No Data	NA	DG
Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	1.61	No Data	NA	DG

PBDE	No Benchmark	No Data	NA	DG
PCBs	0.0227	No Data	NA	DG
Nutrients, Chlorophyll, and pH				
Ammonia	NA	NA	NA	NA
Total Nitrogen	NA	NA	NA	NA
Total Phosphorus	NA	NA	NA	NA
Chlorophyll a	NA	NA	NA	NA
pH	NA	NA	NA	NA
Estrogens				
Estradiol	NA	NA	NA	NA
Ethinyl estradiol	NA	NA	NA	NA
Estrone	NA	NA	NA	NA

Table 4. Categorization of the general list of the contaminants of concern for **water** in the **Great Plains Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples (N) available to evaluate each contaminant is listed. NA = Not Applicable. * = a hardness dependent benchmark where values were calculated using the range of hardness values present in the GPMU. # = values based on EPA's aggregate nutrient ecoregion IV reference conditions.

Contaminant	**Benchmark (µg/L)**	**# Exceedances of N**	**Hazard Quotient**	**Decision**
Trace Elements				
Arsenic	5	116 of 528	1.9	COC
Beryllium	5.3	2 of 101	4.1	COC
Boron	1500	0 of 319	NA	NC
Cadmium*	0.25	29 of 284	3.1	COC
Total Chromium	11	54 of 287	2.6	COC
Copper*	9	42 of 391	3.1	COC
Lead*	2.5	55 of 395	3.9	COC
Mercury	0.7	0 of 215	NA	NL
Nickel*	52	9 of 403	2.2	COC
Selenium	2	53 of 496	1.6	COC
Zinc	30	94 of 471	3.3	COC
Pesticides				
2,4-D	70	0 of 38	NA	DG
Carbaryl	0.5	0 of 186	NA	DG
Chlordane	0.00215	0 of 2	NA	DG
Chlorpyrifos	0.041	0 of 263	NA	DG
Diazinon	0.17	0 of 264	NA	DG
Dieldrin	0.056	0 of 229	NA	DG
DDT	0.0005	0 of 2	NA	DG
DDD	0.0064	0 of 2	NA	DG
DDE	10.5	0 of 193	NA	DG
Metolachlor	100	0 of 269	NA	DG
Triazine herbicides	0.5	0 of 257	NA	DG
Industrial Organics				
Dioxins/Furans	0.00001	No Data	NA	DG

Nonylphenol	5	No Data	NA	DG
PAHs	No Benchmark	No Data	NA	DG
PBDE	No Benchmark	No Data	NA	DG
PCBs	0.014	No Data	NA	DG
Nutrients, Chlorophyll, and pH				
Total Nitrogen	310 - 700 #	178 of 350	2.1	COC
Ammonia	300 at pH 8, Temp at 25˚C	3 of 493	5.7	COC
Total Phosphorus	10 – 90 #	584 of 690	3.3	COC
Chlorophyll a	0.93 – 3.00	35 of 150	1.8	COC
pH	6.5 – 9.0	2 of 740	1.1	COC
Estrogens				
Estradiol	0.005	No Data	NA	DG
Ethinyl estradiol	0.003	No Data	NA	DG
Estrone	0.05	No Data	NA	DG

Table 5. Categorization of the general list of the contaminants of concern for **tissue** in the **Great Plains Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available (N) to evaluate the constituent is listed. NA = not applicable. Tissue data are from 1992 and 1994.

Contaminant	Benchmark (mg/kg)	# Exceedances of N	Hazard Quotient	Decision
Elements				
Arsenic	2	0 of 2	NA	DG
Beryllium	No Benchmark	No Data	NA	NL
Boron	No Benchmark	No Data	NA	NL
Cadmium	0.11	2 of 2	2.1	COC
Total Chromium	No Benchmark	No Data	NA	DG
Copper	10.56	0 of 2	NA	DG
Lead	0.34	2 of 2	19	COC
Mercury	0.04	2 of 2	1.8	COC
Nickel	No Benchmark	No Data	NA	DG
Selenium	4 (dw)	0 of 2	NA	DG
Zinc	No Benchmark	No Data	NA	DG
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.6	0 of 2	NA	DG
Chlorpyrifos	No Benchmark	No Data	NA	DG
Diazinon	No Benchmark	No Data	NA	DG
Dieldrin	0.11	0 of 2	NA	DG
DDT	0.025	0 of 2	NA	DG
DDD	0.6	0 of 2	NA	DG
DDE	0.29	0 of 2	NA	DG
Metolachlor	No Benchmark	No Data	NA	DG
Triazine Herbicides	No Benchmark	No Data	NA	DG

Industrial Organics				
Dioxins/Furans	0.0021	No Data	NA	DG
Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	No Benchmark	No Data	NA	DG
PBDE	No Benchmark	No Data	NA	DG
PCBs	0.15	1 of 2	1.9	DG
Nutrients, Chlorophyll, and pH				
Total Nitrogen	NA	NA	NA	NA
Ammonia	NA	NA	NA	NA
Total Phosphorus	NA	NA	NA	NA
Chlorophyll a	NA	NA	NA	NA
pH	NA	NA	NA	NA
Estrogens				
Estradiol	NA	NA	NA	NA
Ethinyl estradiol	NA	NA	NA	NA
Estrone	NA	NA	NA	NA

Table 6. Preliminary hazard conclusion table for the **Great Plains Management Unit**. Data are presented as % exceedances, total number observations in parentheses, and hazard quotient in bold. NA = not applicable; NB = no benchmark.

Contaminant	Water Exceedances	Sediment Exceedances	Tissue Exceedances	Preliminary Hazard Conclusion
Elements				
Arsenic	22 (528) **1.9**	16 (51) **1.5**	0 (2)	COC
Beryllium	2 (101) **4.1**	NB	NB	COC
Boron	0 (319)	NB	NB	NC
Cadmium	10 (284) **3.1**	0 (51)	100 (2) **2.1**	COC
Total Chromium	19 (287) **2.6**	0 (51)	NB	COC
Copper	11 (391) **3.1**	0 (10)	0 (2)	COC
Lead	14 (395) **3.9**	0 (50)	100 (2) **19**	COC
Mercury	0 (215)	0 (41)	100 (2) **1.8**	COC
Nickel	2 (403) **2.2**	50 (10) **1.1**	NB	COC
Selenium	11 (496) **1.6**	0 (10)	0 (2)	COC
Zinc	20 (471) **3.3**	4 (52) **3.6**	NB	COC
Pesticides				
2,4-D	0 (38)	NB	NB	DG
Carbaryl	0 (186)	NB	NB	DG
Chlordane	0 (2)	No Data	0 (2)	DG
Chlorpyrifos	0 (263)	NB	NB	DG
Diazinon	0 (264)	NB	NB	DG
Dieldrin	0 (229)	No Data	0 (2)	DG
DDD	0 (2)	No Data	0 (2)	DG
DDE	0 (193)	No Data	0 (2)	DG
DDT	0 (2)	No Data	0 (2)	DG
Metolachlor	0 (269)	NB	NB	DG
Triazine Herbicides	0 (257)	NB	NB	DG
Organic contaminants				
Dioxins/Furans	No Data	No Data	No Data	DG
Nonylphenol	No Data	NB	NB	DG
PAHs	NB	No Data	NB	DG
PBDE	NB	NB	NB	DG

Contaminant	Water Exceedences	Sediment Exceedences	Tissue Exceedances	Preliminary Hazard Conclusion
PCBs	No Data	No Data	50 (2) **1.9**	COC
Nutrients, Chlorophyll, and pH				
Total Nitrogen	51 (350) **2.1**	NA	NA	COC
Ammonia	1 (493) **5.7**	NA	NA	COC
Total Phosphorus	85 (690) **3.3**	NA	NA	COC
Chlorophyll a	23 (150) **1.8**	NA	NA	COC
pH	< 1 (740) **1.1**	NA	NA	COC
Estrogens				
Estradiol	No Data	NB	NB	DG
Ethinyl estradiol	No Data	NB	NB	DG
Estrone	No Data	NB	NB	DG

Table 7. Categorization of the general list of the contaminants of concern for **sediment** in the **Central Lowlands Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available (N) to evaluate the constituent is listed. NA = not applicable. * = total number of data points available.

Contaminant	Benchmark (mg/kg)	# Exceedances of N	Hazard Quotient	Decision
Elements				
Arsenic	9.8	5 of 22	1.2	COC
Beryllium	No Benchmark	*1	NA	NL
Boron	No Benchmark	No Data	NA	NL
Cadmium	1	0 of 32	NA	DG
Total Chromium	43	0 of 21	NA	DG
Copper	32	1 of 36	1.0	COC
Lead	36	0 of 36	NA	DG
Mercury	0.18	0 of 32	NA	DG
Nickel	23	3 of 36	1.2	COC
Selenium	2	1 of 18	3.2	COC
Zinc	121	0 of 36	NA	DG
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.0017	0 of 24	NA	DG
Chlorpyrifos	No Benchmark	*14	NA	DG
Diazinon	No Benchmark	*14	NA	DG
Dieldrin	0.0019	0 of 11	NA	DG
DDT	0.00119	1 of 24	1.4	COC
DDD	0.0033	0 of 10	NA	DG
DDE	0.00142	0 of 10	NA	DG
Metolachlor	No Benchmark	No Data	NA	DG
Triazine herbicides	No Benchmark	No Data	NA	DG

Industrial Organics				
Dioxins/Furans	8.5 x 10^{-7}	No Data	NA	DG
Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	1.61	No Data	NA	DG
PBDE	No Benchmark	*60	NA	DG
PCBs	0.0227	0 of 9 (as 18 congeners)	NA	DG
Nutrients, Chlorophyll, and pH				
Total Nitrogen	NA	NA	NA	NA
Ammonia	NA	NA	NA	NA
Total Phosphorus	NA	NA	NA	NA
Chlorophyll a	NA	NA	NA	NA
pH	NA	NA	NA	NA
Estrogens				
Estradiol	NA	NA	NA	NA
Ethinyl estradiol	NA	NA	NA	NA
Estrone	NA	NA	NA	NA

Table 8. Categorization of the general list of the contaminants of concern for **water** in the **Central Lowlands Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available to evaluate the constituent is listed. NA = not applicable. * = a hardness dependent benchmark where values were calculated using the range of hardness values present in the CLMU. ** = total number of data points available.

Contaminant	**Benchmark (µg/L)**	**# Exceedances of N**	**Hazard Quotient**	**Decision**
Trace Elements				
Arsenic	5	55 of 406	1.3	COC
Beryllium	5.3	0 of 310	NA	NL
Boron	1500	0 of 370	NA	NC
Cadmium*	0.25	0 of 80	NA	DG
Total Chromium	11	0 of 25	NA	DG
Copper*	9	0 of 103	NA	NL
Lead*	2.5	0 of 80	NA	NL
Mercury	0.7	0 of 58	NA	NL
Nickel*	52	0 of 48	NA	NL
Selenium	2	122 of 225	1.4	COC
Zinc	30	0 of 51	NA	DG
Pesticides				
2,4-D	70	0 of 18	NA	DG
Carbaryl	0.5	0 of 466	NA	NC
Chlordane	0.00215	No Data	NA	DG
Chlorpyrifos	0.041	1 of 281	1.5	COC
Diazinon	0.17	0 of 381	NA	NC
Dieldrin	0.056	0 of 381	NA	NC
DDT	0.0005	No Data	NA	NL
DDE	10.5	0 of 32	NA	NC
DDD	0.0064	No Data	NA	NL
Metolachlor	100	0 of 383	NA	NC
Triazine herbicides	0.5	64 of 393	4.1	COC

Industrial Organics				
Dioxins/Furans	0.00001	No Data	NA	DG
Nonylphenol	5	0 of 4	NA	DG
PAHs	No Benchmark	**1	NA	DG
PBDE	No Benchmark	No Data	NA	DG
PCBs	0.014	No Data	NA	DG
Nutrients, Chlorphyll, and pH				
Total Nitrogen	310 - 2180	82 of 285	1.9	COC
Ammonia	300 at pH 8, Temp at 25˚C	9 of 286	1.9	COC
Total Phosphorus	10 - 128	138 of 286	3.1	COC
Chlorophyll a	0.93 - 3.00	26 of 31	14.6	COC
pH	6.5 – 9.0	11 of 1411	1.6 - 1	COC
Estrogens				
Estradiol	0.005	No Data	NA	DG
Ethinyl estradiol	0.003	No Data	NA	DG
Estrone	0.05	No Data	NA	DG

Table 9. Categorization of the general list of the contaminants of concern for **tissue** in the **Central Lowlands Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available (N) to evaluate the constituent is listed. Data are for whole body wet weight unless otherwise indicated. dw = dry weight. NA = not applicable. * = total number of data points available.

Contaminant	Benchmark (mg/kg)	# Exceedances of N	Hazard Quotient	Decision
Trace Elements				
Arsenic	2	0 of 24	NA	DG
Beryllium	No Benchmark	*24	NA	NL
Boron	No Benchmark	*24	NA	NL
Cadmium	0.11	4 of 24	2.3	COC
Total Chromium	No Benchmark	*24	NA	DG
Copper	10.56	0 of 24	NA	DG
Lead	0.34	6 of 24	2.4	COC
Mercury	0.04	8 of 24	2.4	COC
Nickel	No Benchmark	*24	NA	DG
Selenium	4 (dw)	22 of 42	1.3	COC
Zinc	No Benchmark	*24	NA	DG
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.6	0 of 34	NA	DG
Chlorpyrifos	No Benchmark	No Data	NA	DG
Diazinon	No Benchmark	No Data	NA	DG
Dieldrin	0.11	0 of 14	NA	DG
DDT	0.025	0 of 28	NA	DG
DDD	0.6	0 of 28	NA	DG
DDE	0.29	0 of 28	NA	DG
Metolachlor	No Benchmark	*21	NA	DG
Triazine herbicides	No Benchmark	*57	NA	NL

Industrial Organics				
Dioxins/Furans	0.0021	No Data	NA	DG
Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	No Benchmark	No Data	NA	DG
PBDE	No Benchmark	No Data	NA	DG
PCBs	0.15	5 of 10	2.7	COC
Nutrients, Chlorophyll, and pH				
Total Nitrogen	NA	NA	NA	NA
Ammonia	NA	NA	NA	NA
Total Phosphorus	NA	NA	NA	NA
Chlorophyll a	NA	NA	NA	NA
pH	NA	NA	NA	NA
Estrogens				
Estradiol	NA	NA	NA	NA
Ethinyl estradiol	NA	NA	NA	NA
Estrone	NA	NA	NA	NA

Table 10. Preliminary hazard conclusion table for the **Central Lowlands Management Unit**. Data are presented as % exceedances, totoal number observations in parentheses, and hazard quotient in bold. NA = not applicable. NB = no benchmark.

Contaminant	Water Exceedances	Sediment Exceedances	Tissue Exceedances	Preliminary Hazard Conclusion
Elements				
Arsenic	14 (406) **1.3**	23 (22) **1.2**	0 (24)	COC
Beryllium	0 (310)	NB	NB	NL
Boron	0 (370)	NB	NB	NC
Cadmium	0 (80)	0 (32)	16 (24) **2.3**	COC
Total Chromium	0 (25)	0 (21)	NB	DG
Copper	0 (103)	3 (36) **1.0**	0 (24)	COC
Lead	0 (80)	0 (36)	25 (24) **2.4**	COC
Mercury	0 (58)	0 (32)	33 (24) **2.4**	COC
Nickel	0 (48)	8 (36) **1.2**	NB	COC
Selenium	54 (225) **1.4**	6 (18) **3.2**	52 (42) **1.3**	COC
Zinc	0 (51)	0 (36)	NB	DG
Pesticides				
2,4-D	0 (18)	NB	NB	DG
Carbaryl	0 (466)	NB	NB	DG
Chlordane	No Data	0 (24)	0 (34)	DG
Chlorpyrifos	<1 (281) **1.5**	NB	NB	COC
Diazinon	0 (381)	NB	NB	DG
Dieldrin	0 (381)	0 (11)	0 (14)	DG
DDD	No Data	0 (10)	0 (28)	DG
DDE	0 (32)	0 (10)	0 (28)	DG
DDT	No Data	4 (24) **1.4**	0 (28)	COC
Metolachlor	0 (383)	NB	NB	DG
Triazine Herbicides	16 (393) **4.1**	NB	NB	COC
Industrial Organics				
Dioxins/Furans	No Data	No Data	No Data	DG
Nonylphenol	0 (4)	NB	NB	DG
PAHs	NB	No Data	NB	DG

PBDE	NB	NB	NB	DG
PCBs	No Data	0 (9)	50 (10) **2.7**	COC
Nutrients, Chlorophyll, and pH				
Total Nitrogen	29 (285) **1.9**	NA	NA	COC
Ammonia	3 (286) **1.9**	NA	NA	COC
Total Phosphorus	48 (286) **3.1**	NA	NA	COC
Chlorophyll a	84 (31) **14.6**	NA	NA	COC
pH	< 1 (1411) **1**	NA	NA	COC
Estrogens				
Estradiol	No Data	NB	NB	DG
Ethinyl estradiol	No Data	NB	NB	DG
Estrone	No Data	NB	NB	DG

Table 11. Categorization of the general list of the contaminants of concern for **sediment** in the **Interior Highlands Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available (N) to evaluate the constituent is listed. NA = not applicable. * = total number of data points available.

Contaminant	Benchmark (mg/kg)	# Exceedances of N	Hazard Quotient	Decision
Elements				
Arsenic	9.8	3 of 51	1.2	COC
Beryllium	No Benchmark	*6	NA	NL
Boron	No Benchmark	No Data	NA	NL
Cadmium	1	2 of 54	2.1	COC
Total Chromium	43	12 of 51	1.3	COC
Copper	32	0 of 54	NA	DG
Lead	36	2 of 52	23.4	COC
Mercury	0.18	0 of 36	NA	DG
Nickel	23	11 of 54	1.1	COC
Selenium	2	0 of 22	NA	DG
Zinc	121	1 of 54	40.7	COC
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.0017	0 of 5	NA	DG
Chlorpyrifos	No Benchmark	0 of 5	NA	DG
Diazinon	No Benchmark	0 of 5	NA	DG
Dieldrin	0.0019	0 of 8	NA	DG
DDT	0.00119	No Data	NA	DG
DDD	0.0033	No Data	NA	DG
DDE	0.00142	No Data	NA	DG
Metolachlor	No Benchmark	No Data	NA	DG
Triazine herbicides	No Benchmark	No Data	NA	DG

Industrial Organics				
Dioxins/Furans	8.5 x 10^{-7}	No Data	NA	DG
Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	1.61	No Data	NA	DG
PBDE	No Benchmark	No Data	NA	DG
PCBs	0.0227	0 of 3	NA	DG
Nutrients, Chlorophyll, and pH				
Total Nitrogen	NA	NA	NA	DG
Ammonia	NA	NA	NA	DG
Total Phosphorus	NA	NA	NA	DG
Chlorophyll a	NA	NA	NA	DG
pH	NA	NA	NA	NC
Estrogens				
Estradiol	NA	NA	NA	DG
Ethinyl estradiol	NA	NA	NA	DG
Estrone	NA	NA	NA	DG

Table 12. Categorization of the general list of the contaminants of concern for **water** in the **Interior Highlands Management Unit.** Note: COC = contaminant of concern, defined as a contaminant that exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but sufficient data is not available to assess its status; NL = not likely, contaminant that is not likely to be of concern based on an expected low likelihood of exposure and toxicity The number of exceedances per the total number of samples available (N) to evaluate each contaminant is listed. NA = not applicable. * = a hardness dependent benchmark where values were calculated using the range of hardness values present in the IHMU.

Contaminant	**Benchmark (µg/L)**	**# Exceedances of N**	**Hazard Quotient**	**Decision**
Trace Elements				
Arsenic	5	17 of 322	1.3	COC
Beryllium	5.3	0 of 151	NA	NC
Boron	1500	0 of 114	NA	NC
Cadmium*	0.25	6 of 151	1.6	COC
Total Chromium	11	0 of 151	NA	DG
Copper*	9	5 of 151	1.6	COC
Lead*	2.5	36 of 151	1.7	COC
Mercury	0.7	0 of 90	NA	NC
Nickel*	52	0 of 151	NA	NC
Selenium	2	28 of 302	1.1	COC
Zinc	30	3 of 151	2.1	COC
Pesticides				
2,4-D	70	0 of 1	NA	NL
Carbaryl	0.5	0 of 110	NA	NC
Chlordane	0.00215	No Data	NA	DG
Chlorpyrifos	0.041	1 of 206	2.3	DG
Diazinon	0.17	0 of 200	NA	NC
Dieldrin	0.056	0 of 205	NA	NC
DDT	0.0005	No Data	NA	NL
DDE	10.5	0 of 178	NA	NC
DDD	0.0064	No Data	NA	NL
Metolachlor	100	0 of 215	NA	NC
Triazine herbicides	0.5	73 of 216	1.4	COC

Industrial Organics				
Dioxins/Furans	0.00001	No Data	NA	DG
Nonylphenol	5	No Data	NA	DG
PAHs	No Benchmark	No Data	NA	DG
PBDE	No Benchmark	No Data	NA	DG
PCBs	0.014	No Data	NA	DG
Nutrients, Chlorophyll, and pH				
Total Nitrogen	310 - 2180	231 of 351	1.3	COC
Ammonia	300 at pH 8, Temp at 25˚C	8 of 373	1.2	COC
Total Phosphorus	10 -128	363 of 396	4.8	COC
Chlorophyll a	0.93 - 3.00	65 of 198	5.4	COC
pH	6.5 – 9.0	0 of 423	NA	NL
Estrongens				
Estradiol	0.005	No Data	NA	DG
Ethinyl estradiol	0.003	No Data	NA	DG
Estrone	0.05	No Data	NA	DG

Table 13. Categorization of the general list of the contaminants of concern for **tissue** in the **Interior Highlands Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available (N) to evaluate the constituent is listed. NA = not applicable. Data are for whole body wet weight unless otherwise indicated. dw = dry weight. * = total number of data points available.

Contaminant	**Benchmark (mg/kg)**	**# Exceedance of N**	**Hazard Quotient**	**Decision**
Elements				
Arsenic	2	No Data	NA	DG
Beryllium	No Benchmark	No Data	NA	NL
Boron	No Benchmark	No Data	NA	NL
Cadmium	0.11	0 of 43	NA	DG
Total Chromium	No Benchmark	No Data	NA	DG
Copper	10.56	No Data	NA	DG
Lead	0.34	0 of 41	NA	DG
Mercury	0.04	24 of 43	2.0	COC
Nickel	No Benchmark	No Data	NA	DG
Selenium	4 (dw)	0 of 2	NA	DG
Zinc	No Benchmark	No Data	NA	DG
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.6	29 of 141	1.7	COC
Chlorpyrifos	No Benchmark	No Data	NA	DG
Diazinon	No Benchmark	No Data	NA	DG
Dieldrin	0.11	14 of 140	1.8	COC
DDT	0.025	21 of 141	2.0	COC
DDD	0.6	0 of 139	NA	NL
DDE	0.29	26 of 139	2.2	COC
Metolachlor	No Benchmark	No Data	NA	DG
Triazine herbicides	No Benchmark	No Data	NA	DG

Industrial Organics				
Dioxins/Furans	0.0021	No Data	NA	DG
Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	No Benchmark	No Data	NA	DG
PBDE	No Benchmark	*95	NA	COC
PCBs	0.15	133 of 141	5.7	COC
Nutrients, Chlorophyll, and pH				
Total Nitrogen	NA	NA	NA	NA
Ammonia	NA	NA	NA	NA
Total Phosphorus	NA	NA	NA	NA
Chlorophyll a	NA	NA	NA	NA
pH	NA	NA	NA	NA
Estrogens				
Estradiol	NA	NA	NA	NA
Ethinyl estradiol	NA	NA	NA	NA
Estrone	NA	NA	NA	NA

Table 14. Preliminary hazard conclusion table for the **Interior Highlands Management Unit**. Data are presented as % exceedances, totoal number observations in parentheses, and hazard quotient in bold. NA = not applicable. NB = no benchmark.

Contaminant	Water Exceedances	Sediment Exceedances	Tissue Exceedances	Preliminary Hazard Conclusion
Elements				
Arsenic	5 (322) **1.3**	6 (51) **1.2**	No Data	COC
Beryllium	0 (151)	NB	NB	NL
Boron	0 (114)	NB	NB	NL
Cadmium	4 (151) **1.6**	4 (54) **2.1**	0 (43)	COC
Total Chromium	0 (151)	24 (51) **1.3**	NB	COC
Copper	3 (151) **1.6**	0 (54)	No Data	COC
Lead	24 (151) **1.7**	4 (52) **23.4**	0 (41)	COC
Mercury	0 (90)	0 (36)	56 (43) **2.0**	COC
Nickel	0 (151)	20 (54) **1.1**	NB	COC
Selenium	9 (302) **1.1**	0 (22)	0 (2)	COC
Zinc	2 (151) **2.1**	2 (54) **40.7**	NB	COC
Pesticides				
2,4-D	0 (1)	No Data	NB	DG
Carbaryl	0 (110)	No Data	NB	DG
Chlordane	No Data	0 (5)	21 (141) **1.7**	COC
Chlorpyrifos	<1 (206) **2.3**	NB	NB	COC
Diazinon	0 (200)	NB	NB	DG
Dieldrin	0 (205)	0 (8)	10 (140) **1.8**	COC
DDD	No Data	No Data	0 (139)	NL
DDE	0 (178)	No Data	19 (139) **2.2**	COC
DDT	No Data	No Data	15 (141) **2.0**	COC
Metolachlor	0 (215)	NB	NB	DG
Triazine Herbicides	34 (216) **1.4**	NB	NB	COC
Industrial Organics				
Dioxins/Furans	No Data	No Data	No Data	DG
Nonylphenol	No Data	NB	NB	DG
PAHs	NB	No Data	NB	DG
PBDE	NB	NB	NB	DG
PCBs	No Data	0 (3)	94 (141) **5.7**	COC

Nutrients, Chlorophyll a, pH				
Total Nitrogen	66 (351) **1.3**	NA	NA	COC
Ammonia	2 (373) **1.2**	NA	NA	COC
Total Phosphorus	92 (396) **4.8**	NA	NA	COC
Chlorophyll a	33 (198) **5.4**	NA	NA	COC
pH	0 (423)	NA	NA	NL
Estrogens				
Estradiol	No Data	NB	NB	DG
Ethinyl estradiol	No Data	NB	NB	DG
Estrone	No Data	NB	NB	DG

Table 15. Categorization of the general list of the contaminants of concern for **sediment** in the **Coastal Plains Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available (N) to evaluate the constituent is listed. NA = not applicable. * = total number of data points available.

Contaminant	Benchmark (mg/kg)	# Exceedances of N	Hazard Quotient	Decision
Trace Elements				
Arsenic	9.8	54 of 99	1.1	COC
Beryllium	No Benchmark	*102	NA	NL
Boron	No Benchmark	*3	NA	DG
Cadmium	1	3 of 102	1.4	COC
Total Chromium	43	95 of 102	1.6	COC
Copper	32	9 of 102	2.1	COC
Lead	36	10 of 102	1.4	COC
Mercury	0.18	79 of 817	1.4	COC
Nickel	23	96 of 101	1.7	COC
Selenium	2	8 of 99	1	COC
Zinc	121	30 of 192	1.1	COC
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.0017	0 of 67	NA	NL
Chlorpyrifos	No Benchmark	*3	NA	DG
Diazinon	No Benchmark	*3	NA	DG
Dieldrin	0.0019	0 of 3	NA	NC
DDT	0.00119	0 of 3	NA	NC
DDD	0.0033	0 of 3	NA	NC
DDE	0.00142	3 of 3	1.1	COC
Metolachlor	No Benchmark	No Data	NA	DG
Triazine herbicides	No Benchmark	No Data	NA	DG
Industrial Organics				
Dioxins/Furans	8.5×10^{-7}	No Data	NA	DG
Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	1.61	No Data	NA	DG

PBDE	No Benchmark	No Data	NA	DG
PCBs	0.0227	No Data	NA	DG
Nutrients, Chlorophyll, and pH				
Total Nitrogen	NA	NA	NA	DG
Ammonia	NA	NA	NA	DG
Total Phosphorus	NA	NA	NA	DG
Chlorophyll a	NA	NA	NA	DG
pH	NA	NA	NA	DG
Estrogens				
Estradiol	No Benchmark	No Data	NA	DG
Ethinyl estradiol	No Benchmark	No Data	NA	DG
Estrone	No Benchmark	No Data	NA	DG

Table 16. Categorization of the general list of the contaminants of concern for **water** in the **Central Plains Management Unit.** Note: COC = contaminant of concern, defined as a contaminant that exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but sufficient data is not available to assess its status; NL= not likely, contaminant that is not likely to be of concern based on an expected low likelihood of exposure and toxicity The number of exceedances per the total number of samples available (N) to evaluate each contaminant is listed. NA = not applicable. * = a hardness dependent benchmark where values were calculated using the range of hardness values present in the CPMU.

Contaminant	Benchmark (µg/L)	# Exceedances of N	Hazard Quotient	Decision
Trace Elements				
Arsenic	5	370 of 2793	1.7	COC
Beryllium	5.3	0 of 174	NA	NC
Boron	1500	0 of 886	NA	NC
Cadmium*	0.25	440 of 634	1.7	COC
Total Chromium	11	64 of 1547	2.4	COC
Copper*	9	292 of 1451	2.7	COC
Lead*	2.5	426 of 1861	2.0	COC
Mercury	0.7	45 of 1618	4.2	COC
Nickel*	52	27 of 1068	2.5	COC
Selenium	2	7 of 1445	25.6	COC
Zinc	30	192 of 1899	1.8	COC
Pesticides				
2,4-D	70	0 of 50	NA	NC
Carbaryl	0.5	0 of 665	NA	NC
Chlordane	0.00215	No Data	NA	DG
Chlorpyrifos	0.041	4 of 1321	4.9	COC
Diazinon	0.17	4 of 1321	1.2	COC
Dieldrin	0.056	0 of 1321	NA	NC
DDT	0.0005	No Data	NA	DG
DDE	10.5	0 of 526	NA	NC
DDD	0.0064	No Data	NA	DG
Metolachlor	100	0 of 1321	NA	NC
Triazine herbicides	0.5	415 of 2368	2.2	COC

Industrial Organics				
Dioxins/Furans	0.00001	No Data	NA	DG
Nonylphenol	5	No Data	NA	DG
PAHs	No Benchmark	No Data	NA	DG
PBDE	No Benchmark	No Data	NA	DG
PCBs	0.014	No Data	NA	DG
Nutrients, Chlorophyll, and pH				
Total Nitrogen	310 - 2180	786 of 1900	1.6 - 1.4	COC
Ammonia	300 at pH 8, Temp at 25˚C	48 of 3421	2.0	COC
Total Phosphorus	10 – 128	1981 of 2847	1.3 - 1.8	COC
Chlorophyll a	0.93 - 3.00	267 of 272	1.6	COC
pH	6.5 – 9.0	631 of 4205	1.1 – 1.0	COC
Estrogens				
Estradiol	0.005	No Data	NA	DG
Ethinyl estradiol	0.003	No Data	NA	DG
Estrone	0.05	No Data	NA	DG

Table 17. Categorization of the general list of the contaminants of concern for **tissue** in the **Coastal Plains Management Unit** as a COC = contaminant of concern, contaminant exceeds its benchmark for one or more sample; NC = contaminant not of concern, contaminant for which there is adequate data available to assess that it does not exceed the benchmark; DG = data gap, contaminant that is likely to occur in the management unit but no data is available to assess its status; NL = not likely, contaminant that is not likely to occur because of the location in the basin. The number of exceedances per the total number of samples available (N) to evaluate the constituent is listed. NA = not applicable. Data are for whole body wet weight unless otherwise indicated. dw = dry weight. * = total number of data points available.

Contaminant	**Benchmark (mg/kg)**	**# Exceedances of N**	**Hazard Quotient**	**Decision**
Trace Elements				
Arsenic	2	2 of 20	1.2	NC
Beryllium	No Benchmark	*20	NA	NL
Boron	No Benchmark	*20	NA	NL
Cadmium	0.11	11 of 20	2.8	COC
Total Chromium	No Benchmark	*20	NA	NL
Copper	10.56	0 of 20	NA	NL
Lead	0.34	15 of 20	2.3	COC
Mercury	0.04	17 of 20	3.5	COC
Nickel	No Benchmark	*20	NA	DG
Selenium[1]	4 (dw)	0 of 20	NA	DG
Zinc	No Benchmark	*20	NA	DG
Pesticides				
2,4-D	No Benchmark	No Data	NA	DG
Carbaryl	No Benchmark	No Data	NA	DG
Chlordane	0.6	0 of 94	NA	NL
Chlorpyrifos	No Benchmark	No Data	NA	DG
Diazinon	No Benchmark	No Data	NA	DG
Dieldrin	0.11	7 of 20	1.7	COC
DDT[1]	0.025	139 of 636	3.5	COC
DDD	0.6	14 of 744	1.5	COC
DDE	0.29	113 of 690	1.4	COC
Metolachlor	No Benchmark	No Data	NA	DG
Triazine herbicides	No Benchmark	No Data	NA	DG
Industrial Organics				
Dioxins/Furans	0.0021	No Data	NA	DG

Nonylphenol	No Benchmark	No Data	NA	DG
PAHs	No Benchmark	No Data	NA	DG
PBDE	No Benchmark	No Data	NA	
PCBs	0.15	11 of 20	5.7	COC
Nutrients, Chlorophyll, and pH				
Total Nitrogen	NA	NA	NA	NC
Ammonia	NA	NA	NA	NC
Total Phosphorus	NA	NA	NA	NC
Chlorophyll a	NA	NA	NA	NC
pH	NA	NA	NA	NC
Estrogens				
Estradiol	No Benchmark	No Data	NA	DG
Ethinyl estradiol	No Benchmark	No Data	NA	DG
Estrone	No Benchmark	No Data	NA	DG

[1]Only wet weight available 6.3, 7.4

Table 18. Preliminary hazard conclusion table for the **Coastal Plains Management Unit**. Data are presented as % exceedances, totoal number observations in parentheses, and hazard quotient in bold. NA = not applicable. NB = no benchmark.

Contaminant	Water Exceedances	Sediment Exceedances	Tissue Exceedances	Preliminary Hazard Conclusion
Elements				
Arsenic	13 (2793) **1.7**	55 (99) **1.1**	10 (29) **1.2**	COC
Beryllium	0 (174)	NB	NB	COC
Boron	0 (886)	NB	NB	NC
Cadmium	69 (634) **1.7**	3 (102) **1.4**	55 (20) **2.8**	COC
Total Chromium	4 (1547) **2.4**	93 (102) **1.6**	NB	COC
Copper	20 (1451) **2.7**	9 (102) **2.1**	0 (20)	COC
Lead	23 (1861) **2.0**	10 (102) **1.4**	75 (20) **2.3**	COC
Mercury	28 (1618) **4.2**	10 (817) **1.4**	85 (20) **3.5**	COC
Nickel	3 (1068) **2.5**	95 (101) **1.7**	NB	COC
Selenium	< 1 (1445) **25.6**	8 (99) **1.0**	0 (20)	COC
Zinc	10 (1899) **1.8**	16 (192) **1.1**	NB	COC
Pesticides				
2,4-D	0 (50)	NB	NB	DG
Carbaryl	0 (665)	NB	NB	DG
Chlordane	No Data	0 (67)	0 (94)	DG
Chlorpyrifos	< 1 (1321) **4.9**	NB	NB	COC
Diazinon	< 1 (1321) **1.2**	NB	NB	COC
Dieldrin	0 (1321)	0 (3)	35 (20) **1.7**	COC
DDD	No Data	0 (3)	2 (744) **1.5**	COC
DDE	0 (526)	100 (3) **1.1**	16 (690) **1.4**	COC
DDT	No Data	0 (3)	22 (636) **3.5**	COC
Metolachlor	0 (1321)	NB	NB	DG
Triazine Herbicides	18 (2368) **2.2**	NB	NB	COC
Industrial Organics				
Dioxins/Furans	No Data	No Data	No Data	DG
Nonylphenol	No Data	NB	NB	DG

PAHs	NB	No Data	NB	DG
PBDE	NB	NB	NB	DG
PCBs	No Data	No Data	55 (20) **5.7**	COC
Nutrients, Chlorophyll, pH				
Total Nitrogen	41 (1900) **1.4**	NA	NA	COC
Ammonia	1 (3421) **2.0**	NA	NA	COC
Total Phosphorus	70 (2847) **1.8**	NA	NA	COC
Chlorophyll a	98 (272) **1.6**	NA	NA	COC
pH	15 (4205) **1.0**	NA	NA	COC
Estrogens				
Estradiol	No Data	NB	NB	DG
Ethinyl Estradiol	No Data	NB	NB	DG
Estrone	No Data	NB	NB	DG