Health Consultation

Evaluation of Fish and Shellfish from Sturgeon Creek, Brunswick River, and Cape Fear River near the Kerr-McGee NPL Site

KERR-MCGEE CHEMICAL CORPORATION NPL SITE

NAVASSA, BRUNSWICK COUNTY, NORTH CAROLINA

EPA FACILITY ID: NCD980557805

Prepared by:
North Carolina Department of Health and Human Services

APRIL 16, 2018

Prepared Under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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North Carolina Department of Health and Human Services
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Occupational and Environmental Epidemiology Branch
Under a Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Foreword

The North Carolina Department of Health and Human Services (DHHS), Division of Public Health (DPH), Health Assessment, Consultation and Education (HACE) program has prepared this Health Consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for the health issues related to hazardous waste. This health consultation was prepared in accordance with the methodologies and guidelines developed by ATSDR and DPH.

The purpose of this health consultation is to identify and prevent harmful health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on health issues associated with specific exposures that have happened in the past, are currently taking place, or are believed to be possible in the future based on current site conditions. The HACE program evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur in the future, reports any potential harmful effects, and then recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time this health consultation was conducted and may not be applicable if site conditions or land uses change in the future.

For additional information or questions regarding the contents of this health consultation please contact:

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INTRODUCTION

The Kerr-McGee Chemical Corporation site (EPA ID: NCD980557805) was listed on the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL) in 2010. The Agency for Toxic Substances and Disease Registry (ATSDR) is authorized to evaluate public health issues at NPL sites. In North Carolina, these evaluations are conducted through a cooperative agreement program with the North Carolina Department of Health and Human Services (DHHS) Division of Public Health (DPH). DPH is evaluating this site because of its listing on the NPL. The DPH's top priority is to make sure the community near the Kerr-McGee NPL site has the best information available to protect its health.

DPH previously released a public health assessment [ATSDR 2012a] evaluating potential health effects related to contamination from the Kerr-McGee NPL site. The 2012 public health assessment evaluated creosote contamination in soil, sediment, and groundwater on site, and in sediment of the adjoining wetlands and Sturgeon Creek. From previous site investigations, polycyclic aromatic hydrocarbons (PAHs) from creosote were noted as the primary contaminant of concern at this site [ATSDR 2012a]. In 2011 and 2013, the North Carolina Department of Environmental Quality (DEQ) and EPA collected and analyzed fish and shellfish from Sturgeon Creek, Brunswick River, and Cape Fear River near the site. This is part of the investigation to determine the extent of contamination from former creosote operations at the site.

This health consultation includes an evaluation of the fish and shellfish data for potential health effects associated with exposure to contaminants near the site. DPH has an existing statewide fish advisory due to mercury levels in fish across the state. This evaluation will determine if the statewide fish advisory is health protective for people eating fish from areas near the Kerr-McGee NPL site.

DPH released a Public Comment version of this health consultation on July 25, 2017. A 60-day public comment period was provided from July 25, 2017 through September 25, 2017. DPH received comments from one community organization. These comments and responses to them are provided in Appendix H.

CONCLUSION

Eating fish and shellfish daily from Sturgeon Creek, Brunswick River, and Cape Fear River near the Kerr-McGee Chemical Corporation NPL site could harm the health of people who eat fish regularly from these areas. Risk of cancer and non-cancer health effects is higher for subsistence fishers compared to recreational fishers. DPH determined that the statewide mercury fish advisory

	is protective of people eating fish and shellfish from these waterbodies, except for three species (striped bass, striped mullet, and blue crab) that require more stringent consumption advisories.
BASIS FOR DECISION	Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), arsenic, hexavalent chromium, mercury, and copper have been found in fish and shellfish near the site at concentrations above DPH levels of concern, indicating the potential for cancer and non-cancer health effects. Doses for subsistence fishers of copper from blue crabs are at levels approaching those shown to cause gastrointestinal effects in people. Additionally, concentrations of other contaminants, excluding mercury and copper, are at levels that may put people who routinely eat fish from these waterbodies for long periods of time at risk for cancer. The current statewide fish consumption advisory for mercury is stricter for most species, except striped bass, striped mullet, and blue crab, than meal recommendations derived from this evaluation.
NEXT STEPS	The DPH recommends: ▪ people follow the existing statewide meal consumption limit recommendations for mercury in fish[1]. This includes the following recommendations for eating fish. ➢ Women of child-bearing age (15-44 years old), pregnant women, nursing mothers, and children less than 15 years old: 1. DO NOT EAT fish HIGH in mercury. Catfish and largemouth bass included in this evaluation are HIGH in mercury. 2. Eat up to 2 meals per week of fish LOW in mercury. Bluegill sunfish, flounder, and red drum included in this evaluation are LOW in mercury. ➢ All other people: 1. Eat only 1 meal per week of fish HIGH in mercury. Catfish and largemouth bass included in this evaluation are HIGH in mercury. 2. Eat up to 4 meals per week of fish LOW in mercury. Bluegill sunfish, flounder, and red drum included in this evaluation are LOW in mercury. ▪ all people follow these additional meal consumption limit recommendations for fish and shellfish from Sturgeon Creek, Brunswick River, and Cape Fear River near Navassa, NC:

[1] See Appendix F or the N.C. DPH Fish Advisories website for a complete list of fish identified as LOW & HIGH in mercury (http://epi.publichealth.nc.gov/oee/fish/advisories.html).

- Eat up to 2 meals per week of striped bass[2] due to high levels of mercury.
- Eat up to 3 meals per week of striped mullet due to high levels of hexavalent chromium.
- Eat up to 3 meals per week of blue crab due to high levels of arsenic, hexavalent chromium, and mercury.

- the local health department post and maintain advisory signs at areas where people may fish along Sturgeon Creek, Brunswick River, and Cape Fear River.
- the DEQ sample fish and shellfish at least every 5 years from Sturgeon Creek, Brunswick River, and Cape Fear River to monitor changes in contaminant levels and to determine the extent of contamination in fish.

The DPH:

- issued a fish and shellfish consumption advisory for striped mullet, striped bass, and blue crabs near Navassa, NC on September 25, 2017.
- attended two public availability sessions on June 20, 2017 and September 19, 2017for the Kerr-McGee NPL site to answer questions about the document and fish consumption advisory and to hear comments from the community.
- has worked with the local health departments impacted to develop signs to inform the local community about the fish consumption advisory.
- will continue to work with the local health departments impacted to inform and educate the local community about potential health hazards associated with eating fish and shellfish from waterbodies near Navassa, NC and how to reduce exposures, including distributing factsheets and other health education materials.
- will continue to monitor and assess the Kerr-McGee NPL site as the EPA or DEQ collects additional fish tissue or other environmental data and update the fish consumption advisory as appropriate.

LIMITATIONS

There are limitations inherent to the public health assessment process. These include the availability of analytical data collected for a site, the type and quantity of health effect study information, and the risk estimation process itself. In addition, for this evaluation, the data collected and following health risk assessment are only relevant to the fish and shellfish species collected at this site. The conclusions and recommendations do not pertain to species not sampled. The data

[2] N.C. DEQ currently has a striped bass harvest moratorium (no striped bass may be kept) for these waterbodies (http://portal.ncdenr.org/web/mf/05-striped-bass-csma-ssr-2016).

	presented in this evaluation is only representative of contaminant concentrations at the time the fish and shellfish were collected. Concentrations could increase or decrease over time. For some species, few samples were collected and DPH is unable to issue fish advisories for these species. DPH procedures require that there be at least 3 composite fillet samples or 5 individual fish fillet samples to issue a fish advisory.
FOR MORE INFORMATION	If you have concerns about your health, you should contact your doctor. Staff from the Division of Public Health is available to assist you in talking to your doctor. Contact us by calling (919) 707-5900, or by sending an e-mail to nchace@dhhs.nc.gov and ask for information on the Kerr-McGee Chemical Corporation NPL site.

Background and Statement of Issues

The Kerr-McGee Chemical Corporation NPL site (EPA ID: NCD980557805) is located on North Navassa Road in Navassa, Brunswick County, North Carolina. The 251-acre site is in the southeast corner of Brunswick County and is bordered on the north and west by North Navassa Road, on the northwest by Rampage Boat Company [ENSR 2006], on the east by the Brunswick River, and to the south by Sturgeon Creek (Figure 1). The site was added to the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL) in 2010 [EPA 2016]. The ATSDR is authorized to evaluate public health issues at NPL sites. In North Carolina, these evaluations are conducted through a cooperative agreement program with the North Carolina Department of Health and Human Services (DHHS) Division of Public Health (DPH). DPH is evaluating this site because of its listing on the NPL.

The site operated as a creosote-based wood treating facility under three different owners from 1936 through 1974 and was dismantled in 1980. The site has not been in use since 1980. The western half of the site was utilized for wood treating activities. Dried lumber to be used for railroad ties, utility poles, and other purposes was pressure treated on site with a creosote solution and stored outside to dry. The eastern portion of the site is heavily wooded and has not been developed except for 3 private residences located in a 2-acre parcel of land in the east central portion of the site [ENSR 2005]. The area across Navassa Road west of the site is primarily residential. Large industrial areas dominate the area north of the site. A railroad line runs east to west on the north side of North Navassa Road. There are additional low density residential areas to the south of the site across Sturgeon Creek [ATSDR 2012a].

Run-off from the site toward Sturgeon Creek and the presence of polycyclic aromatic hydrocarbons (PAHs) from creosote in the sediments has been documented. PAHs can move from the sediment into the aquatic food chain, including fish and shellfish. Sturgeon Creek flows into the Brunswick River. Recreational and subsistence fishing occurs on these waterways [DWM 1995]. During a 2010 site visit, DPH staff observed a fish and tackle store and fishing piers on Sturgeon Creek at Navassa Road. This strongly suggests fishing activities in the area. Additionally, community members noted that they frequently ate fish, shellfish, and turtles from waterways adjacent to the site [ATSDR 2012a].

The objective of this health consultation is to determine if eating fish and shellfish from waterways near the Kerr-McGee Chemical Corporation NPL site poses a current or future health hazard to subsistence and recreational fishermen in the area. DPH discussed past exposures to contaminants at the Kerr-McGee NPL site in detail in the 2012 Public Health Assessment [ATSDR 2012a]. In this health consultation, DPH evaluates fish and shellfish tissue data collected in 2011 and 2013 from Sturgeon Creek, the Brunswick River, and the Cape Fear River. The information reviewed for this health consultation came from reports and data that the EPA and N.C. Department of Environmental Quality (DEQ) generated.

DPH released a Public Comment version of this health consultation on July 25, 2017. A 60-day public comment period was provided from July 25, 2017 through September 25, 2017. DPH received comments from one community organization. These comments and responses to them are provided in Appendix H.

Discussion

Due to the listing of the site on the NPL, the DPH evaluated fish and shellfish tissue samples that EPA and DEQ collected in 2011 and 2013 from Sturgeon Creek, the Brunswick River, and the Cape Fear River. ATSDR does not have contaminant screening levels for fish tissue. Therefore, concentrations of contaminants detected in fish tissue data were compared to DPH screening levels. Contaminants exceeding screening levels required further evaluation, whereas those below screening levels required no further evaluation, as adverse health effects are not expected.

Concentrations of contaminants exceeding screening levels were averaged by species and these averages were used to calculate exposure doses for recreational and subsistence fishermen. These estimated exposure doses were compared to health effects data and used to determine whether health effects may occur from eating fish and shellfish. Estimated doses, in addition to chemical specific cancer potency factors, were used to calculate cancer risk from eating contaminated fish. These cancer risk calculations were done assuming exposure over a 78-year lifetime, per DPH guidance [NCDHHS 2017].

If there was a potential for health effects from eating fish or shellfish, the DPH calculated recommended meal limits for individual species. To be highly health protective, these meal limits were calculated based on subsistence fisher exposure parameters. Further discussion of the health effects evaluation process used for this assessment can be found in Appendix C. Exposure parameters used in this assessment can be found in Appendix D.

This health consultation focuses on contaminated fish and shellfish near the Kerr-McGee NPL site. PAHs from former creosote operations have been detected in sediment on and near the site. PAHs can move from sediment into fish and shellfish. Potentially exposed persons include recreational and subsistence fishers who may be exposed to harmful substances from eating contaminated fish and shellfish caught near the site, including their families or others who may eat fish they catch. The elements of an exposure pathway may change over time, so the time frame of potential exposure is also considered. Past exposures to contaminants at the Kerr-McGee NPL site are discussed in detail in the 2012 Public Health Assessment [ATSDR 2012a]. This report focuses on current and future exposures. Further discussion of exposure pathways can be found in Appendix C.

Fish and Shellfish Sampling and Analysis

In 2011, the DEQ collected 33 fish and 4 shellfish to be used to assess human health risk from eating fish and shellfish near the Kerr-McGee NPL site. Fish were collected upstream from the site in Sturgeon Creek to its confluence with Mill Creek and downstream to where Sturgeon Creek empties into the Brunswick River (Figure 2). The EPA analyzed these samples for semivolatile organic compounds (SVOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCB) congeners, and metals. In 2013, the DEQ collected an additional 6 fish from Sturgeon Creek and 25 fish and 8 shellfish from the Brunswick River and Cape Fear River. These samples were collected from just upstream of the confluence of the Cape Fear River and Brunswick River (northeast of the site) and downstream in the Cape Fear River to the US-17 bridge and in the Brunswick River to the US-17 bridge (Figure 3). The DEQ analyzed these samples for metals only.

All fish were analyzed as fillet samples as this is the portion of the fish that people are most likely to eat. Shellfish were analyzed as either picked meat (guts removed; people generally eat meat portion of shellfish) or whole-body (some people eat portions other than meat, such as the guts). In this assessment, data from both types of shellfish samples are evaluated separately. Fish and shellfish tissue samples were analyzed as single fish or shellfish when possible, but some samples of the same species were composited to obtain enough sample mass for analysis. All contaminant concentrations were reported on a wet weight basis. See Table 1 below for number and type of samples analyzed per species in 2011 and 2013.

Reporting limits for most of the contaminants of concern (PAHs, PCBs, arsenic, mercury, and hexavalent chromium) were high, and the lab was not able to detect small concentrations. These reporting limits were greater than DPH screening levels, and small concentrations of these chemicals can cause health effects in people. Therefore, to be highly health protective, DPH used one-half the reporting limit for analytical results listed as not detected in calculating average concentrations for these contaminants.

Table 1. Number and type of samples analyzed per species during 2011 and 2013 sampling events.

Species	2011	2013
Channel Catfish	3 individual fish	3 individual fish
Blue Catfish	6 individual fish	7 individual fish
Striped Mullet	2 composites	6 individual fish
Striped Bass	2 individual fish, 1 composite	n/a
Largemouth Bass	1 individual fish, 3 composites	6 individual fish
Blue Crab (P)	1 composite	5 individual crab
Blue Crab (W)	n/a	3 individual crab
White Perch	n/a	2 individual fish
Flathead Catfish	n/a	1 individual fish
Bluegill Sunfish	n/a	1 individual fish
Red Drum	n/a	4 individual fish
Summer Flounder	n/a	1 individual fish

Notes: P = picked meat only, guts removed
W = whole body tissue
n/a = not available
2011 samples analyzed for SVOCs, PAHs, PCBs, and metals
2013 samples analyzed for metals only

Fish and Shellfish Data Evaluation by Contaminant

Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), arsenic, hexavalent chromium, and mercury were detected in fish and shellfish above DPH derived screening levels (Tables 3-7). Copper was also detected in whole blue crabs above the DPH screening level (Table 8). PAHs from creosote are the only contaminant of concern found in fish and shellfish known to be associated with the Kerr-McGee NPL site. Other contaminants of concern may be from man-made sources, such as coal burning, manufacturing, or pesticide use, or natural sources, such as rock or soil. More information on these compounds and potential health effects can be found in Appendix E.

Polycyclic Aromatic Hydrocarbons (PAHs)
PAHs were detected in all fish species tested in 2011. Fish collected in 2013 were not analyzed for PAHs. The lowest detection of total PAHs (0.0064 mg/kg), and the highest detection of total PAHs (0.0953 mg/kg) were in largemouth bass (Table 3). None of the 20 PAHs that EPA analyzed for exceeded non-cancer screening levels. Information on the cancer risk evaluation process for PAHs can be found in Appendix D. All species' average benzo(a)pyrene (BaP) equivalent concentrations exceeded the DPH BaP screening level for cancer risk of 0.00129 mg/kg (Table 3). Estimated increased cancer risk for subsistence fishers is low, ranging from 4 in a million for channel catfish, blue catfish, striped bass, largemouth bass, and blue crab meat to 5 in a million for striped mullet. No increased cancer risk for recreational fishers is expected from PAHs in these fish species (Table 12).

Polychlorinated Biphenyls (PCBs)
PCBs were detected in all fish species tested in 2011. Fish collected in 2013 were not analyzed for PCBs. The lowest detection of total PCBs (sum of all congener concentrations) was in blue crab meat (0.000317 mg/kg). The highest detection of total PCBs was in blue catfish (0.0314 mg/kg). Average concentrations of total PCBs for all species exceeded the DPH PCBs screening level for cancer risk of 0.00471 mg/kg. However, the DPH PCBs screening level for non-cancer health effects of 0.0188 mg/kg was only exceeded for striped bass (Table 4). The calculated non-cancer exposure dose for subsistence fishers (2.0×10^{-5} mg/kg/day) eating striped bass exceeded the health guideline. However, the dose for recreational fishers (2.1×10^{-6} mg/kg/day) did not exceed the health guideline (Table 9). The subsistence fishers' dose is below the no observed adverse effect level (NOAEL) for chronic oral exposure in humans (0.093 mg/kg/day), based on neurodevelopmental effects in newborns exposed to PCBs through breast milk [ATSDR 2000].

To assess cancer risk from polychlorinated biphenyls, non-dioxin-like and dioxin-like congeners had to be evaluated separately. Information on the cancer risk evaluation process for PCBs can be found in Appendix D. Average non-dioxin-like PCB concentrations ranged from 0.000534 mg/kg in blue crab meat to 0.0204 mg/kg in striped bass. Estimated increased cancer risk for subsistence fishers is low, ranging from 1 in a million for blue crab meat to 4 in 100,000 for striped bass. Estimated increased cancer risk for recreational fishers is also low, ranging from less than 1 in a million for blue crab meat to 4 in a million for striped bass (Table 13).

Average dioxin-like PCB concentrations ranged from 2.171×10^{-7} mg/kg in largemouth bass to 2.997×10^{-7} mg/kg in channel catfish. Estimated increased cancer risk for subsistence fishers is low, ranging from 3 additional cancers in 100,000 people for largemouth bass, blue crab meat, and striped mullet to 4 additional cancers in 100,000 people for channel catfish, blue catfish, and striped bass. Estimated increased cancer risk for recreational fishers is also low, ranging from 3 additional cancers in a million people for largemouth bass, blue crab meat, and striped mullet to 4 additional cancers in a million people for channel catfish, blue catfish, and striped bass (Table 14).

Combined PAH and PCB Cancer Risk
PAHs and PCBs are both aryl hydrocarbon receptor agonists and are thought to cause their toxicity through their interaction with this receptor [TOX 2013]. Due to similar modes of action, the cancer risks from PAHs and PCBs for subsistence fishers were evaluated together. This was done to provide recommended meal limits for people eating fish near the Kerr-McGee NPL site. Combined estimated increased cancer risk for subsistence fishers from PAHs and PCBs in fish and shellfish ranges from 4 additional cancers in 100,000 people for blue crab meat to 9 additional cancers in 100,000 people for striped bass (Table 15).

Arsenic
Total arsenic was detected in all fish and shellfish species tested, with the lowest detection in channel catfish (0.053 mg/kg) and the highest detection in striped mullet (1.6 mg/kg) (Table 5). The potential for health effects from inorganic arsenic was evaluated only as little is known about the toxicity of organic arsenic. Organic arsenic is believed to be less toxic than inorganic arsenic. For this evaluation, the DPH assumed that 10% of the total arsenic concentration is inorganic arsenic per ATSDR guidance [ATSDR 2007c]. All species' average inorganic arsenic concentrations are above the DPH inorganic arsenic screening level for cancer risk of 0.003137 mg/kg. However, all average concentrations are below the DPH inorganic arsenic screening level for non-cancer health effects of 0.141 mg/kg (Table 5). Estimated increased cancer risk for subsistence fishers ranges from 3 additional cancers in 100,000 people for channel catfish and bluegill sunfish to 2 additional cancers in 10,000 people for striped mullet, striped bass, and blue crab (both meat only and whole crab tissue). Estimated increased cancer risk for recreational fishers ranges from 3 additional cancers in a million people for channel catfish and bluegill sunfish to 2 additional cancers in 100,000 people for striped mullet, striped bass, and blue crab (both meat only and whole crab tissue) (Table 16).

Hexavalent Chromium
Chromium was detected in all fish and shellfish species tested except striped bass. Due to the toxicity of hexavalent chromium and to be highly health protective, all chromium in fish and shellfish was assumed to be hexavalent chromium. The lowest detections of hexavalent chromium were in channel catfish and largemouth bass (0.11 mg/kg). The highest detection of hexavalent chromium was in blue catfish (2.2 mg/kg). All species' average hexavalent chromium concentrations exceeded the DPH hexavalent chromium screening level for cancer risk of 0.00941 mg/kg. However, all average concentrations were lower than the DPH hexavalent chromium screening level for non-cancer health effects of 1.41 mg/kg (Table 6). Estimated increased cancer risk for subsistence fishers ranges from 5 additional cancers in 100,000 people for striped bass to 4 additional cancers in 10,000 people for blue catfish. Estimated increased cancer risk for recreational fishers ranges from 6 additional cancers in a million people for striped bass to 4 additional cancers in 100,000 people for blue catfish (Table 17).

Mercury
Mercury was detected in all fish and shellfish species tested. Measuring methylmercury is expensive and most mercury is present in fish and shellfish as methylmercury. For these reasons, it is assumed that all mercury in fish and shellfish is present as methylmercury for this evaluation. The lowest detection of mercury was in striped mullet (0.02 mg/kg) and the highest

detection was in blue catfish (0.38 mg/kg). All species' average mercury concentrations exceed the DPH methylmercury screening level for non-cancer health effects of 0.00471 mg/kg (Table 7). Calculated exposure doses for subsistence fishers are greater than the health guideline for all species except striped mullet. However, exposure doses for recreational fishers are lower than the health guideline for all species (Table 11). Subsistence fisher doses are below those shown to cause health effects in people [IRIS 2001].

Copper

Copper was detected in all species of fish and shellfish. The lowest detection was in flathead catfish (0.1 mg/kg) and the highest detection was in whole blue crabs (52 mg/kg). The average copper concentration for whole blue crabs is 40.33 mg/kg. This is greater than the DPH copper screening level for non-cancer health effects of 18.8 mg/kg (Table 8). Calculated exposure doses for subsistence fishers are greater than the ATSDR intermediate oral minimal risk level (MRL). However, exposure doses for recreational fishers are lower than this health guideline (Table 10). Subsistence fisher doses are between doses shown to cause gastrointestinal effects in humans following 2 months of exposure (lowest observed adverse effect level) and doses that did not cause these effects (no observed adverse effect level) [ATSDR 2004].

Summary of Fish and Shellfish Meal Limit Recommendations

Table 2 below summarizes meal limit recommendations for fish species evaluated in this health consultation. The table includes meal limit recommendations based on the statewide mercury fish advisory and whether a more restrictive meal limit recommendation is required based on this evaluation. A more detailed list of estimated meal limits broken down by contaminant can be found in Table 18.

Table 2. Kerr-McGee NPL site. Summary of meal limit recommendations based on this evaluation and the statewide mercury advisory.

Species	Statewide Mercury Advisory Category (High or Low in Mercury)	Statewide Advisory Meal Limit Recommendations		More Restrictive Meal Limit Recommendation (based on this evaluation)	Contaminant Driving More Restrictive Meal Limit
		Sensitive Populations[3]	All Other Consumers		
Channel Catfish	High	Do Not Eat	1 ml/wk	None	None
Blue Catfish	High	Do Not Eat	1 ml/wk	None	None
Striped Mullet	n/a	n/a	n/a	3 ml/wk	Hexavalent Chromium
Striped Bass	n/a	n/a	n/a	2 ml/wk - Harvest Moratorium	Mercury
Largemouth Bass	High	Do Not Eat	1 ml/wk	None	None
Blue Crab (P)	n/a	n/a	n/a	3 ml/wk	Arsenic, Hexavalent Chromium, Mercury
Blue Crab (W)	n/a	n/a	n/a		
White Perch	n/a	n/a	n/a	None[4]	None
Flathead Catfish	High	Do Not Eat	1 ml/wk	None	None
Bluegill Sunfish	Low	2 ml/wk	4 ml/wk	None	None
Red Drum	Low	2 ml/wk	4 ml/wk	None	None
Summer Flounder	Low	2 ml/wk	4 ml/wk	None	None

Notes: P = picked meat only, guts removed
W = whole body tissue
n/a = not applicable - species is not included in the statewide mercury fish advisory
ml/wk = maximum recommended number of meals per week

[3] The sensitive populations noted here include women of child-bearing age (15-44 years old), pregnant women, nursing mothers, and children less than 15 years old.
[4] There is no site-specific meal limit recommendation for white perch as not enough samples were collected.

Child Health Considerations

The ATSDR recognizes there are unique exposure risks concerning children that do not apply to adults. Children are at a greater risk than are adults to certain kinds of exposures to hazardous substances. They are also smaller, resulting in higher doses of chemical exposure per body weight compared to adults. If toxic exposures occur during critical growth stages, the developing body systems of children can sustain permanent damage. Probably most important, however, is that children depend on adults for risk identification and risk management, housing, and access to medical care. Thus, adults should be aware of public health risks in their community so they can guide their children accordingly. Child-specific exposure situations were not directly evaluated in this assessment. However, it is expected that making meal recommendations at a highly health protective level will protect children who may eat fish that adults bring home. If fish consumption recommendations are followed, the DPH does not expect health effects in children.

Limitations

There are limitations inherent to the public health assessment process. These include the availability of analytical data collected for a site, the type and quantity of health effect study information, and the risk estimation process itself. In addition, for this evaluation, the data collected and health risk assessment are only relevant to the species collected for this site. The conclusions and recommendations do not pertain to fish and shellfish species not sampled. The data presented in this evaluation is only representative of contaminant concentrations at the time the fish and shellfish were collected. Concentrations could increase or decrease over time. For some species, few samples were collected and DPH is unable to issue fish advisories for these species. DPH procedures require that there be at least 3 composite fillet samples or 5 individual fish fillet samples to issue a fish advisory. Additionally, all chromium in samples was assumed to be hexavalent chromium as no data on specific forms of chromium was available. This could lead to some uncertainty in risk levels but is a health protective assumption. To overcome some of these limitations, highly health protective exposure assumptions were used to evaluate fish tissue data and interpret the potential for adverse health effects.

Conclusions

After reviewing the environmental data, DPH concludes:

> **Eating fish and shellfish daily from Sturgeon Creek, Brunswick River, and Cape Fear River near the Kerr-McGee NPL site could harm the health of people who eat fish regularly from these areas. Risk of cancer and non-cancer health effects is higher for subsistence fishers compared to recreational fishers. DPH determined that the statewide mercury fish advisory is protective of people eating fish and shellfish from these waterbodies, except for three species (striped bass, striped mullet, and blue crab) that require more stringent consumption advisories.** Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), arsenic, hexavalent chromium, mercury, and copper have been found in fish and shellfish near the site at concentrations above DPH levels of concern, indicating the potential for cancer and non-cancer health effects. Doses for subsistence fishers of copper from blue crabs are at levels approaching those shown to cause gastrointestinal effects in people.

Additionally, concentrations of other contaminants, excluding mercury and copper, are at levels that may put people who routinely eat fish from these waterbodies for long periods of time at risk for cancer. The current statewide fish consumption advisory for mercury is stricter for most species, except striped bass, striped mullet, and blue crab, than meal recommendations derived from this evaluation.

Recommendations

The DPH recommends:

- people follow the existing statewide meal consumption limit recommendations for mercury in fish[5]. This includes the following recommendations for eating fish.
  - Women of child-bearing age (15-44 years old), pregnant women, nursing mothers, and children less than 15 years old:
    1. DO NOT EAT fish HIGH in mercury. Catfish and largemouth bass included in this evaluation are HIGH in mercury.
    2. Eat up to 2 meals per week of fish LOW in mercury. Bluegill sunfish, flounder, and red drum included in this evaluation are LOW in mercury.
  - All other people:
    1. Eat only 1 meal per week of fish HIGH in mercury. Catfish and largemouth bass included in this evaluation are HIGH in mercury.
    2. Eat up to 4 meals per week of fish LOW in mercury. Bluegill sunfish, flounder, and red drum included in this evaluation are LOW in mercury.
- all people follow these additional meal consumption limit recommendations for fish and shellfish from Sturgeon Creek, Brunswick River, and Cape Fear River near Navassa, NC:
  - Eat up to 2 meals per week of striped bass[6] due to high levels of mercury.
  - Eat up to 3 meals per week of striped mullet due to high levels of hexavalent chromium.
  - Eat up to 3 meals per week of blue crab due to high levels of arsenic, hexavalent chromium, and mercury.
- the local health department post and maintain advisory signs at areas where people may fish along Sturgeon Creek, Brunswick River, and Cape Fear River.
- the DEQ sample fish and shellfish at least every 5 years from Sturgeon Creek, Brunswick River, and Cape Fear River to monitor changes in contaminant levels and to determine the extent of contamination in fish.

Public Health Action Plan

The purpose of the Public Health Action Plan is to ensure that this health consultation provides a plan of action designed to mitigate or prevent potential adverse health effects.

Public Health Actions Completed

1. DPH issued a fish and shellfish consumption advisory for striped mullet, striped bass, and blue crabs near Navassa, NC on September 25, 2017.

[5] See Appendix F or the N.C. DPH Fish Advisories website for a complete list of fish identified as LOW & HIGH in mercury (http://epi.publichealth.nc.gov/oee/fish/advisories.html).
[6] N.C. DEQ currently has a striped bass harvest moratorium (no striped bass may be kept) for these waterbodies.

2. DPH staff attended two public availability sessions on June 20, 2017 and September 19, 2017 for the Kerr-McGee NPL site to answer questions about the document and fish consumption advisory and to hear comments from the community.
3. DPH staff prepared a summary factsheet that is available on the Health Assessment, Consultation & Education (HACE) program's website[7].
4. DPH has worked with the local health departments impacted to develop signs to inform the local community about the fish consumption advisory.

Public Health Actions Planned

1. DPH will continue to work with the local health departments impacted to inform and educate the local community about potential health hazards associated with eating fish and shellfish from waterbodies near Navassa, NC and how to reduce exposures, including distributing factsheets and other health education materials.
2. DPH will continue to monitor and assess the Kerr-McGee NPL site as the EPA or DEQ collects additional fish tissue or other environmental data and update the fish consumption advisory as appropriate.

[7] http://epi.publichealth.nc.gov/oee/hace/by_site.html#K

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Report Preparation

The North Carolina Department of Health and Human Services prepared this health consultation for the Kerr-McGee Chemical Corporation NPL site under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). We wrote it in accordance with the approved agency methods, policies, and procedures existing at the date of publication.

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Appendix A

Figures

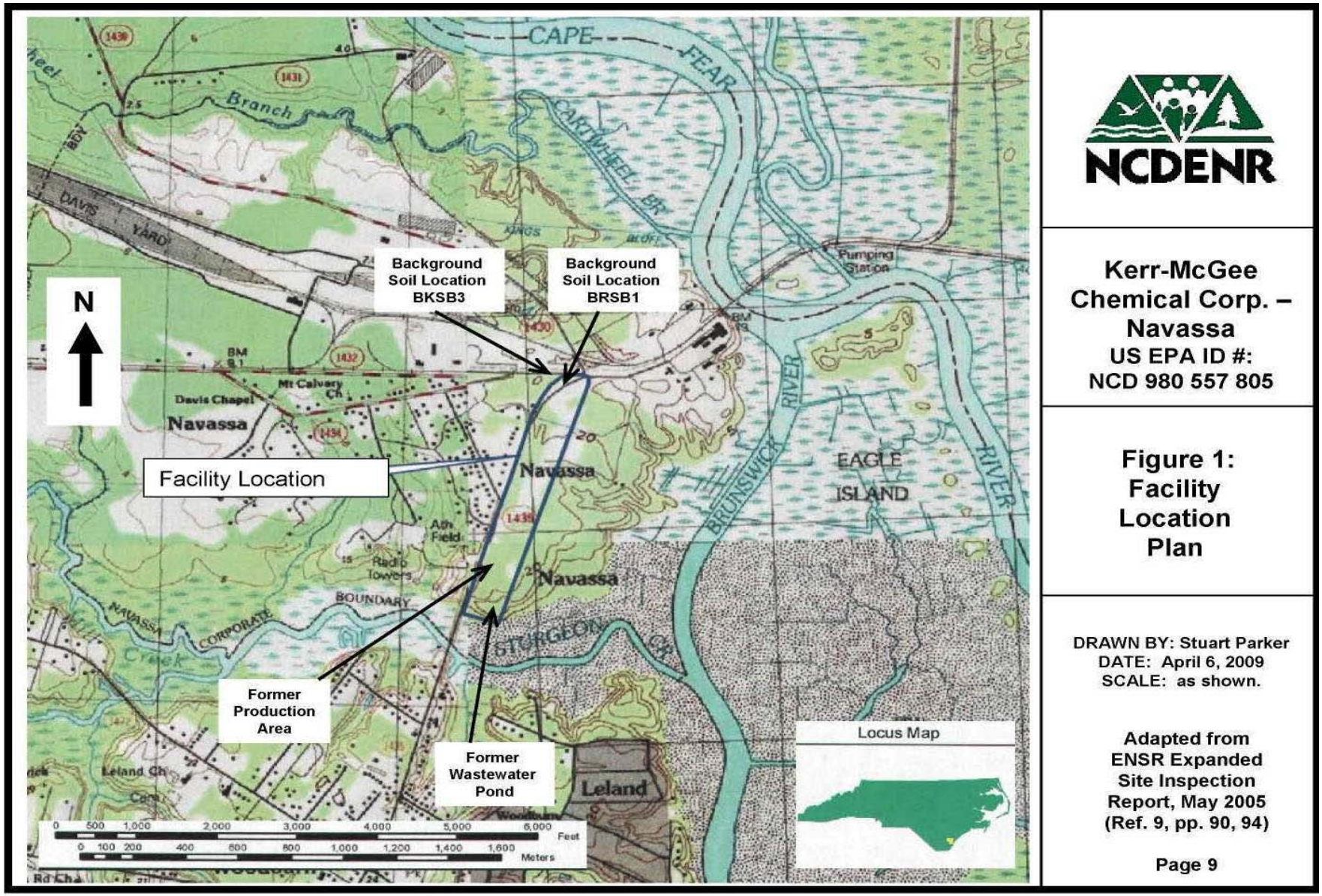

Figure 1. Location of Kerr-McGee Chemical Corp. NPL Site – Navassa, Brunswick County [HRS 2009].

Figure 2. Extent of 2011 fish and shellfish sampling in Sturgeon Creek running through middle of photo).

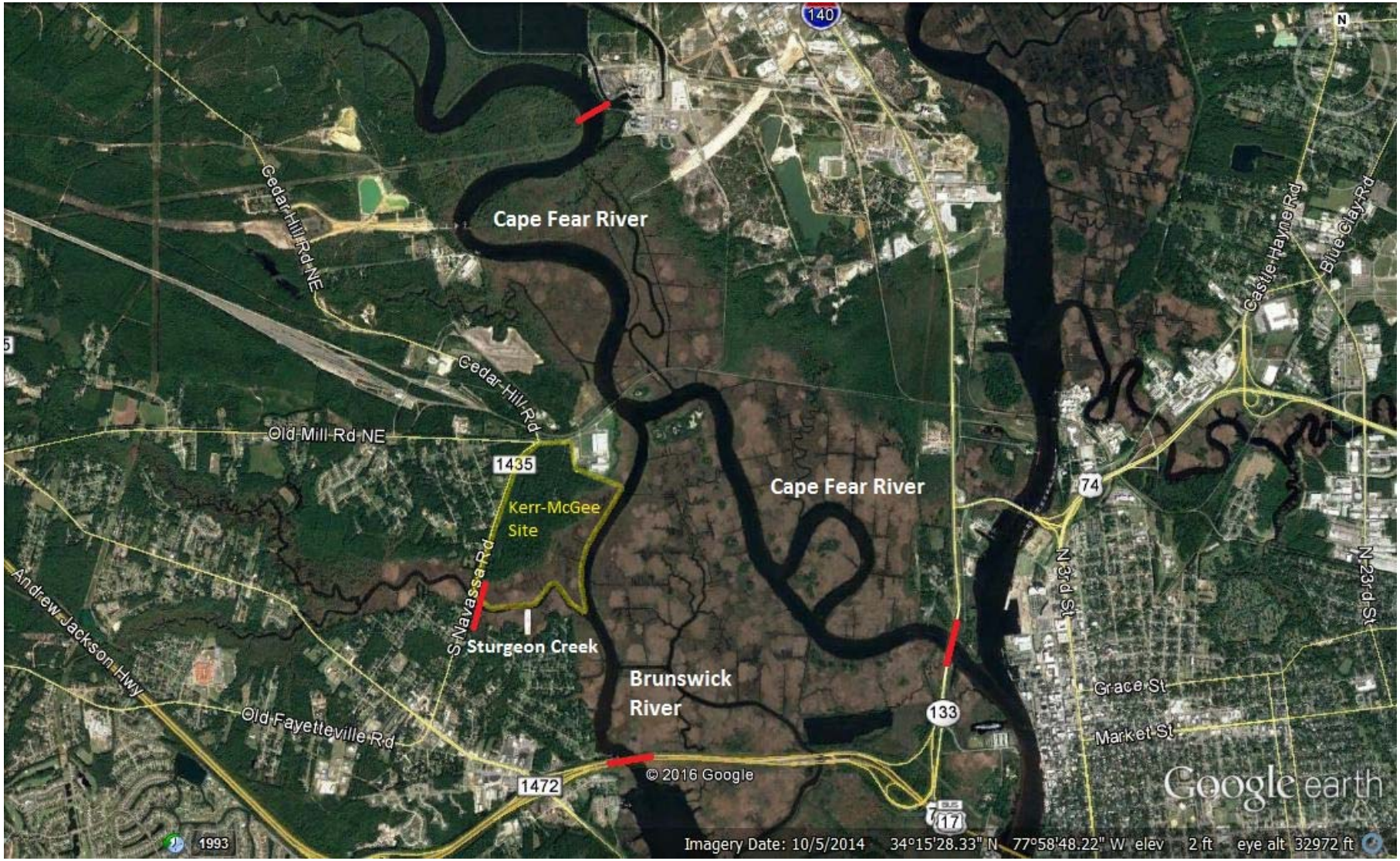

Figure 3. Extent of 2013 fish and shellfish sampling in Sturgeon Creek, Brunswick River, and Cape Fear River (upstream and downstream boundaries marked in red).

Appendix B

Tables

Table 3. Kerr-McGee NPL site. Fish and shellfish samples collected in 2011. Summary of sample polycyclic aromatic hydrocarbon (PAH) detections and average concentrations by species.

Polycyclic Aromatic Hydrocarbons (PAHs)						
Species	**# of samples**	**# of detections**	**Range of Detections (mg/kg)**	**Average B(a)P Equivalent Concentration (mg/kg)[8]**	**Does average exceed screening level?**	**NC DPH Screening Level (mg/kg)**
Channel Catfish	3	2	0.0202 - 0.0348	0.00412	Cancer = YES Non-cancer = NO	0.00129 (cancer), 0.282 (non-cancer)
Blue Catfish	6	6	0.0106 - 0.0628	0.00413	Cancer = YES Non-cancer = NO	
Striped Mullet	2	1	0.0115	0.00424	Cancer = YES Non-cancer = NO	
Striped Bass	3	2	0.0227 - 0.0334	0.00417	Cancer = YES Non-cancer = NO	
Largemouth Bass	4	4	0.0064 - 0.0953	0.00415	Cancer = YES Non-cancer = NO	
Blue Crab (P)	1	1	0.0079	0.00412	Cancer = YES Non-cancer = NO	

Notes: mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
B(a)P = Benzo(a)pyrene
NC DPH = North Carolina Division of Public Health
P = picked meat only, guts removed

[8] Non-detect concentrations are included in the average concentrations as one-half of the reporting limit.

Table 4. Kerr-McGee NPL site. Fish and shellfish samples collected in 2011. Summary of sample polychlorinated biphenyl (PCB) detections and average concentrations by species.

Polychlorinated Biphenyls (PCBs)						
Species	**# of samples**	**# of detections**	**Range of Detections (mg/kg)**	**Average PCB Concentration (mg/kg), all congeners[9]**	**Does average exceed screening level?**	**NC DPH Screening Level (mg/kg)**
Channel Catfish	3	3	0.00390 - 0.0231	0.0122	Cancer = YES Non-cancer = NO	0.00471 (cancer), 0.0188 (non-cancer)
Blue Catfish	6	6	0.00864 - 0.0314	0.0162	Cancer = YES Non-cancer = NO	
Striped Mullet	2	2	0.00415 - 0.00693	0.00565	Cancer = YES Non-cancer = NO	
Striped Bass	3	3	0.0129 - 0.0295	0.0191	Cancer = YES Non-cancer = YES	
Largemouth Bass	4	4	0.00203 - 0.0101	0.00532	Cancer = YES Non-cancer = NO	
Blue Crab (P)	1	1	0.000317	0.000588	Cancer = NO Non-cancer = NO	

Notes: PCB = polychlorinated biphenyl
mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
NC DPH = North Carolina Division of Public Health
P = picked meat only, guts removed

[9] Non-detect concentrations are included in the average concentrations as one-half of the reporting limit.

Table 5. Kerr-McGee NPL site. Fish and shellfish collected in 2011 and 2013. Summary of arsenic detections and inorganic arsenic average concentrations by species.

Arsenic						
Species	**# of samples**	**# of detections**	**Total Arsenic[10] Range of Detections (mg/kg)**	**Average Inorganic Arsenic Concentration (mg/kg)[11]**	**Does average exceed screening level?**	**NC DPH Screening Level (mg/kg)**
Channel Catfish	6	5	0.053 - 0.12	0.0092	Cancer = YES Non-cancer = NO	0.003137 (cancer), 0.141 (non-cancer)
Blue Catfish	13	11	0.077 - 0.89	0.0266	Cancer = YES Non-cancer = NO	
Striped Mullet	8	8	0.12 - 1.6	0.0588	Cancer = YES Non-cancer = NO	
Striped Bass	3	3	0.55 - 0.78	0.0703	Cancer = YES Non-cancer = NO	
Largemouth Bass	10	10	0.14 - 0.36	0.0261	Cancer = YES Non-cancer = NO	
Blue Crab (P)	6	6	0.13 - 1.1	0.0592	Cancer = YES Non-cancer = NO	
Blue Crab (W)	3	3	0.41 - 0.89	0.0690	Cancer = YES Non-cancer = NO	
White Perch	2	2	0.15 - 0.23	0.0190	Cancer = YES Non-cancer = NO	
Flathead Catfish	1	1	0.26	0.0260	Cancer = YES Non-cancer = NO	
Bluegill Sunfish	1	1	0.1	0.0100	Cancer = YES Non-cancer = NO	
Red Drum	4	4	0.36 - 0.62	0.0440	Cancer = YES Non-cancer = NO	
Summer Flounder	1	1	0.3	0.0300	Cancer = YES Non-cancer = NO	

Notes: mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
NC DPH = North Carolina Division of Public Health
P = picked meat only, guts removed
W = whole body tissue

[10] 10% of total arsenic is assumed to be inorganic arsenic [ATSDR 2007c].
[11] Non-detect concentrations are included in the average concentrations as one-half of the reporting limit.

Table 6. Kerr-McGee NPL site. Fish and shellfish collected in 2011 and 2013. Summary of hexavalent chromium detections and average concentrations by species.

Hexavalent Chromium[12]						
Species	**# of samples**	**# of detections**	**Range of Detections (mg/kg)**	**Average Hexavalent Chromium Concentration (mg/kg)[13]**	**Does average exceed screening level?**	**NC DPH Screening Level (mg/kg)**
Channel Catfish	6	5	0.11 - 0.25	0.164	Cancer = YES Non-cancer = NO	0.00941 (cancer), 1.41 (non-cancer)
Blue Catfish	13	9	0.19 - 2.2	0.337	Cancer = YES Non-cancer = NO	
Striped Mullet	8	6	0.23 - 0.30	0.218	Cancer = YES Non-cancer = NO	
Striped Bass	3	0	n/a	0.052	Cancer = YES Non-cancer = NO	
Largemouth Bass	10	7	0.11 - 0.25	0.145	Cancer = YES Non-cancer = NO	
Blue Crab (P)	6	5	0.17 - 0.27	0.215	Cancer = YES Non-cancer = NO	
Blue Crab (W)	3	3	0.19 - 0.34	0.273	Cancer = YES Non-cancer = NO	
White Perch	2	2	0.24 - 0.25	0.245	Cancer = YES Non-cancer = NO	
Flathead Catfish	1	1	0.23	0.230	Cancer = YES Non-cancer = NO	
Bluegill Sunfish	1	1	0.19	0.190	Cancer = YES Non-cancer = NO	
Red Drum	4	4	0.21 - 0.23	0.220	Cancer = YES Non-cancer = NO	
Summer Flounder	1	1	0.22	0.220	Cancer = YES Non-cancer = NO	

Notes: mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
NC DPH = North Carolina Division of Public Health
P = picked meat only, guts removed
W = whole body tissue
n/a = not applicable – no detections of hexavalent chromium in this species

[12] All chromium present in samples is assumed to be hexavalent chromium [NCDHHS 2017].
[13] Non-detect concentrations are included in the average concentrations as one-half of the reporting limit.

Table 7. Kerr-McGee NPL site. Fish and shellfish collected in 2011 and 2013. Summary of mercury detections and average concentrations by species.

Mercury[14]						
Species	**# of samples**	**# of detections**	**Range of Detections (mg/kg)**	**Average Mercury Concentration (mg/kg)[15]**	**Does average exceed screening level?**	**NC DPH Screening Level (mg/kg)**
Channel Catfish	6	6	0.12 - 0.32	0.170	YES	0.00471 (non-cancer)
Blue Catfish	13	13	0.17 - 0.38	0.253	YES	
Striped Mullet	8	6	0.02 - 0.04	0.023	YES	
Striped Bass	3	3	0.12 - 0.23	0.167	YES	
Largemouth Bass	10	10	0.04 - 0.30	0.126	YES	
Blue Crab (P)	6	5	0.08 - 0.15	0.107	YES	
Blue Crab (W)	3	3	0.05 - 0.06	0.057	YES	
White Perch	2	2	0.09 - 0.12	0.105	YES	
Flathead Catfish	1	1	0.11	0.110	YES	
Bluegill Sunfish	1	1	0.15	0.150	YES	
Red Drum	4	4	0.12 - 0.24	0.190	YES	
Summer Flounder	1	1	0.09	0.090	YES	

Notes: mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
NC DPH = North Carolina Division of Public Health
P = picked meat only, guts removed
W = whole body tissue

[14] All mercury present is assumed to be methylmercury.
[15] Non-detect concentrations are included in the average concentrations as one-half of the reporting limit.

Table 8. Kerr-McGee NPL site. Fish and shellfish collected in 2011 and 2013. Summary of copper detections and average concentrations by species.

Copper						
Species	**# of samples**	**# of detections**	**Range of Detections (mg/kg)**	**Average Copper Concentration (mg/kg)**	**Does average exceed screening level?**	**NC DPH Screening Level (mg/kg)**
Channel Catfish	6	5	0.17 - 0.24	0.167	NO	18.8 (non-cancer)
Blue Catfish	13	9	0.12 - 0.39	0.145	NO	
Striped Mullet	8	8	0.20 - 2.0	0.485	NO	
Striped Bass	3	3	0.29 - 0.38	0.347	NO	
Largemouth Bass	10	10	0.14 - 0.43	0.252	NO	
Blue Crab (P)	6	6	6.9 - 16	11.18	NO	
Blue Crab (W)	3	3	26 - 52	40.33	YES	
White Perch	2	2	0.19 - 0.26	0.225	NO	
Flathead Catfish	1	1	0.1	0.1	NO	
Bluegill Sunfish	1	1	0.14	0.14	NO	
Red Drum	4	4	0.18 - 0.23	0.205	NO	
Summer Flounder	1	1	0.16	0.16	NO	

Notes: mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
NC DPH = North Carolina Division of Public Health
P = picked meat only, guts removed
W = whole body tissue

Table 9. Kerr-McGee NPL site. Fish collected in 2011. Estimated polychlorinated biphenyl (PCB) exposure doses for subsistence and recreational fishers for non-cancer health effects evaluation.

Polychlorinated Biphenyls (PCBs)						
Species	**Health Guideline / Type (non-cancer) (mg/kg/day)**	**Average PCBs Concentration (mg/kg), all congeners**	**Subsistence Fishers Estimated Dose (mg/kg/day), all congeners**	**Does calculated dose exceed HG?**	**Recreational Fishers Estimated Dose (mg/kg/day), all congeners**	**Does calculated dose exceed HG?**
Striped Bass	2×10^{-5} ATSDR chronic oral MRL[1]	0.0191	2.0×10^{-5}	YES	2.1×10^{-6}	NO

Notes: mg/kg/day = milligrams of contaminant per kilogram of body weight per day
PCBs = polychlorinated biphenyls
mg/kg = milligrams of contaminant per kilogram of fish tissue
HG = health guideline
ATSDR = Agency for Toxic Substances and Disease Registry
MRL = minimal risk level

Table 10. Kerr-McGee NPL site. Shellfish collected in 2013. Estimated copper exposure doses for subsistence and recreational fishers.

Copper						
Species	**Health Guideline / Type (non-cancer) (mg/kg/day)**	**Average Copper Concentration (mg/kg)**	**Subsistence Fishers Estimated Dose (mg/kg/day)**	**Does calculated dose exceed HG?**	**Recreational Fishers Estimated Dose (mg/kg/day)**	**Does calculated dose exceed HG?**
Blue Crab (W)	0.01 ATSDR intermediate oral MRL	40.33	0.086	YES	0.0088	NO

Notes: mg/kg/day = milligrams of contaminant per kilogram of body weight per day
mg/kg = milligrams of contaminant per kilogram of shellfish tissue
HG = health guideline
W = whole body tissue
ATSDR = Agency for Toxic Substances and Disease Registry
MRL = minimal risk level

Table 11. Kerr-McGee NPL site. Fish and shellfish collected in 2011 and 2013. Estimated mercury exposure doses for subsistence and recreational fishers. All mercury present is assumed to be methylmercury.

Mercury						
Species	**Health Guideline / Type (non-cancer) (mg/kg/day)**	**Average Mercury Concentration (mg/kg)**	**Subsistence Fishers Estimated Dose (mg/kg/day)**	**Does calculated dose exceed HG?**	**Recreational Fishers Estimated Dose (mg/kg/day)**	**Does calculated dose exceed HG?**
Channel Catfish	1×10^{-4} EPA RfD	0.170	3.6×10^{-4}	YES	3.7×10^{-5}	NO
Blue Catfish		0.253	5.4×10^{-4}	YES	5.5×10^{-5}	NO
Striped Mullet		0.023	4.8×10^{-5}	NO	4.9×10^{-6}	NO
Striped Bass		0.167	3.5×10^{-4}	YES	3.7×10^{-5}	NO
Largemouth Bass		0.126	2.7×10^{-4}	YES	2.8×10^{-5}	NO
Blue Crab (P)		0.107	2.3×10^{-4}	YES	2.3×10^{-5}	NO
Blue Crab (W)		0.057	1.2×10^{-4}	YES	1.2×10^{-5}	NO
White Perch		0.105	2.2×10^{-4}	YES	2.3×10^{-5}	NO
Flathead Catfish		0.110	2.3×10^{-4}	YES	2.4×10^{-5}	NO
Bluegill Sunfish		0.150	3.2×10^{-4}	YES	3.3×10^{-5}	NO
Red Drum		0.190	4.0×10^{-4}	YES	4.2×10^{-5}	NO
Summer Flounder		0.090	1.9×10^{-4}	YES	2.0×10^{-5}	NO

Notes: mg/kg/day = milligrams of contaminant per kilogram of body weight per day
mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
HG = health guideline
P = picked meat only, guts removed
W = whole body tissue
EPA = U.S. Environmental Protection Agency
RfD = reference dose

Table 12. Kerr-McGee NPL site. Fish and shellfish collected in 2011. Increased cancer risk estimates from eating fish and shellfish near the Kerr-McGee site based on average benzo(a)pyrene equivalent polycyclic aromatic hydrocarbon (PAH) concentrations by species. Cancer risk calculated assuming daily ingestion over a 78-year lifetime.

Polycyclic Aromatic Hydrocarbons (PAHs)						
Species	**B(a)P CSF $(mg/kg/day)^{-1}$**	**Average B(a)P Equivalent Concentration (mg/kg)**	**Subsistence Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Subsistence Fishers**	**Recreational Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Recreational Fishers**
Channel Catfish	1.0	0.00412	4.4×10^{-6}	4 / million	4.5×10^{-7}	<1 / million
Blue Catfish		0.00413	4.4×10^{-6}	4 / million	4.5×10^{-7}	<1 / million
Striped Mullet		0.00424	4.5×10^{-6}	5 / million	4.6×10^{-7}	<1 / million
Striped Bass		0.00417	4.4×10^{-6}	4 / million	4.6×10^{-7}	<1 / million
Largemouth Bass		0.00415	4.4×10^{-6}	4 / million	4.5×10^{-7}	<1 / million
Blue Crab (P)		0.00412	4.4×10^{-6}	4 / million	4.5×10^{-7}	<1 / million

Notes: B(a)P = Benzo(a)pyrene
CSF = cancer slope factor
mg/kg/day = milligrams of contaminant per kilogram of body weight per day
mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
P = picked meat only, guts removed

Table 13. Kerr-McGee NPL site. Fish and shellfish collected in 2011. Increased cancer risk estimates from eating fish and shellfish near the Kerr-McGee site based on average non-dioxin-like polychlorinated biphenyl (PCB) congener concentrations by species. Cancer risk calculated assuming daily ingestion over a 78-year lifetime.

Non-Dioxin-Like Polychlorinated Biphenyl (PCB) Congeners						
Species	**NDL PCBs CSF $(mg/kg/day)^{-1}$**	**Average NDL PCBs Concentration (mg/kg)**	**Subsistence Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Subsistence Fishers**	**Recreational Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Recreational Fishers**
Channel Catfish	2.0	0.0114	1.2×10^{-5}	2 / 100,000	1.3×10^{-6}	2 / million
Blue Catfish		0.015	1.6×10^{-5}	3 / 100,000	1.6×10^{-6}	3 / million
Striped Mullet		0.0054	5.7×10^{-6}	1 / 100,000	5.9×10^{-7}	1 / million
Striped Bass		0.0204	2.2×10^{-5}	4 / 100,000	2.2×10^{-6}	4 / million
Largemouth Bass		0.00506	5.4×10^{-6}	1 / 100,000	5.5×10^{-7}	1 / million
Blue Crab (P)		0.000534	5.7×10^{-7}	1 / million	5.8×10^{-8}	<1 / million

Notes: NDL = Non-Dioxin-Like
PCBs = polychlorinated biphenyls
CSF = cancer slope factor
mg/kg/day = milligrams of contaminant per kilogram of body weight per day
mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
P = picked meat only, guts removed

Table 14. Kerr-McGee NPL site. Fish and shellfish collected in 2011. Increased cancer risk estimates from eating fish and shellfish near the Kerr-McGee site based on average dioxin-like polychlorinated biphenyl (PCB) congener concentrations by species. Cancer risk calculated assuming daily ingestion over a 78-year lifetime.

Dioxin-Like Polychlorinated Biphenyl (PCB) Congeners						
Species	**DL PCBs CSF $(mg/kg/day)^{-1}$**	**Average DL PCBs Concentration (mg/kg), TEF-adjusted**	**Subsistence Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Subsistence Fishers**	**Recreational Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Recreational Fishers**
Channel Catfish	1.3×10^{5}	2.997×10^{-7}	3.2×10^{-10}	4 / 100,000	3.3×10^{-11}	4 / million
Blue Catfish		2.718×10^{-7}	2.9×10^{-10}	4 / 100,000	3.0×10^{-11}	4 / million
Striped Mullet		2.241×10^{-7}	2.4×10^{-10}	3 / 100,000	2.5×10^{-11}	3 / million
Striped Bass		2.735×10^{-7}	2.9×10^{-10}	4 / 100,000	3.0×10^{-11}	4 / million
Largemouth Bass		2.171×10^{-7}	2.3×10^{-10}	3 / 100,000	2.4×10^{-11}	3 / million
Blue Crab (P)		2.204×10^{-7}	2.3×10^{-10}	3 / 100,000	2.4×10^{-11}	3 / million

Notes: DL = Dioxin-Like
PCBs = polychlorinated biphenyls
CSF = cancer slope factor
mg/kg/day = milligrams of contaminant per kilogram of body weight per day
mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
P = picked meat only, guts removed

Table 15. Kerr-McGee NPL site. Fish and shellfish collected in 2011. Increased cancer risk estimates for subsistence fishers from eating fish and shellfish near the Kerr-McGee site based on combined cancer risk from PAHs, non-dioxin-like PCBs, and dioxin-like PCBs by species. Cancer risk calculated assuming daily ingestion over a 78-year lifetime. PAH and PCB cancer risk combined as they both act through the aryl hydrocarbon receptor [TOX 2013].

Polycyclic Aromatic Hydrocarbon (PAH) and Polychlorinated Biphenyl (PCB) Combined Cancer Risk					
Species	**Estimated Cancer Risk, B(a)P equivalent PAHs**	**Estimated Cancer Risk, NDL PCBs**	**Estimated Cancer Risk, DL PCBs**	**Total PCB Estimated Cancer Risk, NDL and DL PCBs**	**Total Estimated Cancer Risk, PAHs and PCBs**
Channel Catfish	4 / million	2 / 100,000	4 / 100,000	7 / 100,000	7 / 100,000
Blue Catfish	4 / million	3 / 100,000	4 / 100,000	7 / 100,000	7 / 100,000
Striped Mullet	5 / million	1 / 100,000	3 / 100,000	4 / 100,000	5 / 100,000
Striped Bass	4 / million	4 / 100,000	4 / 100,000	8 / 100,000	9 / 100,000
Largemouth Bass	4 / million	1 / 100,000	3 / 100,000	4 / 100,000	5 / 100,000
Blue Crab (P)	4 / million	1 / million	3 / 100,000	3 / 100,000	4 / 100,000

Notes: B(a)P = Benzo(a)pyrene
PAHs = polycyclic aromatic hydrocarbons
NDL = Non-Dioxin-Like
PCBs = polychlorinated biphenyls
DL = Dioxin-Like
P = picked meat only, guts removed

Table 16. Kerr-McGee NPL site. Fish and shellfish collected in 2011 and 2013. Increased cancer risk estimates from eating fish and shellfish near the Kerr-McGee site based on average inorganic arsenic concentrations by species. Cancer risk calculated assuming daily ingestion over a 78-year lifetime.

Arsenic						
Species	**Inorganic Arsenic CSF (mg/kg/day)$^{-1}$**	**Average Inorganic Arsenic Concentration (mg/kg)**	**Subsistence Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Subsistence Fishers**	**Recreational Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Recreational Fishers**
Channel Catfish	1.5	0.0092	2.0×10^{-5}	3 / 100,000	2.0×10^{-6}	3 / million
Blue Catfish		0.0266	5.7×10^{-5}	9 / 100,000	5.8×10^{-6}	9 / million
Striped Mullet		0.0588	1.3×10^{-4}	2 / 10,000	1.3×10^{-5}	2 / 100,000
Striped Bass		0.0703	1.5×10^{-4}	2 / 10,000	1.5×10^{-5}	2 / 100,000
Largemouth Bass		0.0261	5.6×10^{-5}	8 / 100,000	5.7×10^{-6}	9 / million
Blue Crab (P)		0.0592	1.3×10^{-4}	2 / 10,000	1.3×10^{-5}	2 / 100,000
Blue Crab (W)		0.0690	1.5×10^{-4}	2 / 10,000	1.5×10^{-5}	2 / 100,000
White Perch		0.0190	4.0×10^{-5}	6 / 100,000	4.2×10^{-6}	6 / million
Flathead Catfish		0.0260	5.5×10^{-5}	8 / 100,000	5.7×10^{-6}	9 / million
Bluegill Sunfish		0.0100	2.1×10^{-5}	3 / 100,000	2.2×10^{-6}	3 / million
Red Drum		0.0440	9.4×10^{-5}	1 / 10,000	9.6×10^{-6}	1 / 100,000
Summer Flounder		0.0300	6.4×10^{-5}	1 / 10,000	6.6×10^{-6}	1 / 100,000

Notes: CSF = cancer slope factor
mg/kg/day = milligrams of contaminant per kilogram of body weight per day
mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
P = picked meat only, guts removed
W = whole body tissue

Table 17. Kerr-McGee NPL site. Fish and shellfish collected in 2011 and 2013. Increased cancer risk estimates from eating fish and shellfish near the Kerr-McGee site based on average hexavalent chromium concentrations by species. Cancer risk calculated assuming daily ingestion over a 78-year lifetime.

Hexavalent Chromium						
Species	**Hexavalent Chromium CSF $(mg/kg/day)^{-1}$**	**Average Hexavalent Chromium Concentration (mg/kg)**	**Subsistence Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Subsistence Fishers**	**Recreational Fishers Estimated Dose (mg/kg/day)**	**Estimated Increased Cancer Risk for Recreational Fishers**
Channel Catfish	0.5	0.164	3.5×10^{-4}	2 / 10,000	3.6×10^{-5}	2 / 100,000
Blue Catfish		0.337	7.2×10^{-4}	4 / 10,000	7.4×10^{-5}	4 / 100,000
Striped Mullet		0.218	4.6×10^{-4}	2 / 10,000	4.8×10^{-5}	2 / 100,000
Striped Bass		0.052	1.1×10^{-4}	5 / 100,000	1.1×10^{-5}	6 / million
Largemouth Bass		0.145	3.1×10^{-4}	2 / 10,000	3.2×10^{-5}	2 / 100,000
Blue Crab (P)		0.215	4.6×10^{-4}	2 / 10,000	4.7×10^{-5}	2 / 100,000
Blue Crab (W)		0.273	5.8×10^{-4}	3 / 10,000	6.0×10^{-5}	3 / 100,000
White Perch		0.245	5.2×10^{-4}	3 / 10,000	5.4×10^{-5}	3 / 100,000
Flathead Catfish		0.230	4.9×10^{-4}	2 / 10,000	5.0×10^{-5}	3 / 100,000
Bluegill Sunfish		0.190	4.0×10^{-4}	2 / 10,000	4.2×10^{-5}	2 / 100,000
Red Drum		0.220	4.7×10^{-4}	2 / 10,000	4.8×10^{-5}	2 / 100,000
Summer Flounder		0.220	4.7×10^{-4}	2 / 10,000	4.8×10^{-5}	2 / 100,000

Notes: CSF = cancer slope factor
mg/kg/day = milligrams of contaminant per kilogram of body weight per day
mg/kg = milligrams of contaminant per kilogram of fish or shellfish tissue
P = picked meat only, guts removed
W = whole body tissue

Table 18. Kerr-McGee NPL site. Estimated meal limits for fish and shellfish from Sturgeon Creek, Brunswick River, and Cape Fear River near the site.

Species	# and type of samples	PAH & PCB Cancer Risk Meal Limit	Inorganic Arsenic Cancer Risk Meal Limit	Hexavalent Chromium Cancer Risk Meal Limit	Mercury Non-Cancer Meal Limit	Copper Non-Cancer Meal Limit	Most Restrictive Meal Limit Estimate	Enough samples to issue FCA?	Statewide Mercury Advisory (High or Low)[16]	FCA
Channel Catfish	6 ind.	no limit	no limit	4 ml/wk	2 ml/wk	no limit	2 ml/wk	Yes	High	Statewide mercury FCA more restrictive
Blue Catfish	13 ind.	no limit	no limit	2 ml/wk	1 ml/wk	no limit	1 ml/wk	Yes	High	Statewide mercury FCA more restrictive
Striped Mullet	6 ind., 2 comp.	no limit	3 ml/wk	3 ml/wk	no limit	no limit	3 ml/wk	Yes	n/a	3 ml/wk
Striped Bass	2 ind., 1 comp.	no limit	3 ml/wk	no limit	2 ml/wk	no limit	2 ml/wk	Yes	n/a	2 ml/wk - Harvest Moratorium
Largemouth Bass	7 ind., 3 comp.	no limit	no limit	4 ml/wk	2 ml/wk	no limit	2 ml/wk	Yes	High	Statewide mercury FCA more restrictive
Blue Crab (P)	5 ind., 1 comp.	no limit	3 ml/wk	3 ml/wk	3 ml/wk	no limit	3 ml/wk	Yes	n/a	3 ml/wk
Blue Crab (W)	3 ind.	no data	3 ml/wk	2 ml/wk	5 ml/wk	3 ml/wk	2 ml/wk	No	n/a	
White Perch	2 ind.	no data	no limit	2 ml/wk	3 ml/wk	no limit	2 ml/wk	No	n/a	None
Flathead Catfish	1 ind.	no data	no limit	2 ml/wk	3 ml/wk	no limit	2 ml/wk	No	High	Statewide mercury FCA
Bluegill Sunfish	1 ind.	no data	no limit	3 ml/wk	2 ml/wk	no limit	2 ml/wk	No	Low	
Red Drum	4 ind.	no data	5 ml/wk	3 ml/wk	1 ml/wk	no limit	1 ml/wk	No	Low	
Summer Flounder	1 ind.	no data	no limit	3 ml/wk	3 ml/wk	no limit	3 ml/wk	No	Low	

Notes: P = picked meat only, guts removed
W = whole body tissue
ind. = individual fish sample

[16] See Appendix F or the N.C. DPH Fish Advisories web site for additional information for fish identified as LOW & HIGH in mercury (http://epi.publichealth.nc.gov/oee/fish/advisories.html).

comp. = composite fish sample

PAH = polycyclic aromatic hydrocarbon

PCB = polychlorinated biphenyl

ml/wk = maximum recommended number of meals per week

n/a = not applicable – these species are not included in the statewide mercury advisory

FCA = fish consumption advisory

Appendix C

Health Effects Evaluation Process and Exposure Pathway Analysis

Health Effects Evaluation Process

This section provides a summary of the DPH and the Agency for Toxic Substances and Disease Registry (ATSDR) health effects evaluation process.

The first step in the health effects evaluation process is the "environmental guideline comparison" and involves comparing site contaminant concentrations to water, soil, air, or food chain[17] comparison values (CVs). These comparison values are highly health protective values and for fish tissue are derived by DPH from default exposure values [NCDHHS 2017]. During this first step of the screening process, site contaminants are divided into two categories: those exceeding their media specific CVs and those not exceeding CVs. Those contaminant concentrations greater than CVs require a more in-depth evaluation of the potential for adverse health effects. However, concentrations greater than CVs do not automatically indicate adverse health effects are expected. Those contaminant concentrations that are below CVs require no further evaluation, as adverse health effects would not be expected. However, further evaluation may be warranted based on site-specific conditions or community concerns.

The second step in the health effects evaluation process is the "health guideline comparison." This step is a closer look at the contaminants with concentrations greater than CVs from the environmental guideline comparison. The health guideline comparison involves estimating exposure doses[18], based on site-specific conditions, and comparing these doses to health guidelines. For fish tissue evaluations, highly health protective site-specific dose estimates are developed for both subsistence and recreational fishers. These doses are then compared to ATSDR health guideline values. The health guidelines are derived from epidemiologic and toxicological data from the literature with multiple uncertainty factors applied to be highly health protective. Health guidelines represent daily human exposure levels to a substance that are likely to have no appreciable risk of adverse health effects during specific exposure durations. Important factors in determining the potential for adverse health effects include:

- the concentration of the chemical,
- how long (duration) people are in contact with the chemical,
- how often (frequency) people are in contact with the chemical,
- the type of contact with the chemical (route of exposure), such as drinking, eating, touching or breathing it, and
- the health status of the people exposed.

Site-specific dose estimates for contaminants in which doses exceed health guidelines are also compared to data from animal and human health effects studies to determine the potential for adverse health effects. The health effects data are generally taken from ATSDR or EPA references that summarize human and animal studies that have undergone extensive validation review. Comparisons are made based on the exposure route (ingestion/eating, inhalation/breathing, or dermal/skin contact) and the length of the exposure. Preference is given to human study data and chemical doses or concentrations where no adverse health effects were

[17] Fish and other animals or plants that people can eat.
[18] The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure.

observed. If no human data or no-adverse-effect data are available, animal data or the lowest chemical dose where adverse health effects were observed may be used.

Exposure Pathway Analysis

Even though a contaminant may be present in the environment, this does not automatically mean that people will be exposed or that there will be adverse health effects. Exposure to the contaminant and the possibility of adverse health effects requires that people come in contact with the contaminant through ingestion (eating or drinking), inhalation (breathing), or dermal (skin) absorption. The ability of the chemical to cause adverse health effects will also depend on the amount of chemical a person is exposed to (dose), how long a person is exposed (duration), how often a person is exposed (frequency), and how much and what type of damage the chemical can cause in the body (toxicity). Knowing or estimating the frequency with which people have contact with hazardous substances is essential to assessing the public health impact of exposure to these contaminants.

Individuals or groups of individuals, such as children, the elderly, or persons with weakened immune responses, or other chronic health issues may respond differently to potentially harmful substances. These susceptible populations may have different or heightened responses as compared to most people exposed at the same concentration to a particular chemical in the environment. Reasons for these differences may include genetic makeup, age, health status, nutritional status, and exposure to other toxic substances (such as cigarette smoke or alcohol). These factors may limit that person's ability to detoxify or eliminate the harmful chemicals from their body, or may increase the effects of damage to their organs or alter physiological systems. Child-specific exposure situations and susceptibilities are also considered in DPH health evaluations. For fish tissue evaluations, the use of highly health protective exposure parameters for subsistence fishers in developing fish advisories should also protect children's health.

Exposure pathways (how people may come into contact with contaminants in their environment) are evaluated to determine if people have come into contact with site contaminants, or if they may in the future. An exposure pathway is one that contains a source of contamination (i.e., hazardous waste site), the movement of the contaminant through environmental media (i.e., air, water, or soil), a point of exposure where people come in contact with the contaminated media (i.e., soil in a garden), a route of exposure (i.e., eating contaminated soil on homegrown vegetables), and an exposed population of persons that can come in contact with the contaminants.

Appendix D

Exposure Dose Equations and Cancer Evaluation

Exposure Dose Equations

The equations used to estimate exposure doses from eating contaminated fish and shellfish from waterbodies near the Kerr-McGee NPL site are shown below. These equations can be found in the ATSDR Public Health Assessment Guidance Manual [ATSDR 2005]. Population-specific exposure parameters (meal size and body weight) are consistent with ATSDR and EPA guidance [ATSDR 2014a, EPA 2000]. The use of highly health protective exposure parameters for subsistence fishers in developing fish advisories should protect children's health.

Ingestion of contaminants in fish and shellfish

Exposure doses for ingestion of contaminants in fish and shellfish are calculated using the average concentrations of contaminants in milligram per kilogram (mg/kg) per species. The following equation is used to estimate the exposure doses resulting from ingestion of contaminated fish:

$$ED_f = \frac{C \times IR \times LF \times EF}{BW}$$

Where:

- ED_f = exposure dose fish (mg/kg/day)
- C = contaminant concentration (mg/kg)
- IR = intake rate of contaminated fish (kg/day)
- LF = loss factor due to trimming and cooking (only pertains to organic compounds)
- EF = exposure factor (unitless)
- BW = body weight (kg)

The exposure factor is an expression of how often and how long a person may contact a substance in the environment. The exposure factor is calculated with the following general equation:

$$EF = \frac{F \times ED}{AT}$$

Where:

- F = frequency of exposure (days/year)
- ED = exposure duration (years) = 78-year lifetime [ATSDR 2014b]
- AT = averaging time (ED x 365 days/year)

Table 19. Kerr-McGee NPL site. Exposure parameters used in this assessment for people eating fish.

Exposure Parameter	Value	Source[19]
Body Weight (kg)	80	ATSDR 2014a
Subsistence Fisher Intake Rate (kg/day)	0.17[20]	EPA 2000
Recreational Fisher Intake Rate (kg/day)	0.0175[21]	EPA 2000
Exposure Factor	1	Based on daily consumption for a 78-year lifetime
Loss Factor due to Trimming & Cooking (Organics Only)	50%	NCDHHS 2017
Exposure Duration (years)	78	ATSDR 2014b

Notes: kg = kilogram
kg/day = kilograms of fish per day

Cancer Health Effect Evaluation

Theoretical increased numbers of cancers are calculated for known or suspected cancer-causing contaminants using the estimated site-specific exposure dose and cancer slope factor (CSF) provided in ATSDR health guideline documents. DPH evaluates cancer health effects in terms of possible increased cancer risk over background levels. In North Carolina, approximately 30% of women and 50% of men (about 40% combined), will be diagnosed with cancer in their lifetime from a variety of causes. This is referred to as the "background cancer risk". The term "excess cancer risk" represents the risk on top of the background cancer risk. A "one-in-a-million" excess cancer risk (1/1,000,000 or 10^{-6} cancer risk) means that if 1,000,000 people are exposed to the cancer-causing substance at a certain level every day of their lifetime (considered 78 years), then one cancer above the background number of cancers may develop in those 1 million people. In numerical terms, the background number of cancers expected in 1 million people over their life-time is 40% or 400,000. If they are all exposed to the cancer-causing substance daily throughout their life-time, then 400,001 people may get cancer, instead of the expected 400,000. The expression of the estimated cancer risk is not a prediction that cancer will occur, it represents the upper bound estimate of the probability of additional cancers, and merely suggests that there is a possibility. The actual risk may be much lower, or even no risk.

The estimated cancer risk calculation is:

$$\text{Estimated Cancer Risk} = \text{Dose} \times \text{CSF}$$

Where:

Estimated Cancer Risk = expression of the cancer risk (unitless)
Dose = site-specific dose of carcinogen (mg/kg/day)
CSF = cancer slope factor ($[\text{mg/kg/day}]^{-1}$), a measure of cancer potency

[19] Sources listed refer to references beginning on page 12.
[20] This equivalent to one meal per day of 6 ounces of fish, the recommended serving of fish for an adult. This is approximately the size of the palm of your hand.
[21] This is equivalent to one meal per every 10 days of 6 ounces of fish, the recommended serving of fish for an adult. This is approximately the size of the palm of your hand.

This calculation assumes that there is no safe level of exposure to a chemical that causes cancer. However, the calculated risk estimate is not exact and tends to overestimate the actual risk associated with exposures that may have occurred. This increased cancer risk estimate does not equal the increased number of cancer cases that will occur in the exposed population, but estimates an excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime or other selected period of exposure.

For specific exposure situations DPH may use exposure periods of less than a lifetime to provide a more realistic estimation of the risks that are known or predicted to have occurred for a particular area. If information on the specifics of the exposure situations at a site are not known, then DPH will always use health protective values to estimate the maximum level of risk that we believe to be realistic. For the Kerr-McGee NPL site, a 78-year lifetime was used to calculate cancer risk based on DPH guidance [NCDHHS 2017].

Polycyclic Aromatic Hydrocarbons (PAHs)

Benzo(a)pyrene (BaP) is the most studied of the individual PAH compounds, and is thought to be the most toxic. To evaluate potential cancer risk associated with ingestion of PAH contaminated fish, the concentrations of individual detected PAH compounds are converted to an equivalent BaP concentration and summed to provide a "BaP-equivalent" concentration for all detected PAHs. BaP-equivalent exposure doses are calculated by multiplying the concentration of individual detected PAH compounds by their toxicity equivalency factor (TEF), a value that relates the relative toxicity of the individual PAH compounds to the toxicity of BaP.

For this assessment, DPH used TEF values derived by California Environmental Protection Agency and supplemented these with DPH TEF values when necessary [CalEPA 2015, NCDHHS 2017]. Below is a table of TEF values used by N.C. DPH to calculate BaP-equivalent concentrations. An estimated fish ingestion BaP-equivalent exposure dose is calculated using fish ingestion exposure parameters. Estimated numbers of increased cancers for the combined PAH exposure are calculated by multiplying the EPA Integrated Risk Information System (IRIS) BaP cancer slope factor (1.0 $[mg/kg/day]^{-1}$) by the BaP-equivalent exposure dose [IRIS 2017].

$$PAH_{BaP\text{-}eq} = PAH_{conc} \times TEF$$

$$\text{Cancer Risk}_{PAHs} = \text{Dose}_{\Sigma BaP\text{-}eq} \times CSF_{BaP}$$

Where:

$PAH_{BaP\text{-}eq}$	= benzo(a)pyrene equivalent PAH compound concentration, mg/kg
PAH_{conc}	= concentration of individual PAH compound, mg/kg
TEF	= toxicity equivalency factor for PAH compound, unitless
$\text{Cancer Risk}_{PAHs}$	= estimated cancer risk from all PAH compounds
$\text{Dose}_{\Sigma BaP\text{-}eq}$	= estimated dose calculated using summed BaP-equivalent PAH concentrations, mg/kg/day
CSF_{BaP}	= benzo(a)pyrene cancer slope factor ($[mg/kg/day]^{-1}$)

Table 20. Kerr-McGee NPL site. Toxicity equivalency factor (TEF) values used for the cancer risk assessment of PAHs.

PAH Compound	TEF Value
Benzo(a)anthracene	0.1
Benzo(a)pyrene	1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Indeno (1,2,3-cd) pyrene	0.1
Acenaphthene	0.001
Acenaphthylene	0.001
Anthracene	0.01
Chrysene	0.01
Dibenzo(a,h)anthracene	1
Fluoranthene	0.001
Fluorene	0.001
2-Methylnaphthalene	0.001
Naphthalene	0.001
Phenanthrene	0.001
Pyrene	0.001
Benzo(g,h,i)perylene	0.01

Sources: CalEPA 2015
TEF 2002

Notes: PAH = polycyclic aromatic hydrocarbon
TEF = toxicity equivalency factor

Polychlorinated Biphenyls (PCBs)

To assess cancer risk from PCBs, non-dioxin-like and dioxin-like congeners had to be evaluated separately. Dioxin-like congeners are PCB congeners that have been shown to exhibit similar toxicity as 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). Dioxin-like congener concentrations are multiplied by a congener specific TEF and then summed to derive a single dioxin-like PCB concentration per sample. These TEFs relate each dioxin-like congeners' toxicity to the compound 2,3,7,8-TCDD. Below is a table of TEF values used by DPH to calculate 2,3,7,8-TCDD-equivalent concentrations. An estimated fish ingestion dioxin-like PCB exposure dose is calculated using fish ingestion exposure parameters. Estimated numbers of increased cancers for dioxin-like PCB exposure are calculated by multiplying the California Environmental Protection Agency's (CalEPA) 2,3,7,8-TCDD cancer slope factor (1.3×10^5 $[mg/kg/day]^{-1}$) by the dioxin-like PCB exposure dose.

To assess cancer risk from non-dioxin-like congeners, non-dioxin-like congener concentrations are summed and exposure doses are calculated using fish ingestion exposure parameters. The EPA IRIS high persistence PCB cancer slope factor of 2 $(mg/kg/day)^{-1}$ is used to estimate cancer risk from non-dioxin-like congeners. Total estimated increased cancer risk from PCBs can be estimated by adding the cancer risk from dioxin-like PCBs and non-dioxin-like PCBs.

$$PCB_{TCDD\text{-}eq} = DL\text{-}PCB_{conc} \times TEF$$

$$Cancer\ Risk_{DL\text{-}PCBs} = Dose_{\Sigma TCDD\text{-}eq} \times CSF_{TCDD}$$

Where:

$PCB_{TCDD\text{-}eq}$	= 2,3,7,8-TCDD equivalent TEF adjusted dioxin-like PCB concentration, mg/kg
$DL\text{-}PCB_{conc}$	= concentration of individual dioxin-like PCB congener, mg/kg
TEF	= toxicity equivalency factor for dioxin-like PCB congener, unitless
$Cancer\ Risk_{DL\text{-}PCBs}$	= estimated cancer risk from all dioxin-like PCBs
$Dose_{\Sigma TCDD\text{-}eq}$	= estimated dose calculated using summed TCDD-equivalent dioxin-like PCB concentrations, mg/kg/day
CSF_{TCDD}	= 2,3,7,8-TCDD cancer slope factor ($[mg/kg/day]^{-1}$)

Table 21. Kerr-McGee NPL site. Toxicity equivalency factor (TEF) values used for the cancer risk assessment of dioxin-like PCBs.

Dioxin-Like PCB Congener	TEF Value
PCB Congener #77	0.0001
PCB Congener #81	0.0003
PCB Congener #105	0.00003
PCB Congener #114	0.00003
PCB Congener #118	0.00003
PCB Congener #123	0.00003
PCB Congener #126	0.1
PCB Congener #156	0.00003
PCB Congener #157	0.00003
PCB Congener #167	0.00003
PCB Congener #169	0.03
PCB Congener #189	0.00003

Source: EPA 2010
Notes: PCB = polychlorinated biphenyl
TEF = toxicity equivalency factor

$$Cancer\ Risk_{NDL\text{-}PCBs} = Dose_{\Sigma NDL\text{-}PCBs} \times CSF_{PCBs}$$

Where:

$Cancer\ Risk_{NDL\text{-}PCBs}$	= estimated cancer risk from all non-dioxin-like PCBs
$Dose_{\Sigma NDL\text{-}PCBs}$	= estimated dose calculated using summed non-dioxin-like PCB concentrations, mg/kg/day
CSF_{PCBs}	= EPA IRIS high persistence PCB cancer slope factor ($[mg/kg/day]^{-1}$)

Appendix E

Health Effects of Selected Contaminants

Health Effects of Selected Contaminants

Creosote (PAHs)
Creosote is a mixture of hundreds to thousands of chemicals extracted at high temperatures from beechwood, the creosote bush, or coal. The major chemicals in creosote used for wood treatment are polycyclic aromatic hydrocarbons (PAHs), cresols, and phenols. In the past, wood creosote was used as a disinfectant, a laxative, and a cough treatment [ATSDR 2002b].

Eating food or drinking water contaminated with high levels of creosote may cause a burning in the mouth and throat, and stomach pains. Brief direct contact with large amounts of coal tar creosote may result in a rash or severe irritation of the skin, chemical burns on the surfaces of the eyes, convulsions and mental confusion, kidney or liver problems, unconsciousness, and even death. Longer direct skin contact with low levels of creosote mixtures or their vapors can result in increased light sensitivity, damage to the cornea, and skin damage. Longer exposure to creosote vapors can cause irritation of the respiratory tract [ATSDR 2002a]. People taking large amounts of an herbal supplement containing creosote to treat gastrointestinal problems reported altered taste and drowsiness [ATSDR 2009].

Children exposed to creosote are likely to experience the same health effects as adults exposed to creosote. Children who played on soil contaminated with creosote had more skin rashes than children who played in uncontaminated areas. Studies in animals have shown birth defects in the young of mothers exposed to high levels of creosote during pregnancy, but it is not known whether the same effects would occur in humans. Some animal studies indicate that creosote may cross the placenta and reach the fetus. Because chemical components (PAHs, cresol, phenols) of coal tar creosote may be stored in body fat, they may be found in breast milk and could be passed to nursing infants [ATSDR 2002a].

Long-term exposure to low levels of creosote, especially direct contact with the skin during wood treatment or manufacture of coal tar creosote-treated products, has resulted in skin cancer and cancer of the scrotum. Animal studies have also shown skin cancer from skin exposure to coal tar products. The International Agency for Research on Cancer (IARC) has determined that creosote is probably carcinogenic to humans. The EPA has determined that coal tar creosote is a probable human carcinogen [ATSDR 2002a].

Polychlorinated Biphenyls (PCBs)
PCBs are a group of synthetic chlorinated compounds. PCBs have no known smell or taste and can remain in the environment for long periods of time. Most of the research on health effects from PCB exposure has been done in animals. However, some epidemiological studies looking at human health effects from PCB exposure have been performed. Exposure to high levels of PCBs can cause skin conditions (i.e. acne and rashes) or liver damage. Acne-like skin conditions have been seen in animals in addition to humans. Additionally, in animal studies, PCB exposure has led to eye and skin damage, behavioral changes and liver damage. In epidemiological studies, children exposed to PCBs through their mothers, either prenatally or via breast milk, had slightly lower birth weights, behavioral alterations, and effects on the immune system. The primary source of the PCBs in the mothers was thought to be the diet, particularly contaminated fish [ATSDR 2000].

In addition to the non-cancer health effects described above, studies looking at occupational exposures have reported workers exposed to high levels of PCBs developing cancer of the liver and biliary tract [ATSDR 2014c]. Epidemiological studies have shown exposure to higher chlorinated congeners associated with an increased risk in non-Hodgkin's lymphoma [ATSDR 2011]. Studies in rats have also reported liver tumors after exposure to different Aroclors [IRIS 1996]. The U.S. Department of Health and Human Services (U.S. DHHS) has classified PCBs as reasonably anticipated to be human carcinogens and EPA has classified PCBs as probably carcinogenic to humans. IARC has classified PCBs as carcinogenic to humans [ATSDR 2014c].

Mercury

Mercury is a naturally occurring metal which has several forms. Metallic and inorganic mercury enters the air from mining ore deposits, burning coal and waste, and from manufacturing plants. Mercury enters the water or soil from natural deposits, disposal of wastes, and volcanic activity. Mercury is transported long distances in the air and can fall out of the air onto soil or bodies of water. Bacteria and fungi can change mercury that falls on soil or water to methylmercury, an organic form of mercury. Methylmercury builds up in the tissues of fish. Larger and older fish tend to have the highest levels of mercury. People that eat fish can absorb the mercury in the fish. Eating fish and shellfish contaminated with mercury is how most people are exposed to mercury [ATSDR 1999a].

The nervous system is very sensitive to all forms of mercury. Methylmercury and metallic mercury vapors are more harmful than other forms, because more mercury in these forms reaches the brain. Exposure to high levels of metallic, inorganic, or organic mercury (methylmercury) can permanently damage the brain, kidneys, and developing fetus. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems. Short-term exposure to high levels of metallic mercury vapors may cause effects including lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes and eye irritation [ATSDR 1999a].

Very young children are more sensitive to mercury than adults. Mercury in the mother's body passes to a nursing infant through breast milk, however the benefits of breast feeding may be greater than the possible adverse health effects of mercury in breast milk. Mercury's harmful effects to the fetus include brain damage, mental retardation, incoordination, blindness, seizures and inability to speak. Children exposed to mercury may develop problems with their nervous and digestive systems, and kidney damage [ATSDR 1999a].

There is not enough data to know for certain if mercury causes cancer in humans. In laboratory studies methylmercury caused kidney tumors in male mice. EPA has identified methylmercury (the type in fish and shellfish) as a possible human carcinogen [ATSDR 1999b].

Hexavalent Chromium

Chromium is a naturally occurring element found in rocks, animals, plants and soil, where it exists in combination with other elements to form various compounds. Chromium can be found in air, soil, and water following release from manufacturing plants or burning of natural gas, oil, or coal. The main forms of chromium are: chromium (0), trivalent chromium (III), and hexavalent chromium (VI). Chromium (III) is an essential nutrient. Exposure to higher than

normal levels of chromium may result in increased chromium levels in blood, urine, expired air, hair, and nails. Generally, hexavalent chromium is the more toxic form [ATSDR 2012b].

The most sensitive targets of hexavalent chromium after ingestion are the gastrointestinal tract (effects include irritation or damage to the stomach and small intestine) and male reproductive system and sperm damage. We do not know if children are more susceptible to health effects from chromium than adults. We do not know if exposure to chromium will result in birth defects or other developmental effects in people. Some developmental effects, such as low birth weight and changes in development of the skeleton and reproductive system, have been observed in animals exposed to hexavalent chromium [ATSDR 2012b].

The U.S. DHHS, IARC, and the EPA have determined that hexavalent chromium is a known human carcinogen. An increase in stomach tumors was observed in humans and animals exposed to hexavalent chromium in drinking water [ATSDR 2012c].

Arsenic

Arsenic is a naturally occurring element found in the Earth's crust. In the environment, it is usually in the form of inorganic arsenic as it is found combined with other elements, such as oxygen or chlorine. Inorganic arsenic occurs naturally in minerals and ores. When this ore is heated at smelters, inorganic arsenic is released into the air. Additionally, arsenic has been used in wood-treating and pesticides. Fish and shellfish can take up arsenic, which can build up in fish tissue [ATSDR 2007a].

Ingestion of inorganic arsenic can lead to irritation of the stomach and intestines, including nausea, vomiting, and diarrhea. Oral exposure to inorganic arsenic may also lead to blood changes, which can cause fatigue, abnormal heart rhythm, and bruising. Long-term exposure to inorganic arsenic commonly leads to patches of darkened skin and warts on the palms, soles, and torso. Breathing high levels of inorganic arsenic can lead to a sore throat, irritated lungs, and skin changes similar to oral exposure. Children exposed to inorganic arsenic will likely have the same health effects as adults. Additionally, children exposed to inorganic arsenic over a long period of time may have lower IQ scores. Studies in animals show that organic arsenic compounds are less toxic than inorganic arsenic compounds [ATSDR 2007a].

Ingestion of inorganic arsenic can increase the risk of skin cancer, in addition to liver, bladder, and lung cancer. The U.S. DHHS, IARC, and the EPA have determined that inorganic arsenic is a known human carcinogen [ATSDR 2007b].

Appendix F

N.C. DPH Statewide Fish Advisory for Mercury

What fish are safe to eat?

From the North Carolina Division of Public Health

Most fish are good to eat and good for you - high in protein and other nutrients, and low in fat. But some kinds of fish contain high amounts of mercury, which can cause health problems in people, especially children. To help you make the healthiest choices, North Carolina offers the following advice. For more information, see www.epi.state.nc.us/epi/fish/ or call (919)707-5900.

Avoid or limit fish consumption based on the following:	
Women of childbearing age (15 to 44 years), pregnant women, nursing mothers and children under age 15	**All other people**
Do not eat fish from the HIGH in mercury list.	Eat only 1 meal of fish per week from the HIGH in mercury list.
Eat up to 2 meals per week of fish from the LOW in mercury list.	Eat up to 4 meals of fish per week from the LOW in mercury list.

Eat Fish **LOW** in mercury

Ocean Fish		Freshwater Fish
Black drum	Pollock	Bluegill sunfish
Canned light tuna	Pompano	Farm-raised catfish
Cod	Red drum	Farm-raised trout
Crab	Salmon (canned, fresh or frozen)	Farm-raised crayfish
Croaker	Scallops	Tilapia
Flounder	Sheepshead	Trout
Haddock	Shrimp	
Halibut	Skate	
Herring	Southern kingfish (sea mullet)	
Jacksmelt	Spot	
Lobster	Speckled trout (spotted sea trout)	
Mahi-mahi	Tripletail	
Ocean perch	Whitefish	
Oysters	White grunt	

Avoid Fish **HIGH** in mercury

Ocean Fish		Freshwater Fish
Albacore (white) tuna** fresh or canned	Little tunny	Blackfish (bowfin)*
Almaco jack	Marlin	Black crappie***
Banded rudderfish	Orange roughy	Catfish (caught wild)*
Cobia	Shark	Jack fish (chain pickerel)*
Crevalle jack	Spanish mackerel	Largemouth bass (statewide)
Greater amberjack	Swordfish	Walleye in Lake Fontana & Lake Santeetlah (Graham & Swain counties)
South Atlantic grouper (gag, scamp, red and snowy)	Tilefish	Warmouth*
King mackerel	Tuna, fresh or frozen**	Yellow perch*
Ladyfish		

*High mercury levels have been found in blackfish (bowfish), catfish, jack fish (chain pickerel), warmouth, and yellow perch caught south and east of Interstate 85.
**Different species from canned light tuna
***High mercury levels have been found in black crappie caught south and east of Interstate 95.

Spanish version: "¿Cuáles pescados son seguros para comer?"

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Appendix G

Demographic Data

Demographic Data for Town of Navassa, Brunswick County, and New Hanover County, NC

Presented in the table below is demographic data for areas impacted by fish contamination near the Kerr-McGee NPL site.

Table 22. Kerr-McGee NPL site. Population data for areas near site.

	Navassa, NC	Brunswick County, NC	New Hanover County, NC	North Carolina	U.S.
Total population	1,505	107,431	202,667	9,535,483	308,745,538
Ethnicity					
White	27.1%	83.0%	79.1%	68.5%	72.4%
African American	63.6%	11.4%	14.8%	21.5%	12.6%
Hispanic	10.0%	5.2%	5.3%	8.4%	16.3%
Asian	0.1%	0.5%	1.2%	2.2%	4.8%
American Indian	0.5%	0.7%	0.5%	1.3%	0.9%
Some Other Race	4.9%	2.5%	2.4%	4.3%	6.2%
Percent Below Poverty Level	21.1%	16.3%	17.7%	17.4%	15.5%
High school diploma or higher	78.3%	86.6%	91.7%	85.8%	86.7%
Number of housing units	661	77,482	101,436	4,327,528	131,704,730
Percent occupied housing units	86.2%	59.8%	84.8%	86.5%	88.6%
Percent renter-occupied housing units	23.0%	22.8%	40.2%	33.3%	34.9%
Percentage of population under 5 years of age	7.2%	5.4%	5.8%	6.6%	6.5%
Percentage of population over 65 years of age	11.6%	21.4%	13.9%	12.9%	13.0%

Based on Census 2010 figures. Education and poverty information based on 2011-2015 American Community Survey 2015 Estimates.

Appendix H

Response to Public Comments

Response to Public Comments

This Health Consultation was released as a *Public Comment Release* on July 25, 2017. Copies were made available to members of the local community, Brunswick and New Hanover County officials, N.C. DEQ, U.S. EPA, and other stakeholders at the Kerr-McGee NPL site. This health consultation was made available on the N.C. DPH website and at the U.S. EPA's document repository at the Navassa Town Hall. The document was made available and findings were presented at two public meetings and availability sessions on June 20, 2017 and September 19, 2017. A 60-day public comment period was provided from July 25, 2017 through September 25, 2017. Comments were received from one community organization. Those comments and N.C. DPH's response to those comments follow.

Comments Received from Community Organization

1. We ask that the N.C. DPH and ATSDR state clearly its recommendation for removal of toxic contaminants from the Kerr-McGee NPL site.

N.C. DPH Response: We continue to recommend that the EPA reduce the levels of creosote residuals in soils and sediments or prevent contact with contamination during clean-up and when the site is redeveloped.

2. We urge N.C. DPH to incorporate demographic data into its health consultation.

N.C. DPH Response: We have included demographic data for the areas impacted by fish contamination in Appendix G. This includes the Town of Navassa, Brunswick County and New Hanover County.

3. N.C. DPH must analyze and evaluate how Navassa's demographic makeup affects both patterns of subsistence fishing in the area, the effectiveness of fish consumption advisories, and the additional vulnerabilities faced by communities of color and low-wealth communities from environmental harm.

N.C. DPH Response: Although N.C. DPH does not currently have the resources to enact a largescale study of subsistence fishing patterns in the areas impacted by this fish contamination (Town of Navassa, Brunswick County and New Hanover County), we are currently following, and assisting when possible, work of a group of researchers with the Duke University Superfund Research Center looking at subsistence fishing and effectiveness of fish consumption advisories in the Lower Cape Fear region. We plan to use the findings of this research to improve communication of fish advisories with impacted subsistence populations, as well as others in impacted communities and throughout the state.