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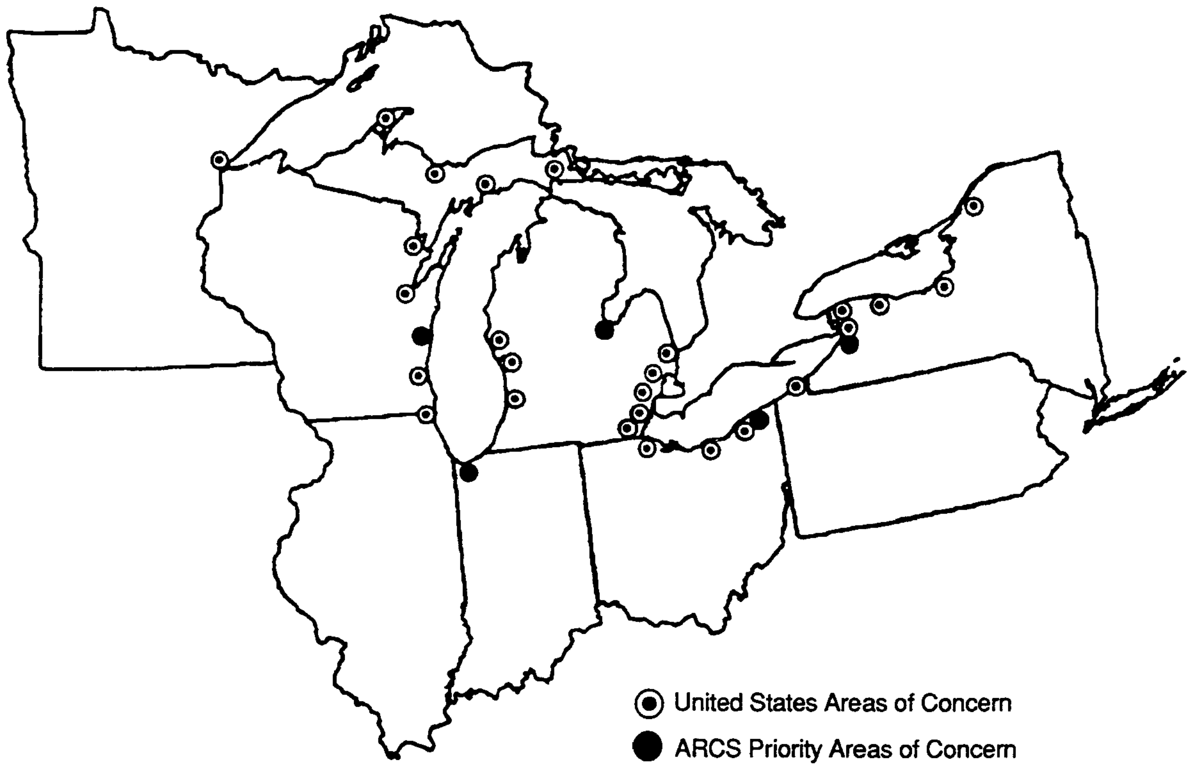
BASELINE HUMAN HEALTH RISK ASSESSMENT: SAGINAW RIVER, MICHIGAN, AREA OF CONCERN



BASELINE HUMAN HEALTH RISK ASSESSMENT: SAGINAW RIVER, MICHIGAN, AREA OF CONCERN

by

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PREFACE

This risk assessment was prepared as part of the Assessment and Remediation of Contaminated Sediments (ARCS) program coordinated by the U.S. EPA Great Lakes National Program Office. The work by AScI Corporation was completed under contract no. 68-C1-0012 with the U.S. EPA Environmental Research Laboratory-Athens by Dr. Judy Crane under the supervision of Dr. James L. Martin, P.E., AScI Site Manager. This work was performed through the U.S. EPA Center for Exposure Assessment Modeling, Mr. Robert Ambrose, Jr., P.E., Manager.

FOREWORD

Risk assessment has been defined as the characterization of the probability of adverse effects from human and ecological exposures to environmental hazards. Risk assessments are quantitative, chemical-oriented characterizations that can use statistical and biological models to calculate numerical estimates of risk to human health or the environment. The concept of risk assessment is a cornerstone on which the U.S. Environmental Protection Agency builds programs to confront pollution problems in air, water, and soil under the direction of Congressional mandates. One such mandate is the Clean Water Act, which includes a directive to the Agency to study the control and removal of toxic pollutants in the Great Lakes, with emphasis on removal of contaminants from bottom sediments. Charged with performing this study is EPA's Great Lakes National Program Office (GLNPO) located in Chicago, IL. GLNPO administers the Assessment and Remediation of Contaminated Sediments (ARCS) program to examine the problem of contaminated sediments using a multidisciplinary approach involving engineering, chemistry, toxicology, modeling, and risk assessment.

In support of the GLNPO, the Environmental Research Laboratory-Athens began a series of studies under the ARCS program that will culminate in a baseline risk assessment for each of five Great Lakes Areas of Concern (AOC)--Buffalo River, NY, Grand Calumet River/Indiana Harbor Canal, IN, Saginaw River, MI, Ashtabula River, OH, and Sheboygan River, WI. This report describes a baseline human health risk assessment for the population within the Saginaw River AOC. The assessment, which is based on available environmental data, is designed to provide a conservative estimate of carcinogenic and noncarcinogenic risks to human health under the baseline, no-action alternative.

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ABSTRACT

The Assessment and Remediation of Contaminated Sediments (ARCS) program, a 5-year study and demonstration project relating to the control and removal of contaminated sediments from the Great Lakes, is being coordinated and conducted by the U.S. Environmental Protection Agency's (EPA) Great Lakes National Program Office (GLNPO). As part of the ARCS program, baseline human health risk assessments are being performed at five Areas of Concern (AOCs) in the Great Lakes region. The Saginaw River, located in east-central Michigan, is one of these AOCs.

In this report, exposure and risk assessment guidelines, developed for the EPA Superfund program, have been applied to determine the baseline human health risks associated with direct and indirect exposures to contaminated sediments in the lower 8 km of the Saginaw River. These risks were estimated for noncarcinogenic (e.g., reproductive toxicity, teratogenicity, liver toxicity) and carcinogenic (i.e., probability of an individual developing cancer over a lifetime) effects.

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ACKNOWLEDGMENTS

Several people provided helpful information about the Saginaw River area including: Greg Goudy (MDNR), Allan Brouillet (MDNR), Tim Kubiak (U.S. Fish and Wildlife Service), Mardi Klevs (U.S. EPA, Region V), Doug Bell (East Central Michigan Planning and Development Region), and John Giesy and Dave Verbrugge (Michigan State University). We especially thank Greg Goudy, Saginaw River/Bay RAP Manager, for providing Michigan DNR data on contaminant levels in sediment, water, and fish collected from the Saginaw River/Bay. Tim Kubiak supplied data on contaminant levels in waterfowl. Members of the ARCS Risk Assessment and Modeling Work Group have also provided useful feedback. The constructive review comments of James Martin (AScI Corporation) and Bill Sutton (ERL-Athens) were much appreciated.

CHAPTER 1

EXECUTIVE SUMMARY

1.1 OVERVIEW

The Assessment and Remediation of Contaminated Sediments (ARCS) program, a 5-year study and demonstration project relating to the control and removal of contaminated sediments from the Great Lakes, is being coordinated and conducted by the U.S. Environmental Protection Agency's (EPA) Great Lakes National Program Office (GLNPO). As part of the ARCS program, baseline human health risk assessments are being performed at five Areas of Concern (AOCs) in the Great Lakes region. The Saginaw River, located in east-central Michigan, is one of these AOCs.

In this report, exposure and risk assessment guidelines, developed for the EPA Superfund program, have been applied to determine the baseline human health risks associated with direct and indirect exposures to contaminated sediments in the lower 8 km of the Saginaw River. These risks were estimated for noncarcinogenic (e.g., reproductive toxicity, teratogenicity, liver toxicity) and carcinogenic (i.e., probability of an individual developing cancer over a lifetime) effects.

1.2 STUDY AREA

This risk assessment covers an area adjacent to the lower 8 km of the Saginaw River as it passes through Bay City, Essexville, and parts of Hampton and Bangor townships before entering Saginaw Bay. This area has a history of water quality problems due to point (i.e., industrial and municipal discharges) and nonpoint (e.g., upstream agricultural runoff) sources of nutrients and contaminants. The extent of contamination and eutrophication in the entire Saginaw River/Bay region led to the International Joint Commission's (IJC) decision to designate this region as a Great Lakes AOC. In response, the Michigan Department of Natural Resources (MDNR) has completed one phase of a remedial action plan (RAP) to identify and implement pollution abatement measures for the Saginaw River/Bay AOC (MDNR, 1988).

High levels of nutrients, heavy metals, polychlorinated biphenyls (PCBs), and in some areas, dioxins, have been measured in different compartments of the Saginaw River (e.g., sediments, water column, and fish). Concentrations of PCBs in excess of 1 mg/kg have been measured in sediments. In addition, fish advisories have been issued against consuming carp and channel catfish from the Saginaw River because of excessive levels of PCBs and dioxins. The transport of these contaminants into Saginaw Bay is of concern, and the Michigan DNR has conducted widespread sampling in the Bay to determine contaminant concentrations in the sediments and fish. However, it was beyond the scope of this risk assessment to estimate human health risks to people using the Bay.

PCBs and other contaminants have been detected in fish (e.g., walleye, yellow perch, carp, and catfish) collected from both the Saginaw River and Bay. Since many species of fish travel between the river and bay, there is some uncertainty as to where the fish accumulated their contaminant burden. Fish collected from the mouth of the Saginaw River during the late 1980s contained higher contaminant concentrations than for similar fish species collected from different points in the Bay. For the purpose of this risk assessment, it was assumed that fish collected from the mouth of the river accumulated most of their contaminant burden from the lower Saginaw River.

Several contact and noncontact recreational activities take place along the Saginaw River, with fishing and boating being the most popular pastimes. Fishing occurs by boat and from shore in the Bay City area; ice-fishing is also a common activity during wintertime. Hunting is another popular sport, with waterfowl hunting taking place in several wildlife refuges near the river.

1.3 EXPOSURE ASSESSMENT

This assessment focused on two pathways by which residents of the lower Saginaw River could be exposed to sediment-derived contaminants: 1) consumption of contaminated fish (i.e., walleye or carp), and 2) consumption of contaminated waterfowl (i.e., mallards and gadwalls). Other exposure pathways were determined to be either incomplete (e.g., ingestion of sediments) or insignificant in terms of risk (e.g., ingestion of surface water while swimming). Swimming does not occur very often in the lower Saginaw River, and there are no beaches in the area.

Only a few species of fish and waterfowl were included in the exposure assessment because of the lack of data for many other species. Walleye were chosen because they are the preferred sport fish in the Saginaw River and could be used to represent a pelagic (open-water) species. Carp were selected because they are generally the most contaminated fish in water bodies due to their benthic feeding habits and high lipid content; carp were used to represent a benthic species. Thus, by examining the estimated risk from consuming either carp or walleye, a range of risk estimates could be determined for a variety of exposure scenarios. In terms of waterfowl consumption, the only available data set containing contaminant levels in wild waterfowl were for two mallards and six gadwalls collected in 1985 from the Saginaw River area; these data sets were combined and used in the exposure assessment.

Noncarcinogenic and carcinogenic risks were estimated for typical, reasonable maximum, and subsistence exposures. Typical (i.e., average) exposures were assumed to occur over a period of 9 years; reasonable maximum (i.e., the maximum exposure that is reasonably expected to occur at a site) and subsistence exposures were assumed to occur over a period of 30 years (USEPA, 1989a). These exposure durations were extrapolated over a period of 70 years for estimating carcinogenic risks. The subsistence pathway was chosen for a small segment of the population that may be relying on the consumption of fish or waterfowl from the area for their main source of protein. For all three exposure scenarios, exposures were determined for each chemical and added for each pathway. In addition, exposures were added across pathways (i.e., consumption of fish and waterfowl) for typical and reasonable maximum exposures; this was not done for the subsistence scenario because subsistence anglers and waterfowl hunters represent two sensitive subpopulations that should be considered separately.

For each of these exposure scenarios, different consumption patterns of fish and waterfowl were assumed to take place (Tables 1.1 and 1.2). These consumptions patterns were based, in part, on recommended values given in EPA Superfund guidance (USEPA, 1989a,b; 1991a) or else on study assumptions.

Several heavy metals and organic compounds were included in the exposure assessment: arsenic, cadmium, copper, mercury, zinc, chlordane, dieldrin, heptachlor epoxide, hexachlorobenzene, PCBs, p,p' dichlorodiphenyl dichloroethane (DDD), p,p' dichlorodiphenyl dichloroethylene (DDE), p,p' dichloridiphenyl trichloroethane (DDT), and styrene. This list was selected for those chemicals detected in fish and waterfowl for which noncarcinogenic and/or carcinogenic toxicity values were available.

1.4 RISK ASSESSMENT

1.4.1 Determination of Risk

Noncarcinogenic effects were evaluated by comparing an exposure level over a specified time period with a reference dose (RfD)[1] derived from a similar exposure period (otherwise known as a hazard quotient (HQ)). Thus, HQ = exposure level/RfD. An HQ value of less than 1 indicates that exposures are not likely to be associated with adverse noncarcinogenic effects. HQ values between 1 and 10 may be of concern, particularly when additional significant risk factors are present (e.g., other contaminants at levels of concern) (USEPA, 1988a). The sum of more than one HQ value for multiple substances and/or multiple exposure pathways is represented by the Hazard Index (HI). This assumption of additivity

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[1] The RfD provides an estimate of the daily contaminant exposure that is not likely to cause harmful effects during either a portion of a persons' life or their entire lifetime (USEPA, 1989a).

TABLE 1.1. AMOUNT OF FISH ASSUMED TO BE CONSUMED PER PERSON PER DAY FROM THE SAGINAW RIVER FOR EACH EXPOSURE SCENARIO

Exposure Scenario	Ingestion Rate* (g/day)	x	FI**	=	Amount of Saginaw R. Fish Consumed (g/day)
Typical	19.2		0.10		1.92
Reasonable Maximum	54		0.25		13.5
Subsistence Fishing	132		0.7		92.4

* Sources: Typical (West, 1989); Reasonable Maximum (USEPA, 1991a); Subsistence [Pao et al (1982) cited in USEPA (1989a)].

** FI = Fraction of fish (i.e., walleye or carp) estimated to be ingested from the Saginaw River (study assumption). Walleye represent skin-on-fillets, whereas carp represent skin-off-fillets.

does not account for any synergistic or antagonistic effects that may occur among chemicals.

Carcinogenic risks were estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposures to potential carcinogens. This risk was computed using average lifetime exposure values that were multiplied by the oral slope factor[2] for a particular chemical. The resulting carcinogenic risk estimate generally represents an upper-bound estimate, because slope factors are usually based on upper 95th percentile confidence limits. Carcinogenic effects were summed for all chemicals in an exposure pathway as well as for multiple pathways (i.e., ingestion of fish and waterfowl). This summation of carcinogenic risks assumed that intakes of individual substances were small, that there were no synergistic or antagonistic chemical interactions, and that all chemicals caused cancer. The EPA believes it is prudent public health policy to consider actions to mitigate or minimize exposures to

[2] Slope factors are estimated through the use of mathematical extrapolation models for estimating the largest possible linear slope (within 95% confidence limits) at low extrapolated doses that is consistent with the data (USEPA, 1989a).

TABLE 1.2. AMOUNT OF WATERFOWL ASSUMED TO BE CONSUMED PER PERSON PER YEAR FROM THE SAGINAW RIVER AREA FOR EACH EXPOSURE SCENARIO

Exposure Scenario	Ingestion Rate* (g/meal)	x	Number of Meals per year**	x	FI***	=	Amount of Saginaw R. Waterfowl Consumed (g/yr)
Typical	85		3		0.33		84
Reasonable Maximum	110		16		0.5		880
Subsistence Hunting	280		16		1.0		4480

* Sources: Typical (University of Georgia Extension Service, personal communication, 1991); Reasonable Maximum and Subsistence [Pao et al. (1982) cited in USEPA (1989a)].

** Study Assumption (see Chapter 5).

*** FI = Fraction of waterfowl (i.e., mallards and gadwalls) assumed to be ingested from the Saginaw River area (study assumption). Waterfowl represents "roaster ready" (i.e., plucked and eviscerated) birds.

contaminants when estimated, upper-bound excess lifetime cancer risks exceed the 10^{-5} to 10^{-6} range, and when noncarcinogenic health risks are estimated to be significant (USEPA 1988a).

1.4.2 Noncarcinogenic Risks

Noncarcinogenic risks, as represented by HI, were less than 0.5 for all exposure levels and pathways except for the subsistence consumption of walleye (HI = 1) and carp (HI = 4) (Table 1.3). For the high consumption of walleye, the noncarcinogenic risk was at a borderline level of concern and was due mostly to the additive risk of methyl mercury and copper. For carp, only heptachlor epoxide had a HQ value exceeding one; this chemical has been found to cause increased liver-to-body weight ratio in both male and female beagle dogs. The rest of the subsistence hazard index for carp was attributable to the combined risk resulting from exposure to chlordane, dieldrin, and copper.

Although some of the chemicals detected in these animals do not presently have RfD values (e.g., PCBs), it would be premature to state that no noncarcinogenic risk exists from consuming fish or waterfowl from the lower Saginaw River area under typical and reasonable maximum exposures. The

TABLE 1.3. ESTIMATED NONCARCINOGENIC AND CARCINOGENIC RISKS TO PEOPLE RESIDING IN THE LOWER SAGINAW RIVER AREA

	Individual Risks			Additive Risks	
Type of Risk and Exposure*	Walleye	Carp	Waterfowl	Walleye + Waterfowl	Carp + Waterfowl
Noncarcinogenic (HI)					
Typical	0.02	0.08	0.001	0.02	0.08
Reasonable Maximum	0.2	0.5	0.02	0.2	0.5
Subsistence	1	4	0.08		
Carcinogenic					
Typical	1E-05	1E-04	6E-06	2E-05	1E-04
Reasonable Maximum	2E-04	3E-03	2E-04	4E-04	3E-03
Subsistence	2E-03	2E-02	1E-03		

* Noncarcinogenic risks were averaged over the same period as the exposure duration while carcinogenic risks were averaged over a period of 70 years (i.e., average lifetime of an individual).

noncarcinogenic risk reported here is an estimated risk based on currently available data and toxicity information and should not be construed as an absolute risk.

1.4.3 Carcinogenic Risks

The estimated, upper-bound carcinogenic risk levels for all pathways and exposure scenarios were at or above concern levels (i.e., 10^{-5} to 10^{-6} range). In all cases, PCBs accounted for nearly all of the carcinogenic risk. There is a possibility that people who ingest, inhale, or have dermal contact with certain PCB mixtures may have a greater chance of incurring liver cancer; however, this statement is based on suggestive evidence rather than on verified data.

These risk estimates may have been overestimated because the only available oral slope factor for PCBs was based on Aroclor 1260. The primary Aroclor mixture detected in fish collected from the Saginaw River resembled Aroclor 1254, while only total PCBs were reported for waterfowl. Since Aroclor 1260 contains more highly chlorinated congeners (as well as potentially toxic coplanar congeners) than Aroclor 1254, these risk estimates may be overly conservative.

In comparison with the typical exposure scenario, carcinogenic risks increased by approximately one order of magnitude for reasonable maximum exposures and by two orders of magnitude for subsistence anglers or hunters. The individual risks from consuming walleye or waterfowl were nearly equivalent for each exposure scenario; in comparison, carp consumption increased carcinogenic risks by an order of magnitude. Although walleye and waterfowl contributed equally to the risks of consuming both of these items, the additive risk of consuming carp and waterfowl was largely due to the risk level for carp.

1.4.4 Uncertainties

Several assumptions and estimated values were used in this baseline risk assessment that contributed to the overall level of uncertainty associated with the noncarcinogenic and carcinogenic risk estimates. As with most environmental risk assessments, the uncertainty of the risk estimates probably varied by at least an order of magnitude or greater. Uncertainties were addressed in a qualitative way for those parameters and assumptions that appeared to contribute the greatest degree of uncertainty. One of the greatest sources of uncertainty was the assumption that exposure intakes and toxicity values would not change during the exposure duration. This assumed that human activities and contaminant levels would remain the same over the exposure duration, and that toxicity values would not be updated.

CHAPTER 2

INTRODUCTION

The 1987 amendments to the Clean Water Act, in Section 118(c)(3), authorize the U.S. Environmental Protection Agency's (EPA) Great Lakes National Program Office (GLNPO) to coordinate and conduct a 5-year study and demonstration project relating to the control and removal of contaminated sediments from recommended areas in the Great Lakes region. To achieve this task, GLNPO has initiated the Assessment and Remediation of Contaminated Sediments (ARCS) program. The overall objectives of the ARCS program (USEPA, 1991b), for selected Areas of Concern (AOCs), are to:

1. Assess the nature and extent of contaminated sediments,

2. Evaluate and demonstrate remedial options (e.g., removal, immobilization, and advanced treatment technologies) as well as the "no action" alternative,

3. Provide risk assessments for humans, aquatic life, and wildlife exposed to sediment-related contaminants, and

4. Provide guidance on the assessment of contaminated sediment problems and on the selection and implementation of necessary remedial actions in the Areas of Concern and other locations in the Great Lakes.

As one part of the ARCS program, baseline human health risk assessments are being prepared for five AOCs: Ashtabula River, OH; Buffalo River, NY; Grand Calumet River/Indiana Harbor Canal, IN; Saginaw River, MI; and Sheboygan River, WI (Figure 2.1). The objectives of these risk assessments are to: 1) estimate the magnitude and frequency of human exposures to contaminants in the AOC, and 2) determine the risk of adverse effects resulting from both typical and reasonable maximum exposures (i.e., the highest exposure that is reasonably expected to occur at a site) to contaminants. Risk estimates are determined for both noncarcinogenic (i.e., chronic or subchronic effects) and carcinogenic (i.e., probability of an individual developing cancer over a lifetime) effects resulting from direct and indirect exposures to sediment-related contaminants.

This document presents a baseline human health risk assessment for one portion of the Saginaw River/Bay AOC (Figure 2.2), the lower 8 km of the Saginaw River. This section of the Saginaw River was chosen because: 1) the site is located in an urban area (Bay City) bisected by the Saginaw River and lies adjacent to Saginaw Bay; 2) several industrial and municipal wastewater treatment plants

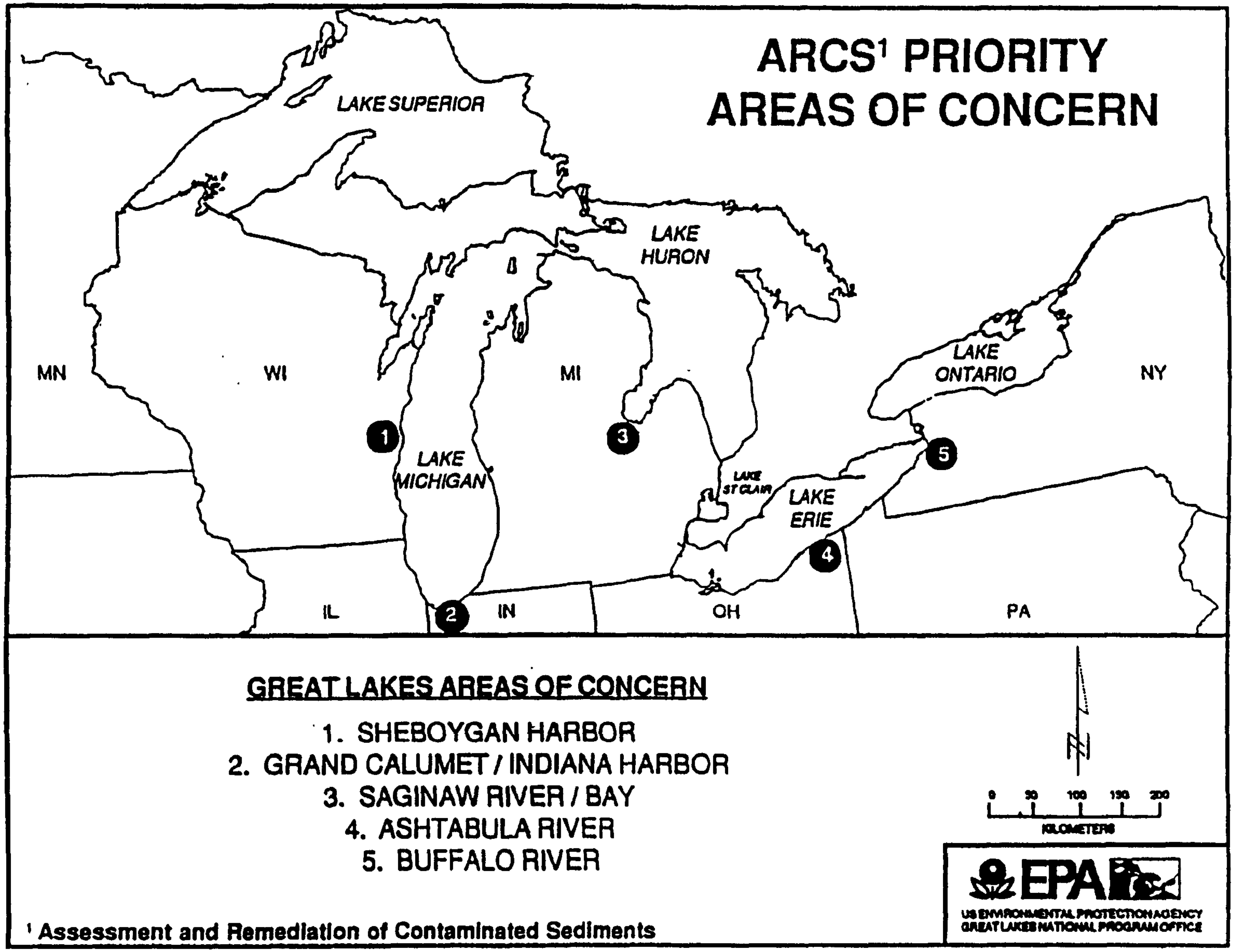

Figure 2.1. Map of ARCS priority Areas of Concern (USEPA, 1991b).

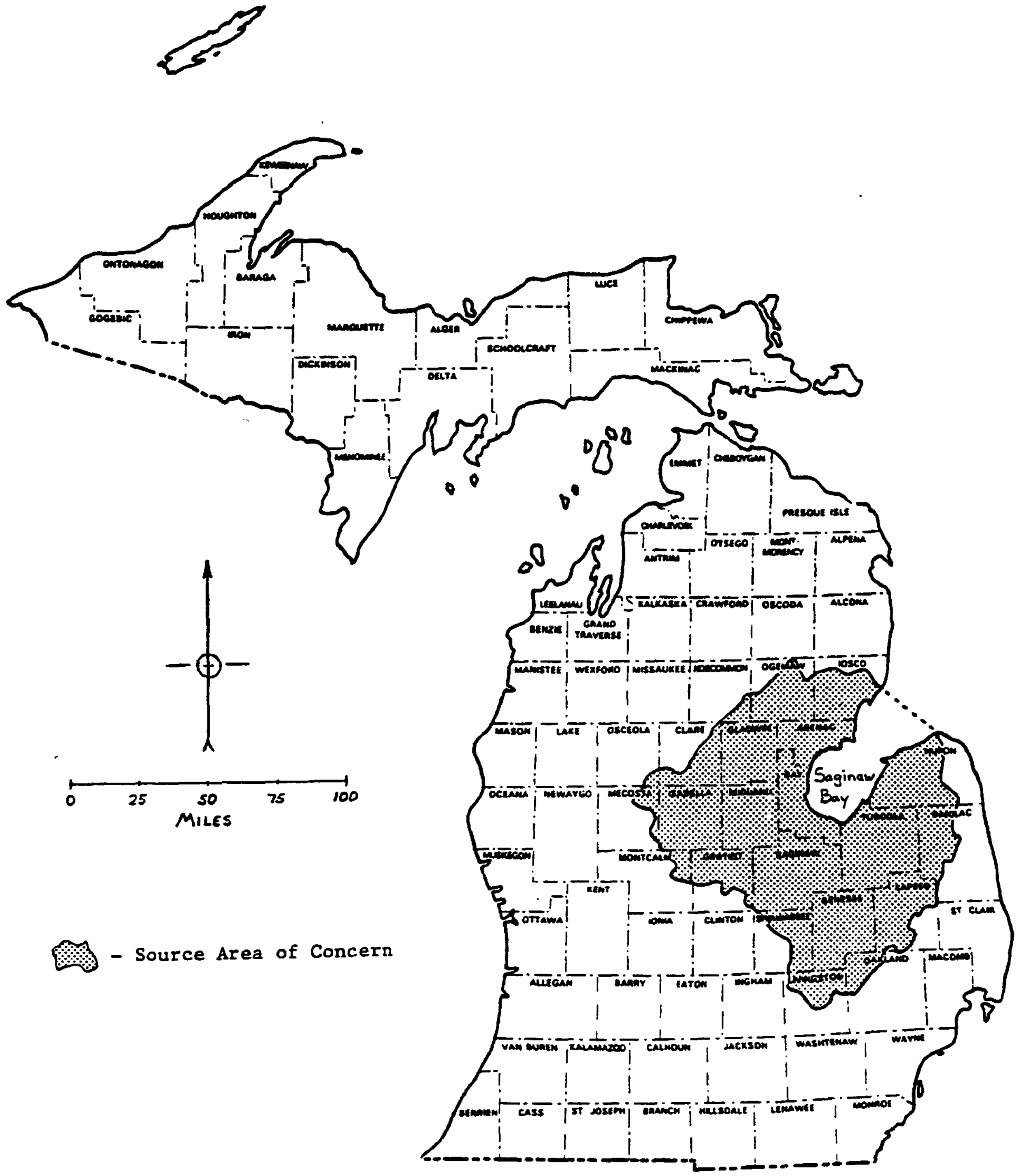

Figure 2.2. Location of the Saginaw River/Bay Area of Concern.

discharge treated effluent into the river; 3) high levels of contaminants, especially PCBs, have been measured in the river sediments; 4) several recreational areas and marinas are located along the river; and 5) contaminant modeling for another task of ARCS (i.e., the comparative risk assessment) is to be conducted in the same region.

CHAPTER 3

LOWER SAGINAW RIVER AREA OF CONCERN

3.1 ENVIRONMENTAL SETTING

The Saginaw River, located in east central Michigan, is a short (35 km), eutrophic river with a drainage basin of 671 km^2 (Figure 3.1). This river receives most of its flow from the Cass, Flint, Shiawassee, and Tittabawassee Rivers and in turn provides approximately 75% of the tributary hydraulic input to Saginaw Bay. The average discharge of the Saginaw River is 114 m^3/sec, and flow reversals have been observed as far upstream as river kilometer 35. During September 1986, extreme flooding took place in the Saginaw, Tittabawassee, and Cass Rivers when over 45 cm of rain fell during a 3-week period [F. Nurnberger, personal communication cited in the Remedial Action Plan or RAP (MDNR, 1988)]. As a result of this flooding, sediments may have been resuspended and transported as far as the bay before settling out again. Consequently, the distribution of contaminants in the sediments, water column, and biota of the Saginaw River may have been altered after this flooding event.

The specific area of concern for this risk assessment is the lower 8 km of the Saginaw River (i.e., from the Lafayette Street Bridge in Bay City to the mouth of the river) (Figure 3.2). This area includes the towns of Bay City and Essexville and part of Bangor and Hampton townships. Several industries are located along the river and a navigation channel is maintained for shipping traffic. The dredged sediments from the navigation channel have been stored in an offshore Confined Disposal Facility (CDF) which is nearing its capacity; no plan has been made for disposing of future dredged sediments.

3.2 WATER QUALITY PROBLEMS

The Saginaw River and Saginaw Bay have been listed as an AOC by the International Joint Commission. This designation is given to areas where environmental quality is degraded and designated uses of the water are impaired. This AOC has a history of water quality problems due to agricultural runoff and industrial and municipal discharges into the river and bay. Although conditions in this AOC have improved over the past 20 years for some pollutants (e.g., phosphorus, suspended solids, oil and grease), problems remain for persistent hydrophobic organic contaminants (e.g., PCBs) and some heavy metals. A RAP for the Saginaw River/Bay AOC has been developed by the Michigan DNR to identify and implement pollution abatement measures. The main objectives of the RAP are to: 1) reduce contaminant levels in fish tissue to the point where fish consumption advisories are no longer needed for any fish species in the AOC, 2) reduce contaminant levels in the AOC to those of Michigan's water quality standards, and 3) reduce eutrophication in Saginaw Bay to a level that will

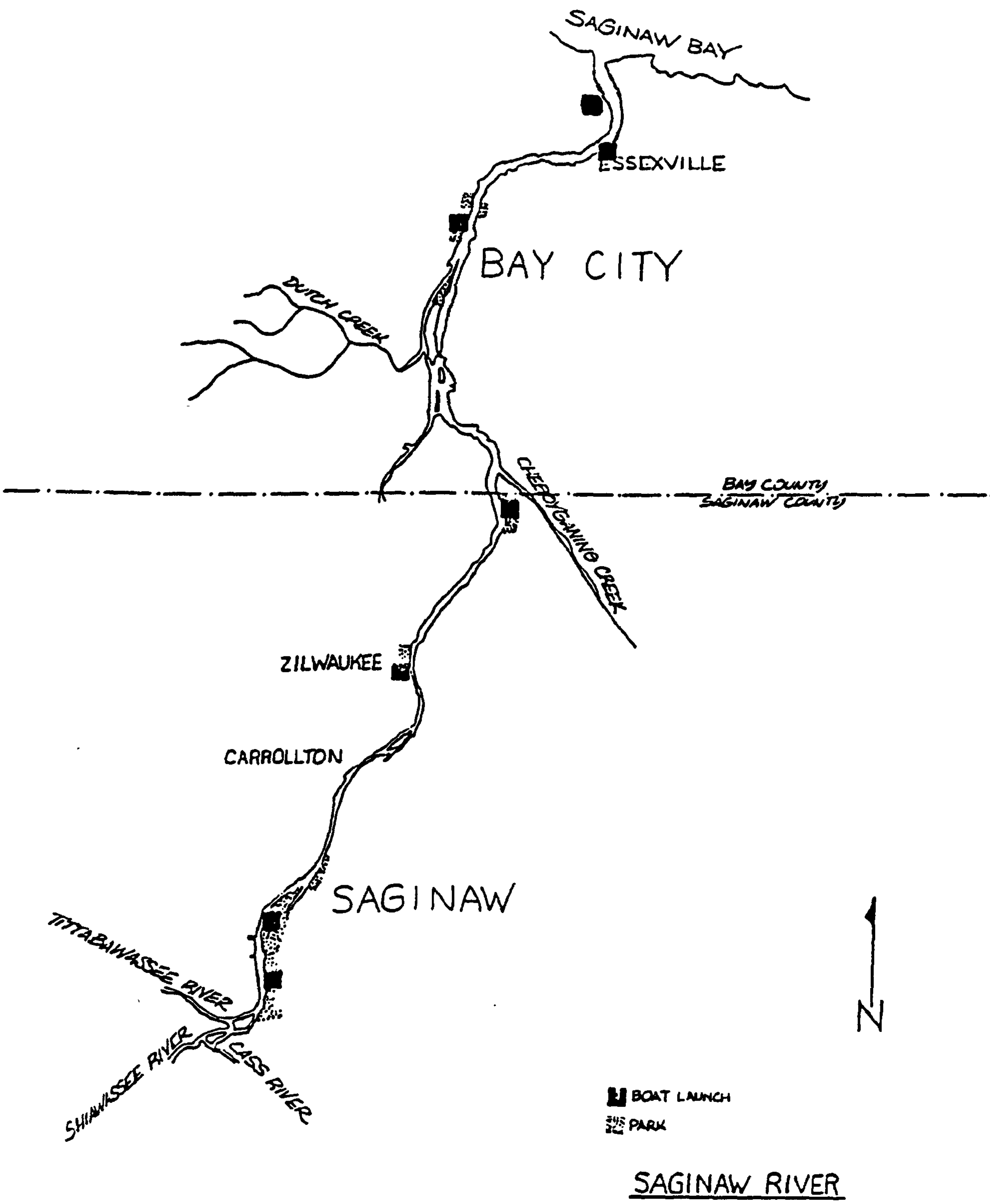

Figure 3.1. Map of the Saginaw River.

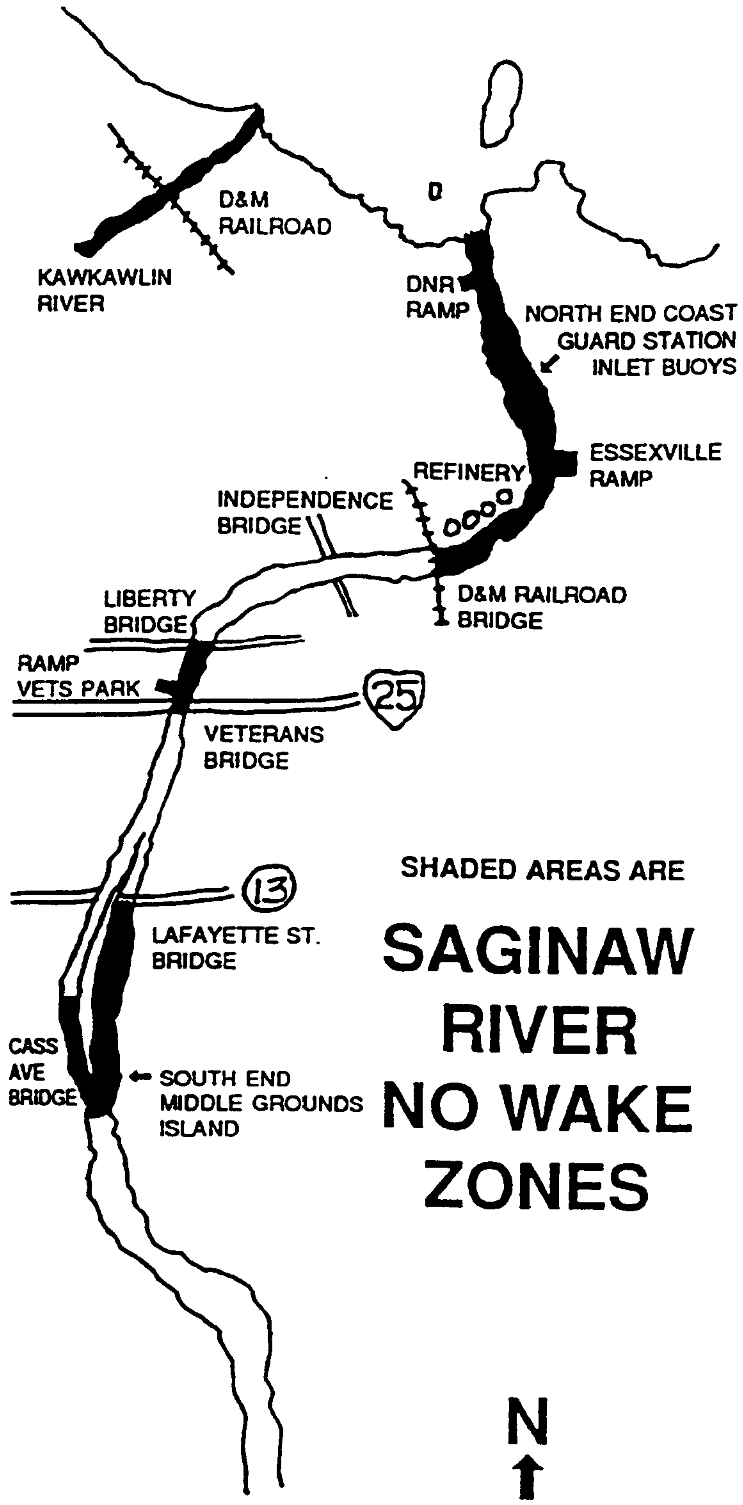

Figure 3.2. Map of the Saginaw River in the vicinity of Bay City, MI.

support a balanced mesotrophic biological community (MDNR, 1990). The RAP was the major source of information for this risk assessment.

There are a number of sources that continue to contribute contaminants to the Saginaw River and Saginaw Bay including industrial and municipal discharges, combined sewer overflows, contaminated sediments in the river and bay bottom, urban and agricultural nonpoint runoff, waste disposal sites, and the atmosphere (MDNR, 1988). The greatest water quality problems in the lower Saginaw River have resulted from industrial and municipal wastewater treatment plant (WWTP) discharges into the river. There are ten major dischargers to the Saginaw River, of which three are located in the lower 8 km of the river: General Motors Corp. (GMC) Powertrain Division (formerly known as GMC Chevrolet-Pontiac-Canada (CPC) Group), Monitor Sugar Company, and the Bay City Wastewater Treatment Plant (WWTP). Of these three industries, the GMC Powertrain Division plant is the only company that lists PCBs in its NPDES permit. The RAP contains additional information about the GMC plant as well as other sources of pollution to the Saginaw River (MDNR, 1988).

As a result of inputs of contaminants into the Saginaw River, the sediments have become contaminated with PCBs, heavy metals, and other compounds. These sediments provide an additional source of contaminants to the water column through processes such as resuspension events, bioturbation, and equilibrium partitioning. Some of the highest concentrations of PCBs (i.e., >1 mg/kg) in the Saginaw River have been measured in the sediments below the GMC Powertrain outfall (G. Goudy (MDNR), personal communication, 1991). These contaminated sediments are of concern because of the potential health risk to people resulting from direct (e.g., dermal contact with sediments) and/or indirect (e.g., consumption of contaminated fish) exposures to sediment-derived contaminants.

3.3 RECREATIONAL USES

The greatest recreational opportunities on the Saginaw River involve fishing and boating. Four parks, seven marinas and yacht clubs, and three public boat ramps are located in the lower 8 km of the Saginaw River. This river is a popular site for fishing from shore and by boat. In addition, ice fishing is prevalent during the winter. Walleye is the main sport fish, but yellow perch, largemouth bass, smallmouth bass, northern pike, crappie, and bluegill are also caught (MDNR, 1988). In addition, the Saginaw River supports spawning runs of salmonids, white bass, and suckers. Waterfowl hunting also occurs in the Quanicasse Wildlife Area bordering Saginaw Bay east of the Saginaw River.

The largest park in this region is Veterans Memorial Park located near Veterans Memorial Bridge (Figure 3.2). Many noncontact recreational activities (e.g., softball, volleyball, jogging/walking, picnicking, and swimming in an outdoor pool) are available. In addition, this park is frequently used by anglers fishing from shore; a walkway and gazebo extending out into the middle of the Saginaw River allows protected fishing for handicapped individuals. Veterans Memorial Park is the site of a popular July 4th celebration that spans several days. Fireworks are set off over the river and thousands of boaters come to view them. Some people have been observed to jump off their boats and swim in the water during the festivities (A. Brouillet (MDNR), personal communication, 1991). Other parks, such as Essexville Park, are regularly used by anglers. Additional recreational opportunities on the Saginaw River will be available when a crew house is completed near the Lafayette Street Bridge.

The Bay City Chamber of Commerce is encouraging tourism in the area to supplement its economic base, which has been weakened by industrial closures. Bay City is becoming a popular place for people from Flint and Detroit to harbor their boats (A. Brouillet (MDNR), personal communication, 1991). A new marina recently opened to accommodate greater boat traffic on the river, partly from people who use the river as an access point to Saginaw Bay.

No swimming areas or beaches exist along the lower 8 km of the Saginaw River. The eutrophic water quality of the Saginaw River does not make it aesthetically pleasing for swimming. In addition, the banks of the river are either filled with rock and cement or else are walled off; thus it is not likely that anyone would be exposed to contaminants through contact with river bank sediments. Official swimming beaches are located along Saginaw Bay at Bay City State Park and adjacent to private residences in Bangor township. Some sporadic swimming may occur in the river from people jumping off their boats and swimming in the water. The water is warm enough for swimming with an average summer (i.e., June - August) temperature of 22 °C (72 °F) (MDNR, 1988). People who use jet skis on the river may be immersed in the water if their jet ski becomes unbalanced. Although jet skiing occurs, water skiing is not likely to take place on the lower Saginaw River because of the prevalence of no wake zones. Other activities that may result in immersion in the water (e.g., wind surfing) are unlikely to occur in the lower Saginaw River because of heavy boat traffic and flow reversals in the surface water.

3.4 WATER SUPPLY

The Saginaw River is not used as a drinking water source by municipalities in the region. Instead, the Bay City Water Supply System draws water from a point on the bay just west of the mouth of the Saginaw River. This system serves 80,815 people and withdraws an average of 11.9 million gallons/day (Bendell, 1982 cited in MDNR, 1988). Raw water samples taken from this system did not exceed primary drinking water standards during 1985 (USEPA, 1985 cited in MDNR, 1988).

3.5 CONTAMINATION OF FISH

3.5.1 Routes of Contamination

One of the primary ways in which people in the Great Lakes region, including the Bay City area, have been exposed to sediment-derived contaminants is through the consumption of contaminated fish. The specific mechanisms by which contaminants may be transferred from sediments to fish are still being elucidated. Part of the problem with determining these mechanisms is that different fish species occupy different habitats in the water column (e.g., benthic (bottom) versus pelagic (open water) habitats) and their diet and metabolism may change with age. This section will examine some of the ways in which fish occupying a river/harbor area of the Great Lakes may accumulate contaminants, assuming that the major source of pollutants comes from in-place contaminated sediments. The next section will discuss specific fish advisories for the Saginaw River AOC.

The group of contaminants that have been of major concern in the Great Lakes are hydrophobic organic compounds (HOCs) such as PCBs and DDT. These compounds are persistent in the environment, due to their physical-chemical properties, and will preferentially accumulate in the lipids of organisms relative to other compartments (e.g., muscle, bone). Many of the commercially exploited Great Lakes fish have relatively high amounts of body fat (e.g., lake trout, lake whitefish, and channel catfish), and thus would be expected to contain higher levels of lipid soluble HOCs than species characterized by low body fat (e.g., yellow perch and suckers) (Kononen, 1989).

The accumulation of contaminants in fish lipids can occur by two routes: 1) diffusion across the gills into the body and 2) transfer from the gut into the body after the consumption of contaminated food (Swackhamer and Hites, 1988). For the first route, the uptake of contaminants from water is functionally dependent on fish respiration and is related to the transfer of dissolved oxygen across the gill surfaces (Weininger, 1978). For the second route, the flux of contaminant transfer through feeding is dependent on the following factors: a) contaminant concentration in food, b) rate of consumption of food, and c) degree to which the ingested contaminant in the food is actually assimilated into the tissues of the organism. The assimilation of pollutants is affected by the desorption and excretion of contaminants from body tissues, and by the growth of the organism (Thomann and Connolly, 1984).

There is some uncertainty as to whether compounds sorbed to sediment particles will be available to fish for uptake. A chemical equilibrium model would assume that contaminant concentrations in the fish and sediments would be in equilibrium through their individual equilibrium coefficients with the water column (Connor, 1984). Studies with marine bottom fish in urban bays seem to indicate that the concentration of organic contaminants in the fish is correlated with the sediment concentration of those compounds (Connor, 1984; Mallins et al., 1984). This correlation may depend on the area's physical flushing capacity (residence time of water in a basin) and the metabolism of the organism (Connor, 1984). Similarly, a good correlation between the types of contaminants found in sediments collected from areas of industrial and urban development with the types of contaminants detected in freshwater carp from the same area has been made (Jaffe et al., 1985). Carp tend to remain in a local territory and, for the most part, are benthic feeders; thus, they would be expected to serve as a reasonable barometer of the types of contaminants (especially organic compounds) found in their aquatic environment. In another study, Brown et al. (1985) hypothesized that PCB concentrations in pelagic consumers (i.e., pumpkinseed) of benthic-feeding organisms in the Hudson River were largely controlled by PCB levels in the surficial sediments. While the aforementioned studies seem to indicate some causal linkage between contaminant concentrations in sediment and fish, there is a degree of uncertainty associated with this linkage. One of the difficulties with assessing the impacts of sediment contaminants on fish is that the factors controlling their bioavailability are not well understood, nor is there a basic understanding of trophic transfer from benthic to pelagic food chains (Bierman, 1990).

Due to the difficulty involved with assessing sediment-fish linkages in the field, controlled laboratory experiments have been conducted. Seelye et al. (1982) exposed young-of-the-year perch to a slurry of contaminated sediments for 10 days to simulate the conditions these fish would encounter during dredging. Although the perch accumulated organic compounds and heavy metals from the resuspended sediments, it is not known whether the contaminants in the fish reached steady state. In another experiment by Kuehl et al. (1987), carp exposed to Wisconsin River sediment for 55 days accumulated 7.5 pg/g 2,3,7,8-TCDD; maintaining exposed fish in clean water for an additional 205 days resulted in the depuration of 32-34% of the accumulated 2,3,7,8-TCDD. The most likely uptake route for 2,3,7,8-TCDD in the carp was through the ingestion of contaminated sediments while feeding (Kuehl et al., 1987). In another experiment, lake trout that were exposed to Lake Ontario sediment and smelt in long term lab experiments appeared to bioaccumulate 2,3,7,8-TCDD primarily through the food chain and secondarily through contact with contaminated sediment (Batterman et al., 1989). These lake trout did not bioaccumulate a significant concentration of 2,3,7,8-TCDD from the water column, even under simulated equilibrium conditions and with low suspended solids concentrations (Batterman et al., 1989).

Recent evidence indicates that concentrations of HOCs in fish are primarily the result of food chain biomagnification and not equilibrium partitioning from the sediments or water column (Oliver and Niimi, 1988; Batterman et al., 1989). In Lake Ontario, samples from all trophic levels in the planktonic (water to plankton to mysid to alewive/smelt to salmonid) and the benthic (water to bottom sediment/suspended sediment to amphipod/oligochaete to sculpin to salmonid) food chains showed classic biomagnification of PCBs between successive trophic levels

(Oliver and Niimi, 1988). Thus, the rate at which contaminant concentrations increase with body size will be a function of how efficiently the contaminant is excreted after assimilation (Borgmann and Whittle, 1991). In turn, the assimilation of contaminants in fish will be affected by declines in feeding and clearance rates as growth occurs (Pizza and O'Connor, 1983). Temperature has also been found to affect the accumulation of PCBs in certain adult species of fish because temperature controlled food consumption, growth, and lipid content (Spigarelli et al., 1983).

Other contaminants, such as mercury, are also of concern in the Great Lakes. Unlike HOCs, mercury appears to accumulate in fish tissues through direct uptake from the water column (Gill and Bruland, 1990). The major form of mercury in the water column is the highly toxic methylated mercury species. Because of the problem of mercury contamination in fish in the Great Lakes region, fish advisories have been issued for certain size classes of sport fish.

3.5.2 Fish Advisories

The Great Lakes jurisdictions have issued consumption advisories for sport fish since the late 1960s and early 1970s. These consumption advisories are based on the relationship between tissue concentrations of contaminants in individual size classes and species of fish and on specific trigger levels. When tissue concentrations exceed some trigger level (usually Food and Drug Administration action levels), consumption advice is issued by the states. The governors of the Great Lakes states called for the uniform development of fish consumption advisories by the states in the 1986 Great Lakes Toxic Substances Control Agreement (Foran and VanderPloeg, 1989). However, this mandate has not been followed by all states, and this inconsistent consumption advice may serve to confuse the fishing public and those consuming Great Lakes sport fish.

The Michigan Department of Public Health (MDPH) has issued a fish advisory for the entire Saginaw River. Carp and catfish should not be consumed by anyone because they have been found to contain PCBs and dioxin. In addition, the MDPH suggests that no one should eat large quantities of any species from the Saginaw River. In particular, women who intend to have children should eat no more than one meal per month of fish from this river. In addition, people should restrict their consumption of lake trout, rainbow trout, and brown trout to no more than one meal per week out of Saginaw Bay. Despite these warnings, some anglers may not be aware of specific advisories or may choose to ignore them (West et al., 1989).

CHAPTER 4

RISK ASSESSMENT FRAMEWORK

4.1 CONCEPT OF RISK

People are subject to a number of risks throughout their day that may cause them immediate or delayed harm. Some risks arise from personal choices (e.g., driving a car, participating in sports) while other risks may result from things people have little control over (e.g., breathing urban air, being a victim of a random crime). In terms of human health risks resulting from exposure to some chemical, biochemical, or physical agent, risks are classified into two categories: carcinogenic and noncarcinogenic risks.

Cancer is the leading cause of death for women in the United States, and most cancers, for both men and women, are caused by factors resulting from life style choices [e.g., smoking, drinking alcohol, consuming a diet high in animal fat, being overweight, or staying out in the sun too long (ultraviolet light exposure)] (Henderson et al., 1991). In particular, tobacco (alone or in combination with alcohol) accounts for one of every three cancer cases occurring in the United States today (Henderson et al., 1991). Occupational exposures to specific carcinogens (especially asbestos) account for only about 4% of the cancers in the United States (Henderson et al., 1991). Although nonoccupational exposures to environmental contaminants probably cause an even smaller fraction of the cancers reported in the U.S., it is important to safeguard the public's health from unnecessary and involuntary risks. In addition, environmental contaminants may also pose a noncarcinogenic risk to human health.

Noncarcinogenic risks include a variety of both chronic and subchronic effects to people. Included in this risk category are birth defects, respiratory diseases (e.g., asthma), liver diseases, learning disabilities, etc. One way to examine for incidences of these risks in human populations is through epidemiological studies. Three sets of studies of the impacts of human exposure to PCB contaminated fish from the Great Lakes basin--the Michigan Sports Fisherman Cohort, the Michigan Maternal/Infant Cohort, and the Wisconsin Maternal/Infant Cohort were evaluated using epidemiologic criteria (Swain, 1991). The results from comparing the studies against each other, and against comparable data from other geographic locales, strongly suggest a causal relationship between PCB exposure and alterations in both neonatal and early infancy health status (Swain, 1991). However, there is no evidence that these short-term effects lead to any chronic health effects (Bro, 1989). Possible developmental effects in infants and children will not be addressed in this risk assessment because complex pharmacokinetic models, which are not well developed in the risk assessment field, would have to be used. Thus, it is beyond the scope of the ARCS Program to address this issue in any great detail (USEPA, 1991b).

4.2 RISK FRAMEWORK

Risks associated with environmental exposures to contaminants are difficult to assess because: 1) the exposure itself is often difficult to document and 2) the exposure does not always produce immediately observable effects. Due to these difficulties, human health risks associated with exposures to contaminants must often be estimated via scenarios using standard EPA exposure parameters.

The approach used for this baseline human health risk assessment followed exposure and risk assessment guidelines established by the EPA for use at Superfund sites (USEPA, 1988b; 1989a,b; 1991a). Although the Saginaw River is not a Superfund site, the risk assessment procedures developed for the Superfund Program can be applied to this site to estimate current risks to people residing in the AOC. Unlike the Superfund risk assessments, this assessment did not consider risks resulting from future scenarios (e.g., future risks associated with turning a contaminated site into a playground). Instead, this risk assessment was based on the most up-to-date information available to estimate current noncarcinogenic and carcinogenic risks to human populations in the lower 8 km of the Saginaw River.

The procedures used in this risk assessment are outlined briefly in Figure 4.1. The first step in the process was to obtain information about the Saginaw River from documents such as the Remedial Action Plan or RAP (MDNR, 1988) and ARCS "Information Summary" (Brandon et al., 1991). In addition, a search for the latest data on contaminant levels in the environmental media of interest was conducted to characterize the extent of contamination at the site. The next step was to determine the exposure pathways by which people could come in contact with sediment-derived contaminants from the river. The most complete and current data sets were then evaluated to judge whether adequate QA/QC protocols were followed. Next, based on the exposure pathways and sites of exposures, the most current environmental data were used to determine contaminant intake levels. Intake levels are essentially equivalent to administered doses and are expressed in units of mg chemical per kg body weight per day. These chemical intake levels were then integrated with noncarcinogenic and carcinogenic toxicity data, obtained from verified and interim EPA sources, to estimate the respective human health risks to people in the lower Saginaw River. Finally, because of the number of assumptions that went into each step of the risk assessment procedure, a qualitative listing of the uncertainties involved in these assumptions was made.

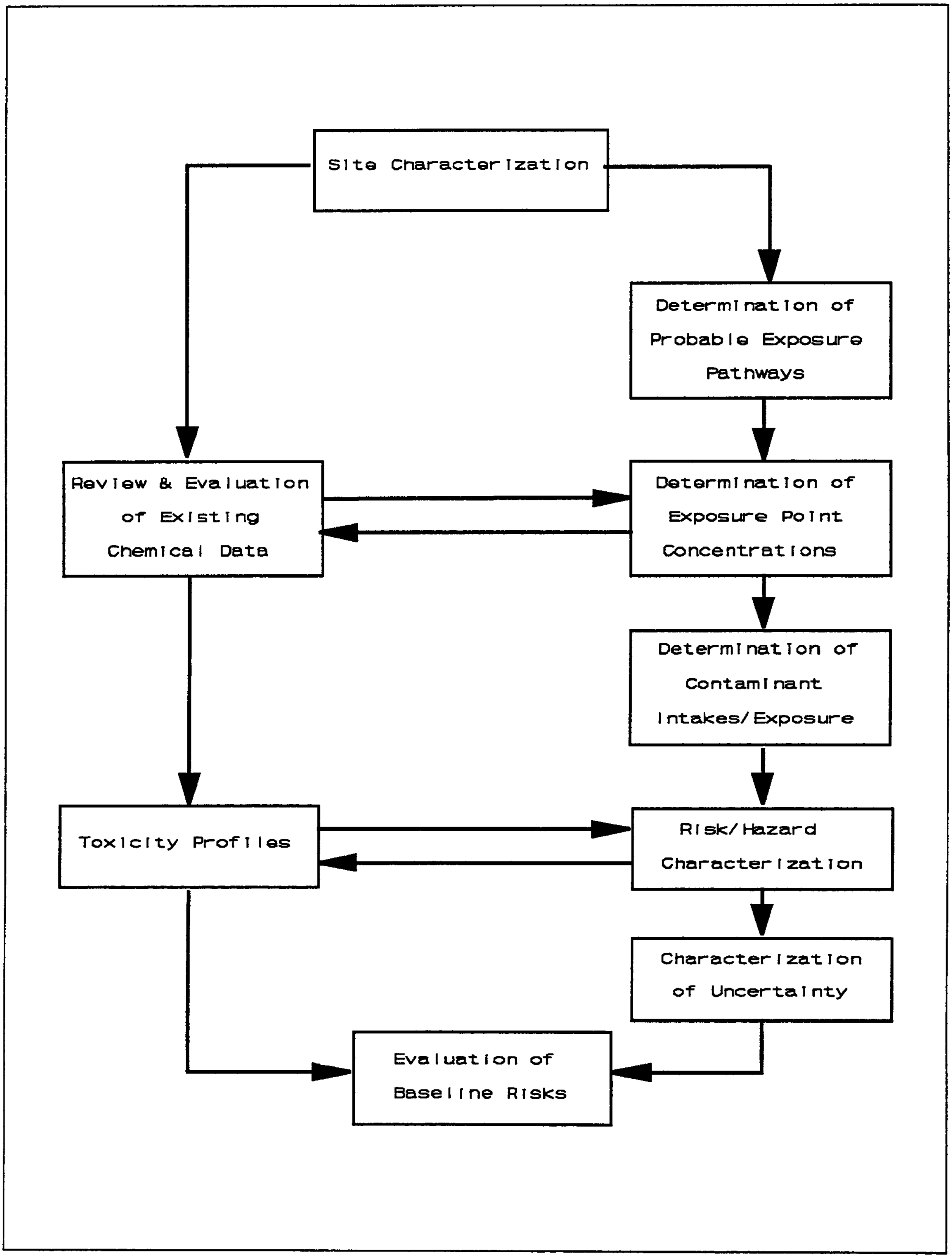

Figure 4.1. Components of baseline human health risk assessments.

CHAPTER 5

EXPOSURE ASSESSMENT

5.1 INTRODUCTION

In this exposure assessment, the magnitude, frequency, duration, and route of direct and indirect exposures of people to sediment-derived contaminants from the Saginaw River AOC will be estimated. The transport of contaminants into Saginaw Bay is also of concern, but it was beyond the scope of this risk assessment to address human health risks in the entire bay.

5.2 EXPOSURE PATHWAYS

Exposures to contaminants in the Saginaw River can potentially occur via three pathways: dermal contact, inhalation, and ingestion. Dermal contact involves direct contact of the skin with either contaminated sediments, riverplain soils, or overlying water. Inhalation of airborne vapors or dust may introduce chemicals of potential concern into the respiratory system. Ingestion of contaminants through the consumption of contaminated soils, sediment, or food (e.g., fish, waterfowl) is potentially significant because of the direct transfer of contaminants across the gut.

The lower 8 km of the Saginaw River was toured during 13-14 May 1991 to observe firsthand how people may be exposed to sediment-derived contaminants from the river. The weather was unseasonably warm (~32 °C or 90 °F) and partly sunny during this period, and a number of outdoor activities were observed. Informal conversations with local residents who were fishing, playing, or working in the parks and marinas along the Saginaw River yielded helpful information about how people utilize the river. In addition, a drive-by tour of the Saginaw River from the city of Saginaw to the mouth of the river with Allan Brouillet, MDNR, was particularly useful because he identified contaminated sites and described industrial, municipal, and recreational uses of the river. Additional conversations were held with Greg Goudy, RAP Manager (MDNR), Tim Kubiak (U.S. Fish and Wildlife Service), John Giesy (Michigan State University), Mardi Klevs, U.S. EPA Coordinator for the Saginaw Bay RAP (USEPA, Region V), and Doug Bell (East Central Michigan Planning and Development Region) to obtain information and/or contaminants data on the river.

The potential pathways by which people may be exposed to contaminants from the lower Saginaw River are given in Table 5.1. These pathways were then examined to determine whether they were complete or incomplete. A pathway is complete if there is: 1) a source or chemical release from a source, 2) an exposure point where contact can occur, and 3) an exposure route by which contact can

TABLE 5.1. POTENTIAL PATHWAYS BY WHICH PEOPLE MAY BE EXPOSED TO CONTAMINANTS FROM THE LOWER SAGINAW RIVER

- INGESTION OF CONTAMINATED:
  - Surface Water
  - Fish and Wildlife
  - Drinking Water
  - Sediments
  - Contaminated Soils
- DERMAL CONTACT WITH CONTAMINATED:
  - Surface Water
  - Sediments
  - Soils
- INHALATION OF AIRBORNE CONTAMINANTS

occur (USEPA, 1989a). Otherwise, the exposure pathway is incomplete if one of these conditions is not met. Five pathways appear to be incomplete:

1) **Ingestion of contaminated drinking water:** the Saginaw River is not used as a source of drinking water in the AOC. Instead, the Bay City Water Supply System draws water from a point 5.6 km out into Saginaw Bay just west of the mouth of the Saginaw River. A study in 1985 indicated that the primary drinking water standards were not exceeded for the raw water supply for Bay City [USEPA (1985) cited in MDNR (1988)].

2) **Ingestion of sediments:** the ingestion of bottom sediments does not appear to be occurring. Only the bottom sediments near the shore would be accessible if, for example, a child reached into the water and grabbed some sediments; however, no evidence of this behavior was available.

3) **Ingestion of contaminated soils:** the ingestion of contaminated soils from the river banks does not appear to be occurring. The banks are either walled-off or are covered with boulders and cement, thus limiting the opportunities for human contact.

4) **Dermal contact with contaminated soils:** the river bank soils are mostly inaccessible to people; thus, this pathway is unlikely to be complete.

5) **Ingestion of certain types of wildlife:** people are known to consume snapping turtles and muskrats from the lower Saginaw River area [T. Kubiak (U.S. Fish and Wildlife Service) personal communication, 1991]. However, no data are currently available on contaminant levels in these animals.

TABLE 5.2. COMPLETE EXPOSURE PATHWAYS IN THE LOWER SAGINAW RIVER

- Ingestion of Contaminated Fish
- Ingestion of Contaminated Waterfowl
- Ingestion of Surface Water while Swimming or Playing in the Water
- Dermal Contact with Water while Boating, Fishing, Swimming, Wading, Jet-skiing, etc.
- Dermal Contact with Sediments while Entering or Leaving the Water
- Inhalation of Airborne Contaminants

Although the six exposure pathways in Table 5.2 were considered complete in the lower Saginaw River, not all of these exposure pathways may result in significant human health risks. In particular, it was assumed that if insignificant risks were associated with the ingestion of surface water while swimming, then the risk associated with dermal exposure to surface water or sediments in the Saginaw River would also be insignificant (see Appendix A for the reasons behind this assumption). As described in Chapter 3, swimming does not occur frequently in the Saginaw River. The estimated lifetime cancer risk for ingesting surface water containing 1.72×10^{-5} mg/L PCBs from downstream of the Bay City WWTP (~30 m upstream of the Bay Harbor Marina) was calculated as 2×10^{-10} (Appendix A). This risk assumed that someone swam 3 days/yr for 0.5 hr/event over a period of 30 years and ingested water at a rate of 5×10^{-2} L/hr. In addition, the cancer risk was extrapolated over a period of 70 years to represent the estimated lifetime carcinogenic risk to people. This risk estimate also assumed that PCBs were the major source of carcinogenic risk. Based on this low carcinogenic risk estimate for the ingestion of surface water, dermal exposures to water and sediments were also considered to be insignificant. A noncarcinogenic risk estimate could not be calculated for this scenario because of the lack of an approved noncarcinogenic toxicity value for PCBs.

In terms of inhaling airborne contaminants, it would be difficult to separate out the contribution of contaminants from the river and that from industrial, municipal, and background sources. In addition, the contribution of airborne contaminants from the river may be small compared to other sources. Although this exposure pathway may be complete, the currently available data set of atmospheric contaminant levels in the Bay City area is inadequate to quantitatively assess the risks to human health.

The only complete exposure pathways that will be considered for this risk assessment are the consumption of fish and waterfowl. Noncarcinogenic and carcinogenic risks will be determined for typical (i.e., average) and reasonable maximum exposures (i.e., the maximum exposure that is reasonably expected to occur at a site), as well as for exposures resulting from subsistence fishing and hunting. The subsistence pathway was chosen because of anecdotal evidence about people who consumed high quantities of fish or waterfowl. In one case, a young woman in Veterans Park mentioned that her family ate fish from the river nearly every day while she was growing up because they were poor. This anecdotal evidence is supported by a fish consumption survey of Michigan anglers during the off-season which showed that a small minority (<1%) of sample household members consumed fish at subsistence levels (>132 g/day) (West et al., 1989). In another case, T. Kubiak (U.S. Fish and Wildlife Service, personal communication, 1991) knew of a man who consumed the breast meat of up to 60 ducks/year collected from the Saginaw River area. Thus, a small number of people in the area may be relying on local fish and/or waterfowl for their main source of protein.

5.3 DATA USED IN THE EXPOSURE ASSESSMENT

5.3.1 Data Sources

Data on contaminant levels in fish and waterfowl (ducks) were obtained from the Michigan DNR and the U.S. Fish and Wildlife Service, respectively. In addition, the water quality data used to determine the risk from ingesting surface water also were obtained from the Michigan DNR. Other data containing contaminant levels in water, sediment, and caged fish were obtained but not used in this risk assessment. These data were not used because dermal exposure pathways to surface water and sediment were not considered to be important, and data from natural fish populations were used instead of short-term caged fish exposures to the Saginaw River.

No assumptions about the temporal and spatial variability of contaminants data in the Saginaw River will be made here. As mentioned in Chapter 3, heavy flooding occurred during the fall of 1986; this flooding may have scoured and resuspended contaminated sediments in the river. Thus, pre- and post-1986 data sets may differ due to this hydraulic event.

An effort was made to obtain data collected after the flood of 1986; however, current data sets were not always available. The only waterfowl data (i.e., mallards and gadwalls) for the area were collected in 1985. The water quality data used in the estimation of risk from ingesting surface water were collected at a joint Michigan DNR/EPA sampling station from 7-9 August 1989. Two DNR data sets were used to estimate contaminant levels in Saginaw River fish. Carp, catfish, yellow perch, and walleye were collected from the mouth of the Saginaw River on 17 May 1987 and were analyzed for mercury and organic contaminants. A DNR data set for carp and walleye collected on 10 June 1986 (i.e., pre-flood) were used for other metals. The DNR also collected fish samples from other locations in Saginaw Bay, but these data were not used because the fish collected at the mouth of the river contained higher concentrations of contaminants. Fish have been collected from the Saginaw River for the ARCS program, and these data may be incorporated into future updates of this risk assessment when they become available.

5.3.2 Data Review

All of the data used in this risk assessment underwent a QA/QC review by Lockheed Engineering and Sciences Company (Lockheed-ESC) under a contract with the EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV. Lockheed-ESC could not conduct a complete review of the data because insufficient QA/QC information was available. Thus, an assessment of the accuracy of the data could not be made. All of the data used for this risk assessment were either in the form of data sheets released from an analytical laboratory (i.e., waterfowl data) or as a spreadsheet of contaminant concentrations compiled by the Michigan DNR (i.e., fish and water quality data). Although inadequate QA/QC information was available to fully assess the quality of the data, the data were assumed to be of adequate quality for use in this risk assessment.

5.3.3 Data Sets

Not all of the fish species sampled by the DNR for contaminants were used in this risk assessment. Data were obtained for both bottom feeders (i.e., carp and channel catfish) and open water feeders (i.e., yellow perch and walleye). Since walleye are the preferred sport fish in the Saginaw River, this fish was selected for inclusion in the risk assessment. Carp were also included since they generally accumulate the highest levels of contaminants in water bodies due to their feeding habits and high fat content. In addition, walleye and carp could be used to generally represent pelagic and benthic fish species, respectively. The yellow perch data were not used because all of the fish collected were very small (<0.1 kg) and would not be of an edible size. The channel catfish data were not used because higher contaminant levels were observed in the carp. Thus, by determining separate exposures for the consumption of carp and walleye, a range of risk estimates could be determined for a variety of exposure scenarios.

The mean contaminant levels, number of samples, and standard deviations of the walleye and carp data sets are given in Tables 5.3 and 5.4, respectively. The walleye data were based on skin-on fillets, whereas the carp data were for skin-off fillets. In cases where part of the sample set contained nondetected values, one-half of the detection limit was used in determining the mean concentration levels. Higher contaminant levels were observed in the carp as would be expected for these benthic feeders.

Neither the carp or walleye were analyzed for 2,3,7,8-TCDD (dioxin), another chemical of concern in the Saginaw River. The Tittabawassee River, downstream of the Dow Chemical Company Midland facility, has been contaminated with chlorinated dibenzo-p-dioxins and dibenzofurans (CDDs and CDFs) (USEPA, 1988). Because the Tittabawassee River contributes about 50% of the flow entering the Saginaw River, there is concern that fish could accumulate CDDs and CDFs in the Saginaw River. The Michigan DNR set out cages containing juvenile catfish to assess their uptake of 2,3,7,8-TCDD (MDNR, 1991a). Twenty-one caged catfish that had been placed in the Saginaw River at Essexville for 1 month during the summer of 1988 accumulated an average 2,3,7,8-TCDD concentration of 3.1 ng/kg (MDNR, 1991a). The results of this caged fish study do not indicate whether all contaminant concentrations reached equilibrium in the fish tissue, nor does the study consider different uptake rates for different ages of fish (e.g., juvenile versus adult). The uptake of PCBs did not appear to reach equilibrium after 29 days (based on measurements taken after 4, 8, 16, and 29 days). Thus, other hydrophobic organic compounds, like 2,3,7,8-TCDD, may not have reached equilibrium either. The caged fish study also does not take into consideration that natural fish populations will be exposed to varying amounts of contaminant concentrations in the water column as they travel through the river. Due to these uncertainties in how representative the contaminants data from the caged fish study corresponded to contaminant levels in natural fish populations in the Saginaw River, the caged fish data for 2,3,7,8-TCDD were not used in this risk assessment.

The waterfowl data for two mallards and four or five gadwalls were combined to determine mean contaminant concentrations (Table 5.5); these data were based on "roaster ready" (i.e., plucked and eviscerated) birds. Although these waterfowl are migratory, they reside in the Saginaw River area from about April through October-November. This area is on a major migratory flyway and several waterfowl refuges are located near the Saginaw River and Bay; thus, it seemed reasonable to assume that these waterfowl accumulated their greatest contaminant burdens from the Saginaw River AOC, especially from their food (e.g., invertebrates).

TABLE 5.3. MEAN CONTAMINANT CONCENTRATIONS IN WALLEYES (SKIN-ON-FILLETS) COLLECTED FROM THE MOUTH OF THE SAGINAW RIVER

Chemical	Mean Conc.♦ (mg/kg)	N	SD
METALS			
Cadmium	ND (0.010)	3	
Chromium	ND (0.100)	3	
Copper	3.00E-01	3	1.40E-01
Lead	ND (0.100)	3	
Mercury	1.22E-01	9	7.68E-02
Nickel	ND (0.100)	3	
Zinc	6.30E+00	3	6.80E-01
AROMATIC HYDROCARBONS			
Hexachlorobenzene	1.06E-03	9	1.21E-03
PCBs (total)*	3.73E-01	9	2.80E-01
ORGANOCHLORINE INSECTICIDES			
Chlordane (total)**	6.33E-03	9	
Dieldrin	4.00E-03	9	2.30E-03
Heptachlor epoxide	ND (0.003)	9	
p,p' DDD	1.53E-02	9	1.32E-02
p,p' DDE	5.57E-02	9	4.53E-02
p,p' DDT	4.11E-03	9	2.53E-03
PURGEABLES			
Styrene (total)***	3.95E-03	9	
OTHER ORGANICS (NO TOXICITY VALUES)			
Aldrin	ND (0.005)	9	
beta-BHC	ND (0.005)	9	
cis-Nonachlor	3.11E-03	9	2.53E-03
trans-Nonachlor	5.78E-03	9	5.37E-03
g-BHC (lindane)	ND (0.005)	9	
Heptachlor	ND (0.005)	9	
Heptachlorostyrene	ND (0.001)	9	
Hexachlorostyrene	ND (0.001)	9	
Mirex	ND (0.005)	9	
Octachlorostyrene	1.28E-03	9	1.09E-03
Oxy-chlordane	ND (0.003)	9	
Pentachlorostyrene	2.67E-03	9	3.05E-03
PBB (Firemaster BP-6)	ND (0.005)	9	
PCB - A. 1242	ND (0.025)	9	
PCB - A. 1248	ND (0.0250	9	
PCB - A. 1254	3.73E-01	9	2.80E-01
PCB - A. 1260	ND (0.025)	9	
Terphenyl	ND (0.250)	9	
Toxaphene	ND (0.050)	9	

* PCBs represent a group of 209 congeners that were manufactured by Monsanto under the trade name Aroclor. Aroclors contain a mixture of congeners, and are named with numbers which indicate the weight percent of chlorine in each mixture (e.g., Aroclor 1242 represents 42% chlorination of the biphenyl ring).

** Total Chlordane was not reported; a-chlordane and g-chlordane were summed to represent total chlordane.

*** Total styrene was not reported; octachlorostyrene, pentachlorostyrene, hexachlorostyrene, and heptachlorostyrene were summed to represent total styrene.

♦ Detection limits reported in parentheses.

TABLE 5.4. MEAN CONTAMINANT CONCENTRATIONS IN CARP (SKIN-OFF-FILLETS) COLLECTED FROM THE MOUTH OF THE SAGINAW RIVER

Chemical	Mean Conc.♦ (mg/kg)	N	SD
METALS			
Cadmium	6.00E-03	5	2.00E-03
Chromium	ND (0.100)	5	
Copper	4.40E-01	5	2.24E-01
Lead	ND (0.100)	5	
Mercury	6.90E-02	10	4.01E-02
Nickel	ND (0.100)	5	
Zinc	1.30E+01	5	7.42E+00
AROMATIC HYDROCARBONS			
Hexachlorobenzene	5.35E-03	10	4.06E-03
PCBs (total)	5.24E+00	10	3.89E+00
ORGANOCHLORINE INSECTICIDES			
Chlordane (total)*	4.23E-02	10	
Dieldrin	1.80E-02	10	2.39E-02
Heptachlor epoxide	1.53E-02	10	1.11E-02
p,p' DDD	1.74E-01	10	1.28E-01
p,p' DDE	7.47E-01	10	6.00E-01
p,p' DDT	3.75E-03	10	3.95E-03
PURGEABLES			
Styrene (total)**	5.90E-02	10	
OTHER ORGANICS (NO TOXICITY VALUES)			
Aldrin	ND (0.005)	10	
beta-BHC	ND (0.005)	10	
cis-Nonachlor	1.94E-02	10	1.84E-02
trans-Nonachlor	3.29E-02	10	2.86E-02
g-BHC (lindane)	ND (0.005)	10	
Heptachlor	ND (0.005)	10	
Heptachlorostyrene	2.40E-03	10	1.87E-03
Hexachlorostyrene	1.65E-03	10	1.33E-03
Mirex	ND (0.005)	10	
Octachlorostyrene	2.34E-02	10	1.24E-02
Oxy-chlordane	5.70E-03	10	6.54E-03
Pentachlorostyrene	3.16E-02	10	2.31E-02
PBB (Firemaster BP-6)	ND (0.005)	10	
PCB - A. 1242	ND (0.025)	10	
PCB - A. 1248	ND (0.025)	10	
PCB - A. 1254	5.24E+00	10	3.89E+00
PCB - A. 1260	ND (0.025)	10	
Terphenyl	ND (0.250)	10	
Toxaphene	ND (0.050)	10	

* Total Chlordane was not reported; a-chlordane and g-chlordane were summed to represent total chlordane.

** Total styrene was not reported; octachlorostyrene, pentachlorostyrene, hexachlorostyrene, and heptachlorostyrene were summed to represent total styrene.

♦ Detection limits reported in parentheses.

TABLE 5.5. MEAN CONTAMINANT CONCENTRATIONS IN WATERFOWL COLLECTED FROM THE SAGINAW RIVER AREA

Chemical	Mean Conc.♦ (mg/kg)	N	SD
METALS			
Arsenic	6.40E-02	6	2.56E-02
Cadmium	4.10E-02	6	4.16E-03
Lead	3.15E+00	6	1.78E+00
Mercury	4.80E-02	6	1.92E-02
Selenium	4.63E-01	6	6.57E-02
AROMATIC HYDROCARBONS			
Hexachlorobenzene	ND (0.01)	7	
PCBs (total)	1.73E+00	7	9.50E-01
ORGANOCHLORINE INSECTICIDES			
Dieldrin	ND (0.01)	7	
Heptachlor epoxide	ND (0.01)	7	
p,p' DDD	ND (0.01)	7	
p,p' DDE	5.03E-01	7	3.89E-01
p,p' DDT	ND (0.01)	7	
OTHER ORGANICS (NO TOXICITY VALUES)			
cis-Nonachlor	ND (0.01)	7	
trans-Nonachlor	ND (0.01)	7	
Endrin	ND (0.01)	7	
Octachlorostyrene	ND (0.01)	7	
oxy-chlordane	ND (0.01)	7	
Toxaphene	ND (0.01)	7	

♦ Detection limits reported in parentheses. These birds were not analyzed for 2,3,7,8 TCDD.

5.4 EXPOSURE ASSESSMENT

5.4.1 General Determination of Chemical Intakes

Once the complete exposure pathways were identified and contaminant concentrations for relevant media were obtained, an exposure assessment could be conducted for each pathway. Exposures were normalized for time and body weight to determine chemical "intakes," expressed in units of mg chemical per kg body weight per day. For the ingestion of contaminated fish and waterfowl, intakes represent the amount of chemical available for absorption in the gut. The general equation for calculating chemical intakes is given in Table 5.6. Several variables were used to determine intakes, including specific information about the exposed population and the period over which the exposure was averaged. Noncarcinogenic effects were averaged over the same time period as the exposure duration [i.e., 9 years for typical exposures and 30 years for reasonable maximum exposures (RME)]. Carcinogenic effects were averaged over a lifetime (i.e., 70 years). Intake variable values were selected so that the combination of all values resulted in a conservative estimate of either the typical, reasonable maximum, or subsistence exposure intakes.

TABLE 5.6. GENERIC EQUATION FOR CALCULATING CHEMICAL INTAKES (USEPA, 1989a)

$$I = \frac{C \times CR \times EFD}{BW \times AT}$$

where:	
I	Intake = the amount of chemical at the exchange boundary (mg/kg body weight-day)
	Chemical-Related Variables
C	Chemical Concentration = the average concentration contacted over the exposure period (e.g., mg/L)
	Variables that Describe the Exposed Population
CR	Contact Rate = the amount of contaminated medium contacted per unit time or event (e.g., L/day)
EFD	Exposure Frequency and Duration = how long and how often exposure occurs. Often calculated using two terms, EF and ED, where EF = exposure frequency (days/year) ED = exposure duration (years)
BW	Body Weight = the average body weight over the exposure period (kg)
	Assessment-Determined Variables
AT	Averaging Time = period over which exposure is averaged (days)

The contaminant intake levels were based on the consumption of raw fish fillets and duck meat. At the present time, contaminant concentrations in raw meat cannot be extrapolated to concentrations in cooked products. For the past 20 years, Mary Zabik and coworkers from Michigan State University have been investigating whether cooking methods can reduce pesticide and PCB residues in meat and fish (Smith et al., 1973; Stachiw et al., 1988; Zabik, 1974, 1990; Zabik et al., 1979, 1982). They found that PCB-contaminated chicken that had either been stewed or pressure-cooked contained significantly lower PCB levels than raw meat (Zabik, 1974), and roasting reduced the PCBs in contaminated turkey rolls by approximately 60% (Zabik, 1990). However, their results have not been consistent between and within species of fish. In one instance, different cooking methods did not result in significant changes in the level of PCBs, DDE, or DDT in cooked carp fillets (Zabik et al., 1982). In another case, cooking resulted in reductions of TCDD in restructured, deboned carp fillets (Stachiw et al., 1988).

In order to further assess how cooking techniques may alter the level of contaminants in fish, the Michigan Department of Public Health and Michigan State University have just begun a 2-year investigation (H. Humphrey, Michigan Department of Public Health, personal communication, 1991). This study will be done for a variety of sport fish in the Great Lakes (e.g., chinook and coho salmon) for skin-on and skin-off fillets. The results of the Michigan study will be useful for future human health risk assessments for determining better estimates of contaminant levels in cooked fish. At the present time, the Michigan DNR recommends that anglers use the following cooking techniques to reduce their risk to contaminants: 1) trim fatty areas, 2) puncture or remove skin before cooking so that fats drain away, or 3) deep-fry trimmed fillets in vegetable oil and discard the oil (MDNR, 1991b). Some of these protocols could be applied to preparing ducks too.

5.4.2 Intakes: Ingestion of Contaminated Fish

The equation used to estimate intakes of contaminants due to the ingestion of contaminated fish is provided in Table 5.7. The parameter values used in that equation are given in Table 5.8. Parameter values were obtained mostly from recommended EPA sources. The exposure parameters used in the typical scenario were assumed to be applicable to the general population of anglers and their families in Bay City, whereas the reasonable maximum exposure scenario applied to more recreational anglers and their families.

At the present time, specific information on fish consumption rates and trends in the Saginaw River AOC is lacking. The Michigan Sport Anglers Fish Consumption Survey, conducted by West and co-workers at the University of Michigan, may give a better indication of ingestion rates of fish by Saginaw River anglers than the default EPA parameter values that are applied to general populations. West et al. (1989) found that, for their survey conducted during the January-June 1988 time frame, the average fish consumption was 18.3 g/person/day with a standard deviation of 26.8 g/person/day; approximately 26% of the sample household persons who ate fish consumed between 20-40 g/person/day, whereas another 10% consumed between 40-75 g/person/day. From the survey results, West et al. (1989) estimated a year-round average fish consumption rate of 19.2 g/person/day. This exposure assessment used a reasonable maximum ingestion rate of 54 g/person/day; this number seems appropriate because it falls within the upper 10% ingestion rate of the Michigan anglers. This exposure assessment also assumed that the only contaminated fish ingested by local residents came from the Saginaw River AOC. Because there was not any

TABLE 5.7. EQUATION USED TO ESTIMATE CONTAMINANT INTAKES DUE TO INGESTION OF FISH OR WATERFOWL

$$Intake = \frac{C \ X \ IR \ X \ FI \ X \ EF \ X \ ED}{BW \ X \ AT}$$

where:	
Intake	Intake Rate (mg/kg-day)
C	Contaminant Concentration in Fish or Waterfowl (mg/kg)
IR	Ingestion Rate (kg/day for fish; kg/meal for waterfowl)
FI	Fraction Ingested from Contaminated Source (unitless)
EF	Exposure Frequency (days/yr for fish; meals/yr for waterfowl)
ED	Exposure Duration (yr)
BW	Body Weight (kg)
AT	Averaging Time (days)

quantitative information available on the fraction of fish ingested from the Saginaw River (i.e., FI), conservative estimates were made. Chemical intake values will be incorporated into the estimation of risk presented in Chapter 7; thus, separate tables of intake values will not be presented here.

5.4.3 Intakes: Ingestion of Contaminated Waterfowl

The equation used to estimate ingestion of contaminated waterfowl is provided in Table 5.7, and the parameter values used in that equation are given in Table 5.9. More study assumptions were used with this exposure pathway than for the consumption of fish. This is because fewer data are available on consumption patterns of waterfowl than there are for fish. The exposure frequency was based on the limited hunting season for ducks (6 October to 4 November 1990), the number of weekend days that someone might have time to go hunting (11 days), the bag limit for ducks (3 ducks/day), and the portion of the bag limit that a hunter would fill each day (assumed to be 50%). Thus, it was assumed that a hunter would shoot and retrieve 16 ducks/season of which 8 ducks would come from the Saginaw River area; this value was used for the reasonable maximum exposure and subsistence hunting scenarios. Under typical exposures, an individual was assumed to consume three servings of waterfowl per year of

TABLE 5.8. PARAMETERS USED IN ESTIMATING CONTAMINANT INTAKES DUE TO INGESTION OF FISH IN THE LOWER 8 KM OF THE SAGINAW RIVER

Var.	Units	Value Used	Comment
IR	kg/day	0.0192	Typical: West et al. (1989)
		0.054	Reasonable Maximum Exposure (RME): USEPA (1991a)
		0.13	Subsistence fishing: used the 95th percentile daily intakes averaged over 3 days for consumers of fin fish [Pao et al. (1982) cited in USEPA (1989a)]
FI	-	0.1	Typical: study assumption
		0.25	RME: study assumption
		0.7	Subsistence fishing: study assumption
EF	day/yr	350	USEPA (1991a)
ED	yrs	9	Typical: USEPA (1989a)
		30	RME and Subsistence: USEPA (1989a)
BW	kg	70	50th percentile average for adult men and women (USEPA, 1989b)
AT:	days	3285	9 yrs x 365 days/yr (typical noncarcinogenic risk)
		10950	30 yrs x 365 days/yr (RME and subsistence noncarcinogenic risk)
		25550	70 yrs x 365 days/yr (carcinogenic risk)

which one serving was assumed to come from the Saginaw River area. Chemical intake values were calculated in the same manner as for the ingestion of fish.

TABLE 5.9. PARAMETERS USED IN ESTIMATING CONTAMINANT INTAKES DUE TO INGESTION OF WATERFOWL IN THE LOWER SAGINAW RIVER AREA

Var.	Units	Value Used	Comment
IR	kg/meal	0.085	Typical: recommended consumption of poultry (University of Georgia Extension Service, personal communication, 1991)
		0.11	RME: 50th percentile value given for beef (assumed equivalent to waterfowl) [Pao et al. (1982) cited in USEPA (1989a)]
		0.28	Subsistence hunting: 95th percentile value given for beef (assumed equivalent to waterfowl) [Pao et al. (1982) cited in USEPA (1989a)]
FI	-	0.33	Typical: study assumption
		0.5	RME: study assumption
		1	Subsistence hunting: study assumption
EF	meals/yr	3	Typical: study assumption
		16	RME and Subsistence: study assumption
ED	yrs	9	Typical: USEPA (1989a)
		30	RME and Subsistence: USEPA (1989a)
BW	kg	70	50th percentile average for adult men and women (USEPA, 1989b)
AT:	days	3285	9 yrs x 365 days/yr (Typical noncarcinogenic risk)
		10950	30 yrs x 365 days/yr (RME and subsistence noncarcinogenic risk)
		25550	70 yrs x 365 days/yr (Carcinogenic risk)

CHAPTER 6

TOXICITY ASSESSMENT

6.1 TOXICITY VALUES

Two types of toxicity values were used in combination with exposure estimates (i.e., chemical intake values) to calculate noncarcinogenic and carcinogenic health risks. One toxicity value, the reference dose (RfD), provides an estimate of the daily contaminant exposure that is not likely to cause harmful effects during either a portion of a persons' life or his/her entire lifetime. The RfD is the toxicity value used in evaluating noncarcinogenic effects. The other toxicity value, the slope factor, is used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. In addition, the EPA weight-of-evidence classification scheme indicates the strength of evidence that the contaminant is a human carcinogen (Table 6.1). Slope factors are typically calculated for potential carcinogens in classes A, B1, and B2 as well as for class C on a case-by-case basis. A more detailed description of these toxicity values, summarized from "Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual (Part A)" (USEPA, 1989a), is given in Appendix B.

Chronic oral RfD values and oral slope factors were used for the food ingestion pathways examined in this risk assessment. Toxicity values, which had undergone an EPA review process, were obtained from the EPA's Integrated Risk Information System (IRIS) data base. For chemicals lacking a "verified value," interim toxicity values were obtained from the Health Effects Assessment Summary Tables (HEAST), if available. Table 6.2 lists the toxicity data used for the chemicals of interest. Although RfD values are provided for known carcinogens, it does not imply that these levels are protective against carcinogenicity. This table also includes the form in which the chemical was administered to the test animal or patient (e.g., drinking water, diet, or gavage) for determination of the oral RfD. The endpoints of concern for evaluating noncarcinogenic risks are listed in Table B-1 of Appendix B.

6.2 LIMITATIONS

This risk assessment was limited by the current availability of toxicity information. In some cases, toxicity values were not available for some of the chemicals (e.g., lead) detected in the lower Saginaw River. Toxicity values were not available for individual types of styrenes (e.g., octachlorostyrene) and chlordanes (e.g., a-chlordane) but were available for total styrene and chlordane. Consequently, detected values of heptachlorostyrene, hexachlorostyrene, octachlorostyrene, and pentachlorostyrene were summed and assigned the toxicity values for total styrene. Similarly, detected values of a-chlordane and g-chlordane

TABLE 6.1. EPA WEIGHT-OF-EVIDENCE CLASSIFICATION SYSTEM FOR CARCINOGENICITY (USEPA, 1989a)

Group	Description
A	Human carcinogen
B1 or B2	Probable human carcinogen B1 indicates that limited human data are available B2 indicates sufficient evidence in animals and inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

TABLE 6.2. HUMAN HEALTH RISK TOXICITY DATA FOR CHEMICALS OF INTEREST IN THE LOWER SAGINAW RIVER

Chemical	Oral RfD (mg/kg/day)	Form	Source	Carcinogenic Weight of Evidence Class	Source	Oral Slope Factor 1/(mg/kg/day)	Source
"METALS"							
Arsenic	3.0E-04	diet	a	A	a		
Cadmium	5.0E-04	water	a	B1	a		
Copper	1.3E-03		b	D	a		
Mercury, methyl	3.0E-04	poisonings	a	D	a		
Zinc	2.0E-01		b	D	a		
"AROMATIC HYDROCARBONS"							
Hexachlorobenzene	8.0E-04	diet	a	B2	a	1.60E+00	a
PCBs				B2	a	7.70E+00	a
"ORGANOCHLORINE INSECTICIDES"							
Chlordane	6.0E-05	diet	a	B2	a	1.30E+00	a
Dieldrin	5.0E-05	diet	a	B2	a	1.60E+01	a
Heptachlor epoxide	1.3E-05	diet	a	B2	a	9.10E+00	a
p,p' DDD				B2	a	2.40E-01	a
p,p' DDE				B2	a	3.40E-01	a
p,p' DDT	5.0E-04	diet	a	B2	a	3.40E-01	a
"PURGEABLES"							
Styrene	2.0E-01	gavage	a				

Sources: a: IRIS (current as of 1/28/92)
b: USEPA (1989c)

were summed to represent total chlordane. In other cases, toxicity values were available for a particular metal species rather than for the total metal (e.g., mercury). In particular, methyl mercury was assumed to be the major form of mercury present in this system.

CHAPTER 7

BASELINE RISK CHARACTERIZATION FOR THE LOWER SAGINAW RIVER

7.1 PURPOSE OF THE RISK CHARACTERIZATION STEP

The purpose of the risk characterization step is to combine the exposure and toxicity estimates into an integrated expression of human health risk. This section presents the calculated potential human health risks associated with the consumption of contaminated fish and/or waterfowl from the Saginaw River AOC under the no-action alternative. It is important to recognize that these calculated risk estimates are not intended to be used as actual values. Risk assessment is a regulatory process that provides risk managers with quantitative estimates that are to be used for comparative purposes only. These risk estimates must be interpreted in the context of all the uncertainties associated with each step in the process. Some of the major uncertainties in this risk assessment are addressed in the following chapter.

Three means of expressing the carcinogenic and noncarcinogenic risks of adverse health effects are presented in this chapter. First, chemical specific risks were estimated for each exposure pathway. Secondly, chemical specific risks were added to estimate a cumulative pathway specific risk. Finally, risks were added across all chemicals and relevant pathways to estimate the total human health risks to people residing in the lower Saginaw River AOC.

7.2 QUANTIFYING RISKS

7.2.1 Determination of Noncarcinogenic Risks

Noncarcinogenic effects are evaluated by comparing an exposure level over a specified time period with a RfD derived from a similar exposure period [otherwise known as the hazard quotient (HQ)]. Thus, HQ = exposure level (or intake)/RfD. Hazard quotients are expressed to one significant figure in a nonprobabilistic way. In this risk assessment, HQ values were expressed to two significant figures for each chemical; this was done to reduce round-up error when HQ values were summed for each pathway. An HQ value of less than 1 indicates that exposures are not likely to be associated with adverse noncarcinogenic effects (e.g., reproductive toxicity, teratogenicity, or liver toxicity). As the HQ approaches or exceeds 10, the likelihood of adverse effects is increased to the point where action to reduce human exposure should be considered. Owing to the uncertainties involved with these estimates, HQ values between 1 and 10 may be of concern, particularly when additional significant risk factors are present (e.g., other contaminants at levels of concern). However, the level of concern does not increase linearly as the RfD is approached or exceeded because RfDs do not have equal accuracy or precision; nor are RfDs based on the same severity of toxic effects (USEPA, 1989a).

In assessing health risks, all HQ values are representative of long term chronic exposures (i.e., exposures assumed to occur over a period of 9 or 30 years). The sum of more than one HQ value for multiple substances and/or multiple exposure pathways is the Hazard Index (HI). This assumption of additivity does not account for any synergistic or antagonistic effects that may occur among chemicals. For this risk assessment, no attempt was made to distinguish between risk endpoints (e.g., target organs and related effects) when calculating the HI. Thus, this expression of total risk may be extremely conservative; it would be better to refine the HI to specific endpoints for HQ values greater than one. Additional limitations of HQ values and the segregation of hazard indexes have been described elsewhere (USEPA, 1989a).

7.2.2 Determination of Carcinogenic Effects

Carcinogenic risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. This risk is computed using average lifetime exposure values that are multiplied by the oral slope factor for a particular chemical. Slope factors are used to convert estimated daily intakes averaged over a lifetime of exposure directly to the incremental risk of an individual developing cancer. The resulting carcinogenic risk estimate is generally an upper-bound estimate, because slope factors are usually based on upper 95th percentile confidence limits. The EPA believes it is prudent public health policy to consider actions to mitigate or minimize exposures to contaminants when estimated excess lifetime cancer risks exceed the 10^{-5} to 10^{-6} range, and when noncarcinogenic health risks are estimated to be significant (USEPA, 1988a).

Carcinogenic effects are summed for all chemicals in an exposure pathway as well as for multiple pathways. This summation of carcinogenic risks assumes that intakes of individual substances are small, that there are no synergistic or antagonistic chemical interactions, and that all chemicals produce the same effect (i.e., cancer). The limitations to this approach are discussed in detail elsewhere (USEPA, 1989a).

7.3 HUMAN HEALTH RISKS IN THE LOWER SAGINAW RIVER

7.3.1 Typical and Reasonable Maximum Exposures

7.3.1.1 Noncarcinogenic Risks

Based on typical and reasonable maximum exposure levels over a 9- and a 30-year period, respectively, estimated noncarcinogenic risks were below levels of concern (i.e., <1) for the individual consumption of walleye, carp, and waterfowl

(Tables 7.1-7.6). Since some of the chemicals (e.g., PCBs) detected in these animals do not presently have RfD values, it would be premature to state that no noncarcinogenic risk exists from consuming fish or waterfowl from the lower Saginaw River. The noncarcinogenic risk reported here is an estimated risk based on currently available data and toxicity information and should not be construed as an absolute risk.

7.3.1.2 Carcinogenic Risks

The estimated carcinogenic risks resulting from the consumption of walleye, carp, or waterfowl were 1×10^{-5}, 1×10^{-4}, and 6×10^{-6}, respectively, for typical exposures (Tables 7.1-7.3). Carcinogenic risks increased by about one order of magnitude for reasonable maximum exposures (i.e., 2×10^{-4}, 3×10^{-3}, and 2×10^{-4}) for consuming walleye, carp, or waterfowl, respectively (Tables 7.4-7.6). PCBs accounted for most of this risk, and all of these risk estimates were at or above levels of concern (i.e., $>10^{-6}$). However, these risk estimates may have been overestimated because the only available oral slope factor for PCBs was based on Aroclor 1260. Aroclor 1260 is not representative of the kinds of PCBs found in the lower Saginaw River. The primary Aroclor mixture detected in fish collected from the Saginaw River was Aroclor 1254, whereas only total PCBs were reported for waterfowl. Since Aroclor 1260 contains more highly chlorinated congeners (as well as potentially toxic coplanar congeners) than Aroclor 1254, these risk estimates may be overly conservative.

The carcinogenic risk from consuming either walleye or waterfowl was nearly equivalent under typical and reasonable maximum exposure scenarios. This similarity in risk does not mean that these animals accumulated the same amount of contaminants in their body tissues. Different assumptions about food consumption went into each exposure assessment, and the outcome of similar risk values may have been a coincidence. In addition, these ducks are migratory, and it is not possible to determine the exact geographic location where they accumulated contaminants. However, since the Saginaw River lies on a major migratory flyway and several waterfowl refuges are located in the Saginaw River area, it is plausible that these ducks accumulated most of their contaminant burden from local sources.

Carp had the worst level of carcinogenic risk for the typical and reasonable maximum exposure pathways, as would be expected for these bottom feeders. In addition, carp are fatty fish and hydrophobic organic contaminants (e.g., PCBs) will preferentially accumulate in their lipids. Although fish advisories are in effect against consuming carp and catfish in the Saginaw River, people often disregard these advisories. Consequently, it is not unreasonable to assume that some people may consume carp out of the Saginaw River. In addition, food scientists are examining ways in which carp flesh can be deboned and restructured to form fabricated seafood products (Stachiw et al., 1988); this is of particular interest to Michigan firms as a way of exploiting an underutilized fish in Saginaw Bay.

There is a possibility that people who ingest, inhale, or have dermal contact with certain PCB mixtures may have a greater chance of incurring liver cancer; however, this statement is based on suggestive evidence rather than on verified data. Studies with three strains of rats and two strains of mice have verified the carcinogenic toxicity of PCBs through the occurrence of hepatocellular carcinomas (IRIS data base retrieval for PCBs, 1992). This evidence was used to classify PCBs as a probable human carcinogen.

7.3.2 Subsistence Food Pathways

7.3.2.1 Subsistence Anglers

Subsistence anglers increased their risks to contaminants by an order of magnitude over recreational anglers in the reasonable maximum exposure scenario. Although it is unlikely that a subsistence angler would eat carp or walleye exclusively, these species can be used to obtain a range of risk values resulting from the subsistence fishing scenario. The noncarcinogenic hazard indexes for walleye and carp were 1 and 4, respectively (Tables 7.7 and 7.8). For walleye, the noncarcinogenic risk was at a borderline level of concern and was due mostly to the additive risk of methyl mercury and copper. For carp, only heptachlor epoxide had an HQ value exceeding one; this chemical has been found to cause increased liver-to-body weight ratio in both male and female beagle dogs. The rest of the hazard index for carp was attributable to the combined risk resulting from exposure to chlordane, dieldrin, and copper. Carcinogenic risks ranged from 2×10^{-3} to 2×10^{-2} for the consumption of walleye and carp, respectively (Tables 7.7 and 7.8); the carcinogenic risk was driven by exposure to PCBs. The risks from this exposure pathway will not be added to other pathways because this scenario only applies to a subgroup of the population.

7.3.2.2 Subsistence Hunters

For the subsistence hunter scenario, only the consumption of mallards and gadwalls was considered because of the lack of data for other waterfowl. Although noncarcinogenic risks were below levels of concern (i.e., <1), the carcinogenic risks due to PCBs and p,p' DDE resulted in an estimated lifetime cancer risk of 1×10^{-3} (Table 7.9). These risk estimates may be even higher for fish-eating waterfowl because they are more likely to accumulate higher levels of contaminants through the food chain.

Because the waterfowl data used in this risk assessment were collected in 1985, a more thorough and up-to-date study of the extent of contamination in waterfowl is needed to determine whether contaminant levels have changed. In addition, some estimate of the proportion of contaminants in ducks resulting from exposure to contaminants in the Saginaw River would be helpful. The results of this kind of study could be used by the Michigan DNR to determine whether consumption advisories are needed for waterfowl. In addition, there is a need to monitor contaminant levels in other wildlife (i.e., muskrats and snapping turtles) that people are known to consume in this region (Tim Kubiak, U.S. Fish and Wildlife Service, personal communication, 1991).

7.3.3 Additive Risks

Risks were added along exposure pathways (i.e., consumption of fish and waterfowl) in order to determine cumulative risks under typical and reasonable maximum exposure scenarios. Since subsistence anglers and waterfowl hunters were considered as separate subpopulations, their individual risks were not added together.

Based on typical and reasonable maximum exposure levels, noncarcinogenic risk levels were below levels of concern for both scenarios of the consumption of walleye and waterfowl or carp and waterfowl (Table 7.10). As mentioned previously, the noncarcinogenic risk of exposure to PCBs could not be determined since a RfD value has not been verified for it. Thus, this risk estimate will probably change as verified toxicity information becomes available. Carcinogenic risks for the same exposure scenarios were of concern for both typical and reasonable maximum exposures. The additive, upper-bound carcinogenic risk of consuming walleye and waterfowl was 2×10^{-5} for typical exposures and 4×10^{-4} for reasonable maximum exposures, whereas the risk of consuming carp and waterfowl was 1×10^{-4} for typical exposures and 3×10^{-3} for reasonable maximum exposures (Table 7.10). Based on these upper-bound risk levels, regular monitoring of contaminants in fish and waterfowl from the Saginaw River area should be done to track changes in contaminant levels.

TABLE 7.1. RISK ASSOCIATED WITH THE CONSUMPTION OF WALLEYE FROM THE LOWER SAGINAW RIVER BASED ON TYPICAL EXPOSURE LEVELS

Chemical	9 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Copper	6.1E-03		D
Mercury, methyl	1.1E-02		D
Zinc	8.3E-04		
"AROMATIC HYDROCARBONS"			
Hexachlorobenzene	3.5E-05	5.7E-09	B2
PCBs		9.7E-06	B2
"ORGANOCHLORINE INSECTICIDES"			
Chlordane	2.8E-03	2.8E-08	B2
Dieldrin	2.1E-03	2.2E-07	B2
p,p' DDD		1.2E-08	B2
p,p' DDE		6.4E-08	B2
p,p' DDT	2.2E-04	4.7E-09	B2
"PURGEABLES"			
Styrene	5.2E-07		
TOTAL	0.02	1E-05	

TABLE 7.2. RISK ASSOCIATED WITH THE CONSUMPTION OF CARP FROM THE LOWER SAGINAW RIVER BASED ON TYPICAL EXPOSURE LEVELS

Chemical	9 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Cadmium	3.2E-04		B1
Copper	8.9E-03		D
Mercury, methyl	6.0E-03		D
Zinc	1.7E-03		
"AROMATIC HYDROCARBONS"			
Hexachlorobenzene	1.8E-04	2.9E-08	B2
PCBs		1.4E-04	B2
"ORGANOCHLORINE INSECTICIDES"			
Chlordane	1.9E-02	1.9E-07	B2
Dieldrin	9.5E-03	9.7E-07	B2
Heptachlor epoxide	3.1E-02	4.7E-07	B2
p,p' DDD		1.4E-07	B2
p,p' DDE		8.6E-07	B2
p,p' DDT	2.0E-04	4.3E-09	B2
"PURGEABLES"			
Styrene	7.8E-06		
TOTAL	0.08	1E-04	

TABLE 7.3. RISK ASSOCIATED WITH THE CONSUMPTION OF WATERFOWL FROM THE LOWER SAGINAW RIVER BASED ON TYPICAL EXPOSURE LEVELS

Chemical	9 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Arsenic	7.0E-04		A
Cadmium	2.7E-04		B1
Mercury, methyl	5.3E-04		D
"AROMATIC HYDROCARBONS"			
PCBs		5.6E-06	B2
"ORGANOCHLORINE INSECTICIDES"			
p,p' DDE		7.2E-08	B2
TOTAL	0.001	6E-06	

TABLE 7.4. RISK ASSOCIATED WITH THE CONSUMPTION OF WALLEYE FROM THE LOWER SAGINAW RIVER BASED ON REASONABLE MAXIMUM EXPOSURE LEVELS

Chemical	30 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Copper	4.3E-02		D
Mercury, methyl	7.5E-02		D
Zinc	5.8E-03		
"AROMATIC HYDROCARBONS"			
Hexachlorobenzene	2.5E-04	1.4E-07	B2
PCBs		2.3E-04	B2
"ORGANOCHLORINE INSECTICIDES"			
Chlordane	2.0E-02	6.5E-07	B2
Dieldrin	1.5E-02	5.1E-06	B2
p,p' DDD		2.9E-07	B2
p,p' DDE		1.5E-06	B2
p,p' DDT	1.5E-03	1.1E-07	B2
"PURGEABLES"			
Styrene	3.7E-06		
TOTAL	0.2	2E-04	

TABLE 7.5. RISK ASSOCIATED WITH THE CONSUMPTION OF CARP FROM THE LOWER SAGINAW RIVER BASED ON REASONABLE MAXIMUM EXPOSURE LEVELS

Chemical	30 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Cadmium	2.2E-03		B1
Copper	6.3E-02		D
Mercury, methyl	4.3E-02		D
Zinc	1.2E-02		
"AROMATIC HYDROCARBONS"			
Hexachlorobenzene	1.2E-03	7.2E-07	B2
PCBs		3.2E-03	B2
"ORGANOCHLORINE INSECTICIDES"			
Chlordane	1.3E-01	4.4E-06	B2
Dieldrin	6.7E-02	2.3E-05	B2
Heptachlor epoxide	2.2E-01	1.1E-05	B2
p,p' DDD		3.3E-06	B2
p,p' DDE		2.0E-05	B2
p,p' DDT	1.4E-03	1.0E-07	B2
"PURGEABLES"			
Styrene	5.5E-05		
TOTAL	0.5	3E-03	

TABLE 7.6. RISK ASSOCIATED WITH THE CONSUMPTION OF WATERFOWL FROM THE SAGINAW RIVER AREA BASED ON REASONABLE MAXIMUM EXPOSURE LEVELS

Chemical	30 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Arsenic	7.3E-03		A
Cadmium	2.8E-03		B1
Mercury, methyl	5.5E-03		D
"AROMATIC HYDROCARBONS"			
PCBs		2.0E-04	B2
"ORGANOCHLORINE INSECTICIDES"			
p,p' DDE		2.5E-06	B2
TOTAL	0.02	2E-04	

TABLE 7.7. RISK ASSOCIATED WITH THE CONSUMPTION OF WALLEYE FROM THE LOWER SAGINAW RIVER FOR SUBSISTENCE ANGLERS

Chemical	30 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Copper	2.9E-01		D
Mercury, methyl	5.1E-01		D
Zinc	4.0E-02		
"AROMATIC HYDROCARBONS"			
Hexachlorobenzene	1.7E-03	9.2E-07	B2
PCBs		1.6E-03	B2
"ORGANOCHLORINE INSECTICIDES"			
Chlordane	1.3E-01	4.5E-06	B2
Dieldrin	1.0E-01	3.5E-05	B2
p,p' DDD		2.0E-06	B2
p,p' DDE		1.0E-05	B2
p,p' DDT	1.0E-02	7.6E-07	B2
"PURGEABLES"			
Styrene	2.5E-05		
TOTAL	1	2E-03	

TABLE 7.8. RISK ASSOCIATED WITH THE CONSUMPTION OF CARP FROM THE LOWER SAGINAW RIVER FOR SUBSISTENCE ANGLERS

Chemical	30 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Cadmium	1.5E-02		B1
Copper	4.3E-01		D
Mercury, methyl	2.9E-01		D
Zinc	8.2E-02		
"AROMATIC HYDROCARBONS"			
Hexachlorobenzene	8.5E-03	4.6E-06	B2
PCBs		2.2E-02	B2
"ORGANOCHLORINE INSECTICIDES"			
Chlordane	8.9E-01	3.0E-05	B2
Dieldrin	4.6E-01	1.6E-04	B2
Heptachlor epoxide	1.5E+00	7.6E-05	B2
p,p' DDD		2.3E-05	B2
p,p' DDE		1.4E-04	B2
p,p' DDT	9.5E-03	6.9E-07	B2
"PURGEABLES"			
Styrene	3.7E-04		
TOTAL	4	2E-02	

TABLE 7.9. RISK ASSOCIATED WITH THE CONSUMPTION OF WATERFOWL FROM THE SAGINAW RIVER AREA FOR SUBSISTENCE HUNTERS

Chemical	30 yr HQ (Intake/RfD)	Lifetime Cancer Risk	Carcinogenic Weight of Evidence Class
"METALS"			
Arsenic	3.7E-02		A
Cadmium	1.4E-02		B1
Mercury, methyl	2.8E-02		D
"AROMATIC HYDROCARBONS"			
PCBs		1.0E-03	B2
"ORGANOCHLORINE INSECTICIDES"			
p,p' DDE		1.3E-05	B2
TOTAL	0.08	1E-03	

TABLE 7.10 SUMMARY OF NONCARCINOGENIC AND CARCINOGENIC RISKS IN THE LOWER SAGINAW RIVER

Type of Risk and Exposure	Individual Risks			Additive Risks	
	Walleye	Carp	Waterfowl	Walleye + Waterfowl	Carp + Waterfowl
Noncarcinogenic (HI)					
Typical	0.02	0.08	0.001	0.02	0.08
Reasonable Maximum	0.2	0.5	0.02	0.2	0.5
Subsistence	1	4	0.08		
Carcinogenic					
Typical	1E-05	1E-04	6E-06	2E-05	1E-04
Reasonable Maximum	2E-04	3E-03	2E-04	4E-04	3E-03
Subsistence	2E-03	2E-02	1E-03		

CHAPTER 8

CHARACTERIZATION OF QUALITATIVE UNCERTAINTIES

8.1 INTRODUCTION

A number of assumptions and estimated values are used in baseline risk assessments that contribute to the level of uncertainty about the risk estimates. For most environmental risk assessments, the uncertainty of the risk estimates varies by at least an order of magnitude or greater (USEPA, 1989a). In this chapter, a qualitative listing of the uncertainties associated with each step in the risk assessment process will be made in order to determine the impact of these uncertainties on the final risk assessment results.

8.2 QUALITATIVE LIST OF UNCERTAINTIES

8.2.1 Data Compilation and Evaluation

The data compilation and evaluation step is one part of the risk assessment process where uncertainties arise. These uncertainties are listed below for the following assumptions and statements.

- **The available data for contaminant levels in fish, waterfowl, and water samples collected from the Saginaw River were representative of the true distribution of contaminants in the Saginaw River AOC.** A moderate level of uncertainty is probably associated with this assumption. Additional sampling over a longer period of time would be needed to look for any temporal or spatial variability in contaminant levels, and to obtain a more representative profile of contaminant concentrations in the media of interest.

- **Some data studies may have been missed in the data compilation step.** This is unlikely since the Saginaw River/Bay RAP Manager and U.S. Fish and Wildlife supplied the most recent data available. Other research investigations are currently underway in the Saginaw River, but their data were not available for inclusion in this risk assessment.

- **A complete QA/QC review of the data reports obtained for this risk assessment could not be made because of a lack of information supplied with the reports.** Therefore, no information about the accuracy of the data could be obtained. The uncertainty associated with using this data is unknown, but may have been minimized by using more up-to-date monitoring studies that generally have more rigorous QA/QC plans than older studies.

- **Contaminant burdens in fish and waterfowl may decrease depending on how the meat is prepared and cooked.** Contaminant levels may be reduced 10-70% depending on how the meat is prepared and cooked (H. Humphrey, Michigan Department of Public Health, personal communication). Because of this wide range, the uncertainty associated with the resulting overestimation of risk is not well established.

8.2.2 Exposure Assessment

A number of assumptions were made in the exposure assessment step of this baseline human health risk assessment.

- **An adequate assessment of complete and incomplete exposure pathways was made.** There is a low uncertainty that some exposure pathways were either not identified or else were incorrectly classified as a complete or incomplete exposure pathway.

- **The exclusion of some complete exposure pathways (i.e., dermal exposure to water and sediments) from the exposure assessment was justifiable because of the low probability that these pathways would result in significant human health risks.** The uncertainty associated with this assumption is probably low because the carcinogenic risk from ingesting PCB contaminated water while swimming (3 events per year) was low (4×10^{-10}), and this pathway usually results in greater risk than the dermal exposure pathways (for similar exposure frequencies).

- **The complete exposure pathways chosen for the exposure assessment represent the primary pathways by which people in the lower Saginaw River were exposed to contaminants.** The pathways chosen were based primarily on observed activities and on the availability of data. Data on contaminant levels in other types of waterfowl (e.g., geese) and wildlife (e.g., snapping turtles) were not available and represent incomplete exposure pathways. A medium level of uncertainty is probably associated with not being able to include these incomplete exposure pathways.

- **The assumptions made about exposure frequency and duration variables, body weight, life expectancy, and population characteristics were appropriate.** Many of these assumptions (e.g., body weight, life expectancy, exposure frequency) were based on EPA guidance (USEPA, 1989a,b; 1991a) and probably have a low to moderate level of uncertainty associated with them. A similar level of uncertainty may be attributed to professional judgments about the fraction of fish or waterfowl ingested from contaminated sources.

8.2.3 Toxicity Values

The toxicity values (i.e., oral RfDs and oral slope factors) used in this risk assessment were either verified values obtained from IRIS or interim values obtained from other sources. RfDs and slope factors are subject to change as a result of new information and updates of the IRIS data base. In addition, chemicals will be added to IRIS in the future to expand the data base. Thus, this risk assessment is "dated" to the toxicity values available at the time it was prepared. Listed below are the uncertainties associated with using these toxicity values.

- **RfD values and slope factors have a certain amount of uncertainty associated with them.** Uncertainty and modifying factors are incorporated into the calculation of RfDs (see Appendix B) and take into consideration factors such as extrapolating data from long-term animal studies to humans, etc. In general, RfD values have an uncertainty range of about one order of magnitude. Since slope factors represent an estimate of an upper-bound lifetime probability of an individual developing cancer, these values are already conservative. Thus, the amount of uncertainty associated with slope factor values may be minimized.

- **Toxicity values were not available for all of the chemicals detected in the lower Saginaw River.** For some chemicals, such as lead, a risk characterization could not be done because toxicity values have not been derived yet or else are under review by EPA workgroups. In addition, a RfD value has not been listed yet for PCBs in IRIS; thus, noncarcinogenic risks from exposure to PCBs could not be determined. The uncertainty of not being able to include some chemicals in this risk assessment is unknown.

- **A conservative assumption for metal speciation in the lower Saginaw River was made for mercury because toxicity values for the total metal form were not available.** Thus, toxicity values for methyl mercury were used to represent the major form of mercury. The use of this more toxic chemical species results in a conservative estimate of risk. A moderate level of uncertainty is probably associated with this uncertainty.

8.2.4 Risk Characterization

The uncertainties associated with the risk characterization step are listed below.

- **Exposure intakes and toxicity values will remain the same over the exposure duration.** This assumes that human activities and contaminant levels will remain the same over the exposure duration, and that toxicity values will not be updated. A moderate to high level of uncertainty is probably associated with this assumption since it does not take into consideration the implementation of remedial actions or the deposition of cleaner sediments over contaminated sediments. Furthermore, toxicity values are frequently updated in the IRIS data base as new information becomes available. The level of uncertainty will probably increase with longer exposure durations.

- **Health risks are additive for both noncarcinogenic and carcinogenic effects.** The uncertainty associated with this assumption is unknown. The toxicity exhibited by a mixture of chemicals may involve synergistic and antagonistic effects. However, no guidelines are available to judge the complex interactions a mixture of contaminants may possess in terms of its potential toxicity to humans. At the present time, standard risk assessment guidance assumes that health risks are additive.

8.2.5 Summary

Based on the current information available, a complete description of the level of uncertainty associated with all of the assumptions and data used in this risk assessment cannot be made. This baseline human health risk assessment was based on data and assumptions that, in reality, represent a snapshot in time. One of the greatest sources of uncertainty in this risk assessment arises from assuming that estimated risks will remain constant over the exposure duration (i.e., 9 years for typical exposures and 30 years for reasonable maximum and subsistence exposures). The overall uncertainty of the risk estimates probably varies by over an order of magnitude. As additional data are collected from the Saginaw River and as additional (or revised) toxicity values are generated, a better estimate of human health risk can be determined for people living in this area. Thus, updates of this risk assessment will probably reduce the level of uncertainty associated with it.

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APPENDIX A

IMPORTANCE OF OTHER COMPLETE EXPOSURE PATHWAYS IN THE SAGINAW RIVER AREA OF CONCERN

The dermal exposure of people to water and sediments in the lower Saginaw River was assumed to be insignificant based on the frequency with which these exposures would take place and also in comparison to the estimated carcinogenic risk from ingesting surface water while swimming or playing in the Saginaw River. In this appendix, these assumptions and estimated risk estimates will be described.

Dermal contact with Saginaw River sediments may occur infrequently because there are no designated swimming areas along shore where someone could wade into the water. Another place where dermal contact with sediments may occur is at the boat ramps when people are putting in or taking out their boats; however, most people would probably be wearing some kind of foot protection to shield their feet from rocks, broken glass, etc. Dermal contact with water will occur from a variety of activities in the river, especially boating and fishing.

Although dermal exposures to water and sediment appears to take place in the Saginaw River, it is more difficult to determine the risks from these pathways than from an ingestion or inhalation pathway. This is because toxicity values are not developed specifically for dermal sorption, nor are absorption rates developed well for contaminants. Thus, the estimation of exposure for the dermal pathway, calculated as an absorbed dose, has a greater amount of uncertainty associated with it than exposures that are based on an actual intake of contaminant into the body. Based on dermal exposures calculated for other more contaminated ARCS sites, dermal exposures to water and sediments in the Saginaw River are not likely to result in significant noncarcinogenic and carcinogenic risks. In addition, a greater risk is likely to be encountered due to the ingestion of surface water from the Saginaw River than dermal exposures to it. This is because of the direct intake of contaminants into the gut versus the absorption of contaminants (with varying levels of permeability) across the skin interface.

The lifetime cancer risk for ingesting surface water from the lower Saginaw River was estimated based on exposure and risk assessment guidance developed for the EPA Superfund program (USEPA, 1989a). Based on the other carcinogenic risk estimates determined in this report for the consumption of fish and/or waterfowl, PCBs contribute nearly all of the risk. Consequently, PCBs were the only contaminant chosen to estimate the carcinogenic risk from ingesting Saginaw River water. The Michigan DNR and EPA sampled several stations in the Saginaw River during 7-9 August, 1989 for water column PCBs (G. Goudy, MDNR, personal communication, 1991). The surface water downstream of the Bay City

WWTP (approximately 30 m upstream of the Bay Harbor Marina) contained 1.72 x 10^{-5} mg/L total PCBs. This concentration value was used in this risk estimate. The carcinogenic risk estimate also assumed that a 70-kg person swam 3 days/year for 0.5 hr/event for 30 years and ingested water at a rate of 5 x 10^{-2} L/hr; the risk was then extrapolated over a 70-year period to represent a lifetime carcinogenic risk. These assumptions were based, in part, on study assumptions as well as on values recommended by the EPA Superfund program (USEPA, 1989a).

The estimated lifetime intake of ingesting PCBs in surface water under these conditions was 2 x 10^{-11} mg/kg-day. This value multiplied by the oral slope factor for PCBs (i.e., 7.7/mg/kg-day) yielded an estimated, upper-bound carcinogenic risk of 2 x 10^{-10}. The EPA believes it is prudent public health policy to consider actions to mitigate or minimize exposures to contaminants when estimated excess lifetime cancer risks exceed the 10^{-5} to 10^{-6} range (USEPA, 1988a). Based on this low carcinogenic risk estimate for the ingestion of surface water, dermal exposures to water and sediments were assumed to be insignificant. A noncarcinogenic risk estimate could not be calculated for this scenario because of the lack of a RfD toxicity value for PCBs.

APPENDIX B

HUMAN TOXICITY ESTIMATES FOR CONTAMINANTS PRESENT IN THE SAGINAW RIVER AREA OF CONCERN

B.1 TOXICITY ASSESSMENT

The toxicity assessment step is an integral part of the human health baseline risk assessment. This step includes four tasks: 1) gather qualitative and quantitative toxicity information for substances being evaluated, 2) identify exposure periods for which toxicity values are necessary, 3) determine toxicity values (i.e., reference doses (RfDs)) for noncarcinogenic effects, and 4) determine toxicity values (i.e., slope factors) for carcinogenic effects (USEPA, 1989a). The EPA has performed the toxicity assessment step for a limited number of chemicals and these assessments have undergone extensive peer review. Therefore, the toxicity assessment step of this study involves primarily a compilation of available toxicity data.

Once a "verified" toxicity value is agreed upon by the EPA's toxicologists, it is entered into the EPA's Integrated Risk Information System (IRIS) data base; these values are updated as necessary. IRIS is the primary source of toxicity information used in baseline risk assessments. The Health Effects Assessment Summary Tables (HEAST) are the second most current source of toxicity information and include both verified and interim RfDs and slope factors. Interim values are used for chemicals that have not yet been approved by the EPA. Specific EPA workgroups, such as the Carcinogen Risk Assessment Verification Endeavor (CRAVE) and RfD Workgroups, are another source of interim toxicity values. If toxicity values are not available in the aforementioned sources, then interim values from other reports may be used.

This appendix summarizes pertinent toxicity information obtained from IRIS and other sources for chemicals in the lower 8 km of the Saginaw River. Also included in this appendix are brief descriptions of the most important toxicity values used to evaluate noncarcinogenic and carcinogenic effects; these subsections were summarized from the EPA guidance document: "Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual (Part A)" (USEPA, 1989a).

B.1.1 Noncarcinogenic Chronic Toxicity

The RfD is the toxicity value used most often in evaluating noncarcinogenic effects. The RfD is defined as an estimate of the daily exposure to the human population that is likely to be without an appreciable risk of deleterious effects during either a portion of the lifetime (i.e., subchronic RfD or "RfD_s") or during the lifetime (i.e., chronic RfD or "RfD"). This toxicity value has an uncertainty range of about an order of magnitude and includes exposures to sensitive subgroups in the population. For each chemical, the RfD is calculated from the following equation:

$$RfD = \frac{NOAEL \text{ or } LOAEL}{UF \text{ X } MF}$$

where:

NOAEL = No-Observed-Adverse-Effect-Level

LOAEL = Lowest-Observed-Adverse-Effect-Level

MF = Modifying Factor

UF = Uncertainty Factor

The NOAEL and LOAEL are derived from dose-response experiments. The NOAEL represents the highest exposure level tested at which no adverse effects occurred (including the critical toxic effect), whereas the LOAEL represents the lowest exposure level at which significant adverse effects occurred. Uncertainty factors usually consist of multiples of ten, with each factor representing a specific area of uncertainty included in the extrapolation from available data. An uncertainty factor of ten is usually used to account for variation in the general population so that sensitive subpopulations are protected. An additional ten-fold factor is usually applied for each of the following extrapolations: from long-term animal studies to humans, from a LOAEL to a NOAEL, and when subchronic studies are used to derive a chronic RfD. A modifying factor, ranging from >0 to 10, is included as a qualitative assessment of additional uncertainties.

Table B-1 includes the uncertainty and modifying factors, confidence classifications, and critical effects of the contaminants examined for this risk assessment. Uncertainty factors ranged from 3 to 1000, and either a low, medium, or high level of confidence was given for these RfD values. Better estimates of oral RfD values are needed to reduce these levels of uncertainty, and IRIS is constantly being updated to refine RfD estimates.

B.1.2 Carcinogenicity

Human carcinogenic risks are usually evaluated for a chemical by using its slope factor (formerly designated as a cancer potency factor) and corresponding weight-of-evidence classification. These variables were listed in Table 6.2 for the Saginaw River chemicals. Slope factors are estimated through the use of mathematical extrapolation models, most commonly the linearized multistage model, for estimating the largest possible linear slope (within 95% confidence limits), at low extrapolated doses, that is consistent with the data. The slope

TABLE B-1. ORAL RfD SUMMARY FOR CHEMICALS LISTED IN IRIS AS OF 28 JANUARY 1992

Chemical	UF	MF	Confidence in Oral RfD	Critical Effects
"METALS"				
Arsenic	3	1	Medium	Hyperpigmentation, keratosis, and possible vascular complications in humans
Cadmium	10	1	High	Significant proteinuria in humans
Copper				
Mercury, methyl	10	1	Medium	Central nervous system effects in humans
Zinc				
"AROMATIC HYDROCARBONS"				
Hexachlorobenzene	100	1	Medium	Liver effects in rats
PCBs				
"ORGANOCHLORINE INSECTICIDES"				
Chlordane	1000	1	Low	Regional liver hypertrophy in female rats
Dieldrin	100	1	Medium	Liver lesions in rats
Heptachlor epoxide	1000	1	Low	Increased liver-to-body weight ratio in both male and female dogs
p,p' DDD				
p,p' DDE				
p,p' DDT	100	1	Medium	Liver lesions in rats
"PURGEABLES"				
Styrene	1000	1	Medium	Red blood cell and liver effects in dogs

factor is characterized as an upper-bound estimate so that the true risk to humans, while not identifiable, is not likely to exceed the upper-bound estimate.

The weight of evidence classification for a particular chemical is determined by the EPA's Human Health Assessment Group (HHAG). Chemicals are placed into one of five groups according to the weight of evidence from epidemiological studies and animal studies. These groups are designated by the letters A, B, C, D, and E which represent the level of carcinogenicity to humans (see Table 6.1). Quantitative carcinogenic risk assessments are performed for chemicals in Groups A and B, and on a case-by-case basis for chemicals in Group C.

B.2 UNCERTAINTIES

A number of uncertainties are involved with using toxicity values for estimating noncarcinogenic and carcinogenic risks. Some of these qualitative uncertainties are listed below:

- Using dose-response information from healthy animal or human populations to predict effects that may occur in the general population, including susceptible subpopulations (e.g., elderly, children),
- Using dose-response information from animal studies to predict effects that may occur in human populations,
- Using NOAELs derived from short-term animal studies to predict effects that may occur in humans during long-term exposures,

- Using dose-response information from effects observed at high doses to predict the adverse health effects that may occur following exposure of humans to low levels of the chemical in the environment, and

- Using a toxicity value derived from exposure to a particular chemical mixture (e.g., Aroclor 1260) to represent the level of toxicity for other similar chemical mixtures (e.g., Aroclor 1242, 1248, and 1254).

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