APPENDIX A

POLICIES, PROGRAMS, AND REGULATIONS

CONTENTS

A.1 STATUTES AND REGULATIONS

A.1.1 CLEAN AIR ACT (CAA)

The Clean Air Act (42 USC 7401 *et seq.*) was first enacted in 1970 to regulate airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The 1990 CAA Amendments were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion, and air toxics. The 1990 Clean Air Act Amendments Section 112(b) identifies a list of 189 hazardous air pollutants (HAP) selected by Congress based upon their potential for causing human health or environmental hazards. The U.S. EPA must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations (40 CFR Parts 61 and 63). The list of HAPs includes PCBs; dioxins and furans; chlordane; mercury compounds; DDE; lead compounds (but not elemental lead); cadmium compounds; chromium compounds; arsenic compounds; cyanide compounds; hexachlorobenzene; toxaphene; DEHP; 1,2,4-trichlorobenzene; and selenium compounds.

EPA has developed an action plan for the National Air Toxics Program which is divided into 4 components:

- Source and sector-specific standards;
- Multi-media projects and risk initiatives;
- National air toxics assessments; and
- Education and outreach.

Source and sector specific standards include national technology-based standards, combustion standards, residual risk standards, area source standards, seven specific pollutants designated for special attention, utility determination and regulation, and mobile source standards.

- <u>National Technology-Based Standards</u>: Under the CAA amendments of 1990, EPA is required to develop standards for each of the 174 stationary sources that emit one or more of the 188 identified hazardous air pollutants. These standards, known as Maximum Achievable Control Technology (MACT) standards, are based on the emissions levels that are already being achieved by the better controlled sources in an industry. To date, EPA has promulgated 44 emission standards covering 79 source categories. These stanardards are responsible for annual reductions of approximately 1.5 millions tons of air toxics and 2.5 million tons of VOCs. Over the next 3 years, EPA plans to promulgate additional emission standards, which should achieve annual reductions of another ½ million tons.

- <u>Combustion Standards</u>: Under Section 129 of the CAA, EPA has issued 2 final rules to control emissions of certain toxic pollutants from certain types of solid waste combustion facilities. These rules set emission limits for new solid waste combustion facilities and provide emissions guidelines for existing solid waste combustion facilities. These rules affect municipal waste combustors and hospital/medical/infectious waste incinerators, which account for 30 percent of the national mercury emissions to the air. By the time these rules are fully implemented, they are expected to reduce mercury emissions from these sources by about 90 percent from current levels, and reduce dioxin/furan emissions from these sources by more than 95 percent from current levels. EPA is working on additional rules to address industrial and commercial waste incinerators, other solid waste incinerators, and small municipal waste combustor units.

- Residual Risk Standards: The residual risk program is designed to assess the risk remaining from stationary source categories after EPA implements a technology-based standard. EPA is required to set additional standards if the level of "residual risk" does not provide an "ample margin of safety to protect public health" or if further emissions reductions are needed "to prevent, taking into consideration costs, energy, safety, and other relevant factors, an adverse environmental effect." These residual risk standards are required within 8 years (9 years for the earliest standards) after EPA finalizes the technology-based standard.

- Area Source Standards: Under the Integrated Urban Air Toxics Strategy, EPA must ensure that 90 percent of the area source emissions of the 30 "area source" urban air toxics listed in the Strategy are regulated. In order to accomplish this, EPA identified new source categories of smaller commercial and industrial operations or so-called "area" sources for regulation. EPA plans to finalize regulations for these area source categories by 2004. EPA has completed or nearly completed regulations on an additional 16 area source categories. However, the EPA will be adding source categories to that list for regulation to meet the requirement to regulate 90 percent of the area source emissions.

- Seven Specific Pollutants: The CAA lists seven specific pollutants (alkylated lead compounds, polycyclic organic matter (POM), hexachlorobenzene, mercury, polychlorinated biphenyls, 2,3,7,8-tetrachlorodibenzofurans (TCDF) and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)) for special attention by the EPA. EPA must regulate sources accounting for 90 percent of the emissions of these toxics. On April 3, 1998, EPA issued the list of additional source categories. They are (1) open burning of scrap tires (for POM); and (2) gasoline distribution Stage I Aviation, including evaporative losses associated with the distribution and storage of aviation gas containing lead (for lead). EPA plans to complete these standards by 2003.

- Utility Determination and Actions**:** EPA is continuing to gather data on mercury emissions from coal-fired electric utility power generation plants to evaluate the need for regulation of toxic air pollutants from these sources. Utility plants (primarily coal-fired plants) emit approximately 50 tons per year of mercury nationwide, which is almost 1/3 of the anthropogenic mercury emissions in the U.S. EPA will make a determination on whether to regulate air toxics emissions from electric utilities by December 2000.

- Mobile Source Standards**:** EPA began enforcing the first federal emission standards for passenger cars in 1968. Since then, EPA has developed emission standards for all types of highway vehicles, their fuels, and engines used in virtually every variety of mobile or portable nonroad vehicle/equipment including tractors, construction vehicles, recreational and commercial vessels, and lawn and garden equipment. EPA has promulgated increasingly stringent emission standards. In May of 1999, EPA proposed more stringent standards for all cars and light duty trucks, as well as the gasoline they use. At the same time, EPA issued an advance notice of proposed rulemaking to solicit information relating to control of diesel fuel quality. EPA is currently reviewing standards for heavy-duty highway vehicles and their engines for 2004, and considering new emission standards for these vehicles and engines beyond 2004. EPA is also reviewing standards for nonroad diesel engines.

  In 1990 Congress amended the Clean Air Act to add a requirement that EPA consider motor vehicle air toxics controls. Section 202(l), required EPA to study motor vehicle-related air toxics, and to promulgate requirements for the control of such pollutants based on that study. The study was completed in 1993, and EPA is presently updating the emissions and exposure analyses and working on a rule to regulate motor vehicle toxic air emissions.

Multi-media projects and risk initiatives include the Great Waters Project, the Mercury Total Maximum Daily Load Air Deposition Pilot Project, the Air-Water Interface Action Plan, the Integrated Urban Air Toxics Strategy, urban community-based pilot projects, mercury initiatives, Mercury Research Strategy, and coordination initiatives.

- Great Waters: The CAA directs EPA to monitor, assess, and report on the deposition of toxic air pollutants to the "Great Waters," which include the Great Lakes, Lake Champlain, Chesapeake Bay, and other coastal estuaries. Activities include assessing deposition to these waters by establishing a deposition monitoring network, investigating sources of pollution, improving monitoring methods, evaluating adverse effects, and sampling for the pollutants in aquatic plants and wildlife. Pollutants of concern to the Great Waters include mercury, lead, cadmium, nitrogen compounds, POM/PAHs, dioxins and furans, PCBs, and seven banned or restricted pesticides.

- Mercury Total Maximum Daily Load (TMDL) Air Deposition Pilot Project: The Great Waters program is multimedia in nature and requires cross-program approaches to investigate and address problems. EPA's air and water programs are working together on two studies to address mercury deposition to waterways. The outcome of this effort will influence the development of joint national guidance for addressing Total Maximum Daily Loads (TMDLs) where air deposition is a factor. The study is being conducted on Devil's Lake in Wisconsin and the Florida Everglades. For each of the waterbodies, the project will evaluate techniques for determining the amount of mercury reductions needed to meet water quality standards, and techniques for determining the relative contributions of mercury from various sources, source categories, and source regions. The project will also analyze federal and state regulatory and non-regulatory tools for reducing mercury emissions that may be causing water quality problems. Pilot TMDLs will be developed for each of the study areas. In addition, EPA plans to issue a report on lessons learned from both pilot projects in the summer of 2000.

- Air-Water Interface Action Plan: The action plan is intended to consolidate EPA's efforts to understand and address atmospheric deposition nationwide, including the Great Waters and other state-identified impaired waterbodies. The plan will: target state-identified impaired waterbodies; examine the rules or activities currently in place to address impairment caused by air deposition; and determine what, if any, additional actions are necessary to address impairment caused by air deposition. To date, OAR and OW management have held two meeting with Great Lakes environmental groups to discuss various components of the action plan including TMDLs, upcoming MACT standards, and air toxics monitoring. A draft plan will be developed for external review shortly.

- Integrated Urban Air Toxics Strategy: The urban strategy includes the same components of the overall air toxics strategy, but it has risk-based goals for addressing air toxics in urban areas. Specifically, the strategy has three goals for urban areas: (1) ensure a 75 percent reduction in cancer incidence from stationary sources; (2) ensure a "substantial" reduction in health risks from area sources; and (3) ensure that disproportionate risks are addressed first, thus focusing efforts on sensitive populations or geographic hot spots.

- Urban community-based pilot projects: Since exposure to air toxics vary (in terms of pollutants and sources) between urban areas across the country, EPA's activities to reduce risk on a national scale may not address potential local risks. Consequently, the strategy includes local and community-based initiatives which will involve partnerships between EPA and the state, local, and tribal governments.

- Mercury Initiatives: The CAA requires EPA to issue a report on the sources and impacts of mercury. EPA released the *Mercury Report to Congress* in December 1997. The report includes an assessment of the emissions of mercury from all known anthropogenic sources in the United States, the health and environmental implications of these emissions, and the availability and cost of controlling these emissions. The report supports a plausible link between anthropogenic releases of mercury from industrial and combustion sources in the United States and methylmercury in fish.

- Mercury Research Strategy: EPA's Office of Research and Development's (ORD) *Mercury Research Strategy* seeks to address the scientific questions of greatest concern regarding mercury through a coordinated research program. There are two key fate and transport questions the strategy seeks to address: (1) the quantity of methylmercury in fish contributed by U.S. sources relative to other natural and global sources; and (2) the amount and length of time which levels of methylmercury in fish in the U.S. will decrease as the result of reductions made by U.S. sources.

- Coordination initiatives: EPA has a number of activities to identify and address risks from specific types of pollutants. The Persistent Bioaccumulative Toxics (PBT) Initiative seeks to further reduce risks to human health and the environment from existing and future exposure to persistent, bioaccumulative, and toxic pollutants through a coordinated effort between EPA offices, and other federal, state and local agencies. The CWAion Plan (CWAP) seeks to address the remaining obstacles to the CWA's original goal of "fishable and swimable" water for all Americans. The CWAP identifies non-point sources, including atmospheric deposition, as the most important remaining threat to water quality.

National Air Toxics Assessment Activities (NATA) activities are a primary component of EPA's national air toxics program. These activities help set program priorities, characterize risks, and track progress toward meeting the goals of the national air toxics program, as well as specific risk-based goals. More specifically, NATA activities include: expanding air toxics monitoring; improving and updating emissions inventories; conducting national- and local-scale air quality, multi-media, and exposure modeling; characterizing risks associated with air toxics exposures; and continued research on health and environmental effects and exposures to both ambient and indoor sources of air toxics. EPA is now conducting an initial screening-level assessment to demonstrate an approach to characterizing air toxics risks nationwide. Other planned assessments include pollutant-specific activities such as the Dioxin Reassessment and Action Plan and a proposed National Air Deposition Assessment.

Education and Outreach: EPA believes that public participation is vital for the implementation of the overall air toxics program. EPA is committed to working with cities, communities, state, local and tribal agencies, and other groups and organizations that can help implement activities to reduce air toxics emissions. Outreach and education efforts include:

- Great Waters Program Outreach: The CAA directs EPA to periodically report its findings of monitoring, studies, and investigations conducted under this program. The EPA has already submitted a *First* and *Second Report to Congress* and is in the process of completing the *Third Great Waters Report to Congress*. EPA is also working on additional outreach tools for the public, such as an educational brochure to inform the public about air deposition issues and further enhancements to Great Waters websites. During 2000, EPA will be developing a handbook to assist water resource managers in characterizing air deposition problems.

- Urban Air Toxics Report to Congress: EPA is required under the CAA to provide two reports to Congress on actions taken to reduce the risks to public health posed by the release of toxic air pollutants from area sources. The CAA also requires that the reports identify specific metropolitan areas that continue to experience high risks to public health as a result of emissions from area sources. EPA will complete the first of these two reports in late 1999. The second report is due in 2004.

A.1.2 CLEAN WATER ACT (CWA)

The 1977 amendments to the Federal Water Pollution Control Act, called the CWA (33 USC 1251 *et seq*) regulates discharges to navigable (surface) waters with the goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. Toxic substances were the focus of the 1977 amendments. The CWA authorized EPA to set technology-based effluent standards on an industry basis and continued the obligation to set water quality standards for all surface water contaminants. In addition, EPA may set water quality-based effluent limitations in situations where discharges would otherwise interfere with the attainment and maintenance of water quality sufficient to ensure the protection of public health, public water supplies, and agricultural and industrial uses, as well as the protection and propagation of a balanced population of shellfish, fish, and wildlife.

The CWA prohibits any person from discharging a pollutant from a point source into navigable waters without a National Pollutant Discharge Elimination System (NPDES) permit (33 U.S.C. 1342, 40 CFR 122). Individual facilities are subject to effluent limits and/or monitoring requirements in their NPDES permit. Effluent limitations for discharges are based on the use of Best Available Technology that is economically achievable (BAT) for specific point sources. Pretreatment requirements are established for indirect discharges which are discharged from industries via municipal wastewater treatment plants or sewage treatment plants (33 USC 1314(g), 40 CFR Part 403). A list of 65 toxic pollutants subject to pretreatment requirements can be found at 40 CFR Part 403 Appendix B. This includes categorical standards developed by EPA for each industry, as well as local standards developed by each publicly owned treatment plant (POTW) (40 CFR Part 403 Appendix C).

NPDES permits regulate household and industrial wastes that are collected in sewers and treated at municipal wastewater treatment plants. The permits also regulate industrial point sources and concentrated animal feeding operations that discharge directly into receiving waters. Effluent limits for both direct and indirect discharges are generally sector specific (e.g., for a particular segment of an industry).

Many storm water discharges also require an NPDES permit. These include discharges associated with industrial activities or from large or medium municipal storm sewer systems. In addition, NPDES permits are required for all discharges determined by EPA or the state to contribute to a violation of a water quality standard or to be a significant contributor of pollutants to the waters of the United States.

The CWA identifies approximately 125 pollutants on a Priority Pollutant List. This list includes aldrin, chlordane, mercury, lead, cadmium, copper, zinc, chromium, arsenic, hexachlorobenzene, toxaphene, 1,2,4-Trichlorobenzene and DEHP. EPA has developed water quality criteria for all of the priority pollutants. In addition, the CWA has designated certain substances to be "hazardous substances," including PCBs.

Section 118(c) of the CWA is entitled "Great Lakes Management" and contains provisions for water quality in the Great Lakes. Section 118(c)(2) requires EPA to "specify numerical limits on pollutants in ambient Great Lakes waters to protect human health, aquatic life and wildlife". It also states that EPA shall "provide guidance to the Great Lakes States on minimum water quality standards, antidegradation policies, and implementation procedures for the Great Lakes System."

On October 4, 1999, EPA issued a proposed rule to prohibit mixing zones for bioaccumulative chemicals of concern in the Great Lakes (64 FR 53632). This proposed rule is similar to that proposed on March 23, 1995, as part of the Great Lakes Water Quality Guidance (required under CWA Section 118(c)(2)). A mixing zone is an area beyond the outfall of a point source discharge where ambient water quality may exceed otherwise applicable concentrations of a given pollutant. In effect, the receiving water dilutes the effluent before it reaches the boundary of the mixing zone. A bioaccumulative chemical of concern is defined as "any chemical that (1) accumulates in aquatic organisms by a human health bioaccumulation factor greater than 1,000 (after considering various specified factors), and (2) has the potential upon entering the surface waters to cause adverse effects, either by itself or in the form of its toxic transformation product, as a result of that accumulation" (40 CFR 132.2).

Section 304(a)(1) requires EPA to develop (and to periodically revise as necessary) aquatic life criteria to provide guidance in setting water quality standards. These criteria developed pursuant to Section 304(a) do not take into consideration any economic impacts or technological feasibility; only data and scientific judgment are used to develop the criteria. On October 29, 1999, EPA issued a Notice of Intent to revise aquatic life criteria for several chemical substances and to develop aquatic life criteria for several additional chemical substances.

A.1.3 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)

The Comprehensive Environmental Response, Compensation, and Liability Act (42 USC 9601 *et seq*), commonly referred to as Superfund, was enacted in 1980 following the discovery of the Love Canal hazardous waste site and the attempts to recover cleanup costs from liable parties, bringing to the forefront the issue of hazardous chemicals and the related disposal sites. It creates a federal Superfund to clean up uncontrolled or abandoned hazardous waste sites as well as accidents, spills and other emergency releases of pollutants. In EPA Region 5, CERCLA is administered by the Superfund Division.

Section 102(a) of CERCLA contains an extensive list of hazardous substances that are subject to release reporting regulations. (The list and the corresponding reporting quantities can be found at 40 CFR 302.4. In addition, certain unlisted substances may be subject to reporting regulations. Any substance which is a solid waste, as defined at 40 CFR 261.2, and not excluded from regulation as hazardous wastes by 40 CFR 261.4(b) is a hazardous substance under Section 101(14) of CERCLA if it exhibits any of the characteristics found at 40 CFR 261.20-261.24. All unlisted hazardous substances have reporting quantities of 100 lbs unless they exhibit extraction procedure (EP) toxicity identified in 40 CFR 261.24. These reporting quantities apply to the entire quantity of waste, not just the toxic contaminant (See 40 CFR 302.5(b)).

The National Response Center (NRC) must be notified immediately by the person in charge of a vessel or facility when there is a release to any environmental media of a designated hazardous substance exceeding the predefined reportable quantity within any 24 hour period. The reporting quantities are determined on the basis of aquatic toxicity, acute mammalian toxicity, ignitability, reactivity, chronic toxicity, and carcinogenicity, with possible adjustments based upon biodegradation, hydrolysis, and photolysis. The National Contingency Plan (which was originally developed in 1968 to respond to offshore oil spills following the Torrey Canyon tanker accident in the English Channel) was revised to provide guidelines and procedures needed to respond to releases or threatened releases of hazardous substances, pollutants, or contaminants.

A.1.4 FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA)

The Federal Insecticide, Fungicide, and Rodenticide Act (7 USC 136 *et seq*) was originally passed by Congress in 1947 as a consumer protection statute focused on the registration and labeling of pesticides. FIFRA now also regulates the sale, distribution, use, and cancellation of pesticides within the United States. Under FIFRA, EPA has the authority to study the consequences of pesticide use and to require users to register when purchasing pesticides.

In 1988, Congress amended FIFRA to strengthen and accelerate EPA's re-registration program, commonly called "FIFRA 88." The re-registration requirements apply to all registered pesticide products containing an active ingredient initially registered before November 1, 1984. List A consists of 194 chemical cases (350 individual active ingredients) subject to the amendments. Any pesticide that is no longer an active ingredient in any registered pesticide is considered by EPA to be "canceled." LaMP chemicals considered to be canceled include dieldrin, aldrin, DDT (with limited exceptions), HCB, toxaphene, chlordane, and DDD.

Pesticide producers may voluntarily cancel their pesticide registrations. In addition, EPA may cancel the registration of a pesticide based on several criteria, including the following: (1) the registrant failed to pay the required fees; (2) the registrant failed to make or meet certain re-registration commitments; or (3) EPA determines that the pesticide causes an unreasonable adverse effect on the environment. The United States currently has no legislative authority to prohibit the production or export of a canceled pesticide, but such products are subject to export notification requirements under FIFRA. The Great Lakes states all have cooperative agreements with EPA to implement FIFRA within the states.

A.1.5 OCCUPATIONAL SAFETY AND HEALTH ACT (OSHA)

The Occupational Safety and Health Act (29 USC 651 *et seq*) was enacted in 1970 to ensure the safety of workers and the workplace. In addition, it created the National Institute for Occupational Safety and Health (NIOSH) to establish standards for workplace safety and health as a research arm of the Occupational Safety and Health Administration. OSHA is a division of the Department of Labor and administers and enforces workplace standards in all states.

A.1.6 RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

The Resource Conservation and Recovery Act (42 USC 6901 *et seq*), which was enacted in 1976, establishes a regulatory structure, called "cradle to grave," for the handling, storage, treatment, and disposal of solid and hazardous wastes. The hazardous waste management program established under Subtitle C regulates hazardous wastes from the point of generation up to and including disposal, focusing on active and future facilities. Many products and materials are regulated under RCRA, including commercial chemical products; manufactured chemical intermediates; off-specification commercial chemical products or manufactured chemical intermediates; residue, contaminated soil, water, or other debris resulting from the cleanup of a spill into water or on dry land; and the containers and inner liners of the containers used to hold waste or residue.

Under RCRA, wastes are classified as hazardous if they are included on any of the RCRA lists (F, K, P, or U) or if they exhibit any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity. The lists may be found at 40 CFR 261.30-33. Chemicals on the P list are identified as acute hazardous wastes, and those on the U list are designated toxic wastes. All listed chemicals must be managed in accordance with federal and state hazardous waste regulations.

In 1984, the Federal Hazardous and Solid Waste Amendments (HSWA) required the phasing out of land disposal for hazardous wastes. The corrective action program mandated by the HSWA enables the regulatory agencies to also require remediation of legacy problems at RCRA treatment, storage and disposal facilities.

A.1.7 SAFE DRINKING WATER ACT (SDWA)

The Safe Drinking Water Act of 1974 (42 USC 300f *et seq*) was passed to protect human health from contaminated sources of drinking water and to prevent contamination of existing clean water supplies. Pursuant to the SDWA, EPA determined safe levels of chemicals occurring in drinking water that do or may cause health problems. These enforceable levels are called Maximum Contaminant Levels (MCL) and represent the maximum permissible level of a contaminant in public drinking water systems. MCLs are based on health factors, but are required to reflect technological and economic feasibility of removing the contaminant from the water system. All owners and operators of public water systems must meet these health-related standards. In addition, EPA has established unenforceable MCL goals (MCLG).

EPA may delegate implementation of the SDWA requirements to the states. While EPA enforces primary (health-related) standards, the states generally encourage public water systems to meet secondary (nuisance-related) standards.

A.1.8 SUPERFUND AMENDMENT AND REAUTHORIZATION ACT (SARA)/ EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT (EPCRA)

The Superfund Amendments and Reauthorization Act of 1986 (42 USC 9601 *et seq*) was intended to clarify and strengthen CERCLA. SARA required that all Superfund remedial actions take into consideration state and federal standards and regulations. It provided increased focus on human health problems associated with or posed by hazardous waste sites and encouraged greater state and private citizen participation. In addition, SARA revised the Hazard Ranking System to ensure that it accurately assessed the relative degree of risk to human health and the environment posed by the uncontrolled hazardous waste sites that may be placed on the National Priority List.

Title III of SARA (42 USC 11001 *et seq*) was enacted to help local communities protect public health, safety, and the environment from chemical hazards. It requires that releases of specified chemicals to the air, water, or land be reported to the Toxic Release Inventory (TRI). These requirements apply to specified manufacturing facilities (SIC codes 20-39, plus other specific facilities) that have 10 or more full-time employees and manufacture or process 25,000 pounds of a listed chemical or otherwise use 10,000 pounds of a listed chemical. Each listed chemical has established reporting thresholds, requiring that releases over a certain quantity to be reported; these reporting quantities are found at 40 CFR Part 372. On October 29, 1999, EPA issued a final rule lowering the reporting thresholds for 18 persistent bioaccumulative toxic substances and adding dioxin and dioxin-like compounds to the list with a mandated reporting threshold (64 FR 58665). EPA compiles and provides public access to the annual emissions data.

In order to implement these regulations, each state is required to appoint a State Emergency Response Commission, which is required to divide the state into Emergency Planning Districts. Each Emergency Planning District is to have a Local Emergency Planning Committee.

Emergency planning is required when substances designated as “Extremely Hazardous Substances” (EHS) are present in quantities exceeding Threshold Planning Quantities (TPQ). TPQs are determined by a combination of acute toxicity characteristics and the ability of the substance to become airborne. Facilities with listed EHSs in quantities greater than the TPQ must report to the State Emergency

Response Commission (EPCRA Section 302, 40 CFR Part 355). The list of EHSs and their corresponding TPQs is found at 40 CFR Part 355, Appendix A.

A.1.9 TOXIC SUBSTANCES CONTROL ACT (TSCA)

The Toxic Substances Control Act (15 USC 2601 *et seq.*) was enacted in 1976 to give EPA the authority to track chemicals produced in or imported into the United States. EPA tracks the thousands of new chemicals developed each year and repeatedly screens all chemicals. EPA can (1) require reporting or testing of chemicals that may pose environmental risks or human health hazards and (2) ban the manufacture or importation of any chemicals that may pose unreasonable risks. TSCA supplements the Clean Air Act and TRI under EPCRA.

In addition, TSCA regulations in the U.S. (40 CFR Part 761) dictate restrictions on the manufacture, sale, use, disposal, import and export of PCBs. TSCA also includes provisions for allowable uses of PCBs.

Additional information can be found at http://www.great.lakes.net/law/lawpolicy.html.

A.2 PROGRAMS

A.2.1 BINATIONAL TOXICS STRATEGY

The Binational Toxics Strategy (BNS) challenges the United States to reduce releases to the Great Lakes of identified chemical sources resulting from human activities by 2006. It establishes processes for involving stakeholders and chemical-specific workgroups. An additional challenge of the BNS is assessing atmospheric inputs of the identified substances and, if long range sources are confirmed, working within international frameworks to reduce such releases.

A.2.2 CONTAMINATED SEDIMENT MANAGEMENT STRATEGY (EPA)

The Contaminated Sediment Management Strategy promotes the consideration and reduction of ecological and human health risks posed by sediment contamination through cross-program coordination and a watershed approach. The goal is to remediate contaminated sediments and to prevent future contamination. Methods of remediation and prevention include source control and pollution prevention.

A.2.3 CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION (United Nations Economic Commission for Europe)

The Long Range Transboundary Air Pollution (LRTAP) Protocol of 1998 establishes a framework for controlling, reducing, and eliminating discharges, emissions, and losses of persistent organic pollutants worldwide.

A.2.4 GREAT WATERS PROGRAM

Section 112(m) of the 1990 CAA Amendments establishes research, reporting, and potential regulatory requirements related to atmospheric deposition of HAPs to the “Great Waters” of the United States (including the Great Lakes). This program is intended to coordinate the various activities implementing these requirements.

A.2.5 INTEGRATED ATMOSPHERIC DEPOSITION NETWORK

The Integrated Atmospheric Deposition Network (IADN) is a joint U.S.-Canada monitoring network established to address issues concerning airborne contaminants in the Great Lakes basin. It monitors specific airborne pollutants to assess the magnitude and trends of atmospheric deposition of those substances to the Great Lakes. In addition, sources of those pollutants are to be identified where possible.

A.2.6 INTEGRATED URBAN AIR TOXICS STRATEGY (EPA)

The Integrated Urban Air Toxics Strategy identifies 33 airborne toxics that present the greatest threat to human health in the greatest number of urban areas. Key components of the strategy are (1) regulations to address sources at both national and local levels; (2) initiatives to identify and address specific community risks; (3) air toxics assessments to identify areas of concern, prioritize efforts to reduce risks, and track progress; and (4) public education and outreach efforts that also seek input for program design and implementation.

Episodic Events - Great Lakes Experiment (EEGLE)

The purpose of the Episodic Events - Great Lakes Experiment is to create an integrated observational program and numerical modeling effort to identify, quantify, and develop prediction tools for the winter-spring resuspension event and to assess the impact of this event on the transport and transformation of BIMS and on lake ecology. Three fundamental hypotheses focus this program:

1. that the plume is a result of the first winter-spring storm after ice-out and represents the resuspension of particulate materials (and associated constituents) that have been stored in the lake as surface sediment “floc” for a distribution of times, during which they have undergone differential diagenesis,
2. that the forced, two-gyre vorticity wave response of the lake to episodic wind events, occasionally modified by stratification, is a major mechanism for nearshore-offshore transport of particulate matter and associated constituents in the Great Lakes, and
3. that physical processes (e.g., resuspension, turbulence) associated with the plume event are important in determining the nutrient and light climate, and in structuring the biological communities throughout the spring isothermal period, and in setting the conditions for the critical ‘spring bloom’ period.

Recent satellite observations of suspended sedimentary material in Lake Michigan illustrate a unique opportunity to investigate an annually recurrent major episode of nearshore-offshore transport: 10 km wide plume of resuspended material extending over 200 km along the southern shores of the lake. The plume appears to be initiated by a major late winter storm after the melting of surface ice, and it eventually veers offshore along the eastern shore of the lake, coincident with the area of highest measured sediment accumulation in the lake. The inventory of particulate matter in the plume, dated April 2, 1996, is approximately equal to the total annual load of fine sediments into the southern basin. Preliminary evidence indicates that this episodic event may be the major mechanism for cross-margin sediment transport in Lake Michigan. This type of event is ideal for studying internal recycling of biochemically important materials (BIMS), ecosystem responses, and one of the major processes controlling cross-isobath transport in the Great Lakes.

The episodic resuspension and subsequent transport of surface sediments profoundly influences biogeochemical processes in coastal ecosystems. Resuspension and transport of the large inventories of nutrients and contaminants deposited over the past few decades (e.g., P, Cs ^{137}, PCBs), presently results in much greater fluxes to the water column than from all external inputs. In addition, control of biological processes can occur as a result of effects on light and substrate availability and the introduction of meroplanktonic species. The magnitude and episodic nature of these processes in the Great Lakes has been poorly described from a few point measurements or as the residual term in mass balance models. This multi-disciplinary project will employ a comprehensive measurement and modeling approach to examine and compare effects of episodic physical forcing in relation to more persistent long-term (ie., seasonal meteorological) forcing on nutrient inventories, fluxes, and distributions, and on biological distributions and rate processes.

A.2.7 LAKEWIDE MANAGEMENT PLANS

Annex 2 of the 1987 Amendments to the Great Lakes Water Quality Agreement committed the United States and Canada to developing Lakewide Management Plans (LaMP) for each of the five Great Lakes. Each LaMP is intended to assess critical pollutants as they relate to the impairment of beneficial uses and to develop methods for restoring those impaired uses. The requirement for LaMPs has been codified at Section 118(c)(4) of the CWA.

A.2.8 LEVEL 1 PESTICIDES ACTION PLAN

EPA is currently developing a Level 1 Pesticides Action Plan (pursuant to the BNS). This Plan will address aldrin/dieldrin, chlordane, DDT, and toxaphene, among other pesticides.

A.2.9 MULTIMEDIA STRATEGY FOR PRIORITY PERSISTENT, BIOACCUMULATIVE, AND TOXIC POLLUTANTS (EPA)

The Priority Persistent, Bioaccumulative, and Toxic (PBT) Pollutant Strategy (a draft of which was released in November 1998) builds upon the Binational Toxics Strategy, seeking reductions from such substances at a national level. Additional substances may also be added. The goal is to address cross-media issues associated with PBT pollutants, going beyond the single statute approach, to further reduce risks to human health and the environment from existing and future exposure to priority PBT pollutants. EPA will coordinate the use of its statutory authorities and resources to maximize public health and environmental protection. In addition, EPA will promote stronger multimedia coordination among national and regional EPA programs.

A.2.10 PESTICIDE CLEAN SWEEPS

Pesticide Clean Sweeps are state programs that provide a means of collecting and disposing of waste agricultural pesticides. Unused stocks of many canceled pesticides have been collected in these Clean Sweeps.

A.2.11 REMEDIAL ACTION PLANS

The 1987 Amendments to the Great Lakes Water Quality Agreement contained provisions for Remedial Actions Plans (RAP) to restore beneficial uses to 43 specified Areas of Concern throughout the Great Lakes. These RAPs are designed to incorporate an ecosystem approach to addressing critical pollutants and restoring beneficial uses. The mandate and requirements for developing RAPs are codified at Section 118(c)(3) of the CWA.

A.2.12 BEACH MONITORING

EPA has a web site for up-to-date information about water quality and beach closings at more than 1,000 beaches nationwide, including Chicago, Milwaukee, southwest Michigan, and Indiana Dunes. The information is available at http://www.epa.gov/ost/beaches (EPA 1998(h)). In 1995, 28 of the more than 200 Lake Michigan beaches being monitored were temporarily closed because of poor water quality. Indiana tests waters near beaches on a weekly basis using an EPA-recommended standard for *E. coli* (MDNR 1998a).

A.2.13 HEALTHY BEACHES INITIATIVE

The Healthy Beaches Initiative is a collaborative effort among several agencies seeking to protect the health of the Indiana shoreline of Lake Michigan. This organization is especially concerned about sporadic, unpredictable, high levels of bacteria in the nearshore waters in northern Indiana (MDNR 1998a).

A.2.14 *E. COLI* INTERAGENCY TASK FORCE

In response to bacterial contamination of Indiana beaches in 1996, 18 local, state, and federal agencies formed the *E.coli* Interagency Task Force to share information and address bacterial contamination along Lake Michigan. The Illinois-Indiana Sea Grant Program invested about $80,000 in research to differentiate human waste from animal waste by assessing the presence of a virus and bacteria in the waste. Being able to differentiate the wastes will indicate the source of pollution. This group is also looking at bifidobacteria and poliovirus, both indicators of human fecal pollution. Poliovirus in associated with waste from newly immunized humans (Ting and others 1996).

A.2.15 AQUATIC NUISANCES

A.2.15.1 Current Programs and Information Gathering Efforts

The control of aquatic nuisance species (ANS) has global implications and requires policies and programs at various levels of government. This section provides a brief overview of the role of major programs and responsible agencies addressing ANS. For a more detailed explanation of the responsibilities of each agency, see the *Briefing Paper for Great Lakes Nonindigenous Invasive Species Workshop*.

- **Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA)**

  The NANPCA provides U.S. federal legislative support for programs aimed at ANS prevention and control. The Act was drafted by Congress in recognition of the fact that the ANS threat required well coordinated research, monitoring, and prevention programs at both the regional and national levels. Under the NANPCA, the Great Lakes became the first area where ballast water regulations were imposed.

- **Aquatic Nuisance Species Task Force (ANS Task Force)**

  The ANS Task Force was established under Section 1201 of the 1990 NANPCA legislation and is an intergovernmental organization, made up of representatives from seven federal agencies. This task force is dedicated to the prevention and control of ANS and the implementation of the NANPCA. The main action of the ANS Task Force is the adoption of the cooperative ANS Program. The ANS Program seeks to prevent, detect, monitor, and control ANS.

- **National Invasive Species Act of 1996 (NISA)**

  NANPCA was reauthorized through the National Invasive Species Act of 1996 (NISA). NISA expands the ballast management program to the national level and enhances other national monitoring, management and control programs.

- **Executive Order on Invasive Species**

  President Clinton signed the Invasive Species Executive Order on Feb. 3, 1999, to help complement and build on existing federal authority to aid in the prevention and control of invasive species. President Clinton also proposed $28.8 million in support in the FY2000 budget. The Great Lakes region welcomes the attention the Executive Order has drawn to the effects of ANS on the region.

- **Great Lakes Panel on Aquatic Nuisance Species**

  Under NANPCA, the ANS Task Force requested that the Great Lakes Commission convene the Great Lakes Panel on ANS in accordance with Section 1203 of the Act. The Great Lakes Panel also works for the prevention and control of ANS in the Great Lakes and is made up of representatives from the United States and Canada, as well as the eight Great Lakes states, Ontario, Quebec, and various regional and local agencies.

- **Comprehensive State Management Plans**

  Comprehensive State Management Plans are suggested for states seeking grants for ANS prevention and control under Section 1204 of NANPCA. Comprehensive State Management Plans are developed to identify management practices and measures for the prevention and control of ANS infestations in an environmentally sound manner. State management plans are submitted to the ANS Task Force for approval. Upon approval, states are eligible for grant money upon the recommendation of the Task Force. Thus far, plans have been approved for the Great Lakes states of New York, Michigan, and Ohio and for the St. Croix River Basin.

- **Great Lakes Action Plan for the Prevention and Control of Aquatic Nuisance Species**

  The *Great Lakes Action Plan for the Prevention and Control of Aquatic Nuisance Species* is an attempt to establish a formal policy agreement that articulates a vision for the Great Lakes Basin. The Action Plan is a good faith agreement among its signatories, whose goal is the interjurisdictional cooperation and coordination of ANS prevention and control efforts.

- **Educational Outreach**

  Various educational and outreach measures have been implemented to help raise public awareness of the threat posed by ANS. The state of Minnesota, in particular, has placed an emphasis on educating the public about the impacts of invasive species. The Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency provide literature to the public to help them identify ANS, suggest ways to stop the spread of ANS, and provide information about laws pertaining to ANS, especially through the transport of prohibited species and infested water from one body of water to another.

The Minnesota Sea Grant Program is also active in educating the public about the impacts of ANS on the Minnesota ecosystem. The Sea Grant Program offers an even wider array of literature describing the threat of ANS. This educational material includes identification cards for various species; the cards include a detailed picture and description of the species, the areas the species are restricted to, what to do and who to contact if a specimen is found outside the listed area, and practices for reducing ANS transport between bodies of water. Other contributions from the Sea Grant Program include Traveling Trunks, Field Guides to ANS, and training packages providing details of individual ANS. A Three State Exotic Species Boater Survey, conducted in part by funding from the Minnesota Sea Grant Program, found that Minnesota put forth a substantial effort in getting out the message about ANS in an attempt to change boater behavior. Examples of such efforts in Minnesota include civil penalties for transporting ANS, road checks for the enforcement of regulations, and inspection or education programs at boat accesses to infested waters. In addition, ANS messages have been presented on billboards, the cover of the fishing regulations pamphlet, via the media, at conferences and workshops, at boat and sports shows, in fact sheets and brochures, and in educational packages distributed to lake and fishing associations.

Other programs in the Great Lakes area directed at educating the public about nonindigenous species and ANS include the following:

- National ANS Clearinghouse
- The Sea Grant Nonindigenous Species Site (SGNIS)
- The National Zebra Mussel Training Initiative
- National Sea Grant College Program
- Exotic Aquatics and Zebra Mussel Mania Traveling Trunk Program
- Citizen Monitoring Program
- Purple Loosestrife Project
- Exotic Species Day Camp for Educators

- Detection and Monitoring Efforts

  Detection and monitoring is also an important component of an ANS program. A need exists for a monitoring program that can act as an early warning device to facilitate prevention of other ANS poised to enter the Great Lakes ecosystem. Currently, the U.S. Fish and Wildlife Service maintains a surveillance program for monitoring the spread of ruffe and round goby. An important part of this program is public education. All new reports of ruffe and round goby are maintained in a national database by the U.S. Geological Survey's Alpena Fishery Resource Office. The Michigan Department of Natural Resources monitors Lake Huron fish stocks through two Great Lakes Research Stations on Lake Huron. At these stations, measured changes in fish stocks due to harmful invaders and other external sources are monitored, especially the progress of sea lamprey control assessed using lake trout wounding rates and recovery of lake trout stocks.

Lake Superior currently has several ruffe monitoring programs. The U.S. Fish and Wildlife Service has had ruffe populations under surveillance since 1992. Under this program, likely locations of ruffe populations are looked at; the range of ruffe is then monitored; and the status of peripheral populations is investigated. The Lake Superior Biological Station is also monitoring ruffe populations in the St. Louis River while the U.S. Fish and Wildlife Service has been observing changes in ruffe populations and those of associated fish communities since 1995.

Additional or expanded monitoring efforts are needed to help reduce the threat of future infestations by nonindigenous species.

A.2.15.2 Prevention and Control Efforts

The primary goal of all of the agencies and programs discussed above has been described as prevention and control, specifically, preventing further infestation by ANS and controlling existing ANS so that they do not continue to infest other lakes or waterways.

Prevention Activities

The primary focus of prevention efforts has been ballast water management, including a national ballast management program under NISA. The issue of ballast water in the introduction of nonindigenous species into the Great Lakes ecosystem is discussed in detail below.

All cargo ships contain huge ballast tanks. These tanks are filled in port to help steady ships as they travel, and they are emptied once cargo is loaded. Each tank can hold millions of gallons of water, which can contain any and all of the aquatic life found in port waters and sediments; everything from bacteria and algae to worms and fish have been found in ballast water. All ships traveling into the Great Lakes are required to exchange ballast water in the open ocean prior to entry. However, despite the mandatory emptying of ballast tanks, organisms may establish permanent or semi-permanent communities in the layer of water and sediment that often remains at the bottom of the tanks. In these situations, adult organisms may reproduce and release larvae into ballast water, for eventual release in port, while adults remain in the sediment to reproduce further. In order to stop these harmful discharges, ships must takes steps to avoid taking organisms into ballast tanks, to kill organisms during the voyage, or to avoid discharging organisms when ballast water is released (MIT 1999). To test for compliance with ballast water exchange requirements, the Coast Guard has the authority to randomly sample ballast water for salinity, which is subsequently compared with the salinity standard. The Coast Guard recognizes that salinity cannot be used as the only verification of open ocean exchange at a coastal port.

While adequate under many circumstances, ballast exchange poses safety, effectiveness, and accountability concerns that limit its scope and usefulness. The practice has particularly limited utility in the Great Lakes where most transoceanic vessels enter the system fully loaded with cargo and report no ballast on board (NOBOB). They nonetheless transport organisms into the Great Lakes system in the residual water and sediment in the “empty” ballast tanks. A tool box full of alternative prevention technologies and practices is needed to address the range of vessel types and voyage patterns of today's waterborne transportation. In the long term, these tools may be solutions such as a combination of microfiltration and ultraviolet light treatments, which can be installed or designed into vessels. Technologies such as these could more reliably resolve problems associated with fully loaded vessels (NOBOB vessels).

In an interim rule on implementation of NISA, which became effective July 1, 1999, the Coast Guard presented its position on NOBOB vessels. “A vessel with NOBOB may not have a large quantity of ballast water on board, but the vessel does retain sediment and residual ballast water. The Coast Guard requests in this regulation that all vessels remove sediments in an appropriate manner on a regular basis. We are working on identifying possible management methods to reduce the threat of a vessel operator claiming NOBOB. However, it would be premature to issue regulations specifically for these vessels at this time. To ask a vessel operator in a NOBOB status to conduct a ballast water exchange could destabilize a vessel, causing it to submerge its load line or compromise seaworthiness by exceeding hull girder stress limits, or increase the stresses on the hull to the point they fracture” (Coast Guard 1999).

Alternatives to ballast exchange as a means of control of organisms inhabiting ballast water include filtration, ultraviolet light, acoustics, salinity, heat, chemical biocides, sedimentation, pH treatment, oxygen deprivation, and discharge to reception vessels (Reeves 1996). Despite the available prevention technologies, it is unlikely such solutions will be implemented by the shipping industry without incentives or regulations. The Canadian Coast Guard has expressed a need for biological standards for ballast tanks. Without such a restriction, the Canadian Coast Guard does not foresee voluntary implementation of new technologies for ballast water treatment. This is a forward-looking initiative that will require participation of both the shipping industry and the ballast water management programs.

NISA Section 151.2035(b)(2) states that retaining ballast water on board is an option, and Section 151.2035(b)(4) states that discharging ballast water to an approved reception facility is another option. In order for the Coast Guard to approve a method alternative to ballast exchange, it must consider whether the method conforms to existing laws and standards, how effective the method is in reducing the viability of organisms within the vessel's ballast water, and how the vessel operator will verify that the system is operating as designed (Coast Guard 1999)

There are penalties for failing to comply with the Great Lakes ballast water provisions of NISA, including restriction of operation, revocation of Customs clearance, and possible civil and criminal penalties.

Other prevention programs in the Great Lakes include the following:

- Quick-response teams have been proposed that could be dispatched to an area where a newly introduced species has been reported. The team would try to prevent the spread of the species beyond the introduction point. At this time, planning of such a team has only been discussed, but is still viewed as an option for future consideration.

Control Activities

ANS can be controlled by several general methods, including chemical, biological, mechanical or physical, and habitat management practices. While each of these methods may provide effective control, each has disadvantages as well. The use of chemicals raises concerns about environmental safety and long-term impacts. Identification and screening of biological control agents invariably takes many years, and improperly screened biological control agents have themselves become nuisance species in the past. Mechanical or physical controls are often very expensive. No single method is likely to provide the necessary control of nonindigenous species. Hence, a comprehensive control strategy involving a combination of techniques is often necessary for an effective control program.

Various control mechanisms are currently being implemented in the Great Lakes. To help control the expansion of the goby into other waterways, river barrier systems are being implemented, along with public education programs. Unfortunately, no effective measures have been found to date to decrease established populations of gobies. The ruffe is the subject of the first control program developed under the “Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990.” The control program was implemented in 1992 and has successfully delayed the spread of ruffe through the Great Lake and inland waters. This success was obtained largely through the campaign to stop the transportation of the ruffe, both intentionally and unintentionally, between bodies of water, particularly by controlling the transport of ruffe in ballast water carried out of Lake Superior. The control of ruffe has been given a great amount of attention because if they do spread, ruffe will pose a threat to fisheries and aquatic ecosystems throughout much of eastern North America.

The sea lamprey has cost millions of dollars in losses to fisheries and in costs of control, in addition to the depletion or extirpation of lake trout stocks. In 1956, a joint program between the United States and Canadian governments was implemented to address the harmful impacts of the sea lamprey. The Great Lakes Fishery Commission (GLFC) was created by the *Convention on Great Lakes Fisheries* between the United States and Canada in 1955, and control of sea lampreys within the Great Lakes basin was one of the Commission’s principal responsibilities. The GLFC implemented sea lamprey control on the basis of an agreement between the United States and Canada decided on at the convention. The result was the development and application of an environmentally acceptable lampricide for use in controlling lamprey populations. Other mechanisms of control being used include mechanical and electrical barriers, and the experimental sterile-male-release technique. These methods have achieved some success in controlling sea lamprey populations in the Great Lakes. Populations of sea lampreys in Lake Superior have been reduced to 10 percent of their former abundance, and the lake trout, their major prey, have recovered to self-sustaining populations in several areas. In other areas, lamprey predation continues to be the limiting factor to recovery of lake trout.

While current activities have been moderately successful at preventing and controlling the effects of ANS, continued regulatory efforts and education programs are needed to help reduce the threat these species pose to the Great Lakes.

A.3 REGULATIONS

A.3.1 PCBs

In 1976, Congress charged EPA with responsibility for regulating the manufacturing, processing, distribution in commerce, and use of polychlorinated biphenyls (PCB). EPA issued the first set of regulations in 1977. Subsequently, Section 6(e)(3)(A) of the Toxic Substances Control Act (TSCA) (Pub. L. 94-969, 90 stat. 2003, 15 USC 2601 et. seq.) prohibited all manufacture and importation of PCBs after January 1, 1979. Currently, under TSCA regulations, the discharge of PCB-containing effluents and the production of PCBs in the United States is prohibited; disposal of materials contaminated by PCBs is regulated; as is the use of all PCB-containing materials still in service.

PCBs are regulated to some extent under the Clean Air Act, the CWA[1], the Safe Drinking Water Act, the Resource Conservation and Recovery Act, and the Comprehensive Environmental Response, Compensation, and Liability Act. However, TSCA Section 6(e) [15 USC 2605(e)] provides the primary regulatory framework for controlling how PCBs may be used, processed, distributed, manufactured, or exported or imported (40 CFR 761). In addition, TSCA specifies storage and disposal requirements and recordkeeping and reporting requirements. Under TSCA Section 6(e), all PCB uses or activities are banned unless they fit into one of the following categories: (1) totally enclosed systems, so as to ensure no significant exposure to human beings or the environment; (2) non-enclosed authorized uses listed at 40 CFR 761.30; or (3) exemptions as obtained via petition (for example, research uses). No authorized exemptions are required for (1) most products containing less than 50 parts per million (ppm) PCBs, or (2) certain inadvertent generation (as specifically defined) or for PCBs in certain recycled materials.

The disposal of PCBs is tightly regulated. Specifically, PCB waste must only be disposed of in facilities that are approved by EPA such as an incinerator with a PCB and removal destruction efficiency of 99.9999% or a landfill with adequate liners and leachate collection. Oils or metals contaminated with PCBs at less than 500 ppm can also be disposed of in boilers, furnaces, and smelters (these units must meet specific design and operating requirements), or in facilities which follow specific procedures to decontaminate the materials.

TSCA regulations require specific disposal methods that vary by the type and concentration of PCB items. In the U.S., the pollutant form determines the type of disposal options available. These options include:

- incineration in a regulated PCB incinerator
- disposal at a licensed chemical waste landfill
- disposal in a high efficiency boiler
- alternative disposal methods subject to EPA approval
- disposal as municipal solid waste
- decontamination
- unregulated disposal

EPA has approved several different methods for PCB disposal. Several PCB disposal companies operate a variety of commercially permitted disposal facilities throughout the U.S. and Canada. These companies offer PCB disposal related services that include the following:

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[1] CWA Sections 307(a) and 311(b)(4) are the statutory sources for designation of PCBs as CERCLA hazardous wastes.

- incineration
- alternative thermal treatment
- chemical treatment
- physical separation
- pipeline removal
- PCB transformer decommissioning (disassembly/smelting)
- chemical waste landfills
- biological treatment

In addition to these approved facilities, some PCB waste may be disposed of in facilities which do not have a specific EPA permit such as a state approved municipal or non-municipal non-hazardous landfill or facility. EPA regulations impose a one year time limit on PCB items placed in storage for disposal and certain limitations on storage of PCBs intended to be reused.

PCB releases must be reported in the Toxic Release Inventory (TRI). On October 29, 1999, EPA issued a final rule effective December 31, 1999, which reduces the TRI reporting thresholds for PCB releases to 10 pounds per year (64 FR 58665; 40 CFR Part 372).

Table A-1. Management of PCBs in the Lake Michigan Basin

PCBs						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act**: Section 112(b) hazardous air pollutant; NESHAPS/ MACT Standards (40 CFR Parts 61 and 63)	**TSCA**: Use, disposal, labeling, and management regulations (40 CFR Part 761); land disposal restrictions	**SDWA:** MCL = 0.0005 mg/L; MCLG = 0 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)	No action level established under FDA	**TSCA**: Use, disposal, and management regulations (40 CFR Part 761)	**SARA Section 313**: PCB transfers and releases reported to TRI by qualifying facilities (40 CFR 372.65); reporting threshold > 10 lbs per year (64 FR 58665, 40 CFR Part 372) **CERCLA Section 103**: PCB reporting requirements for spills >1 lb (40 CFR Part 302.4)
Policy and Programs (nonregulatory actions)	- PCB Phasedown Program: Aims to obtain reduction commitments from PCB containing electrical equipment in EPA Region 5 - Remedial Action Plans - U.S. Automobile Pollution Prevention Project: Aims to reduce PCBs and Mercury from the automotive manufacturing sector - PCB Clean Sweeps: Collects PCB-contaminated material in the Great Lakes region - BNS Level 1 substance - PCB Action Plan: Currently being developed by EPA					

A.3.2 DIOXINS AND FURANS

Dioxins and furans are included on the list of 189 HAPs under Section 112(b) of the Clean Air Act.[2] Several categories and subcategories of facilities have been identified for regulation pursuant to Section 112. Many facilities are subject to dioxin effluent limits or monitoring requirements in their NPDES permits. Limits for water discharges are based on the use of Best Available Technology economically achievable (BAT) for specific point sources.

The 1998 Final Pulp, Paper, and Paperboard "Cluster Rule" (63 FR 18504) sets new baseline limits for releases of toxics and nonconventional pollutants, including dioxins and furans, to air and water. NESHAPS require sources within the pulp and paper category to control dioxins using Maximum Achievable Control Technology (MACT), specifically emissions that occur during the pulping and bleaching processes. Water effluent limitations (under NPDES) and pretreatment standards require facilities within the Bleached Papergrade Kraft and Soda subcategory and the Papergrade Sulfite subcategory to limit, based on BAT, dioxins in the wastewater discharged during the bleaching process and in the final discharge from the mills. EPA projects that nationally, 155 of the 565 mills in the United States will be required to control toxic air pollutants and comply with MACT Standards, and that 96 of the 155 will additionally be subject to the effluent limitation guidelines and standards promulgated in the Pulp and Paper Cluster Rule (The Pulp and Paper Cluster Rule is under the statutory authority of section 112(b) of the Clean Air Act and Sections 304(b) and 307 of the CWA).

Dioxin- and furan-containing wastes and products are not RCRA-listed hazardous or toxic wastes. However, there are specific land disposal restrictions and treatment requirements for dioxin-containing wastes, in addition to wood preserving wastes (which often contain dioxins), under RCRA (40 CFR Part 268, Subpart C - Prohibitions on Land Disposal). RCRA also establishes a "Universal Treatment Standard" (40 CFR 268.48) for dioxin and furan levels in waste (wastewater and nonwastewater).

CERCLA Section 103(a) requires that any spills or releases of dioxin in quantities exceeding 1 pound must be reported immediately to the National Response Center (40 CFR 302.4).[3] There are also dioxin reporting and testing requirements for specific industries (such as designated chemical manufacturers) under TSCA Sections 4 and 8(e) (40 CFR Part 766). Dioxin releases were not previously required to be reported in the TRI. However, dioxin and dioxin-like compounds were added to the list of substances regulated under Title III, Section 313 of SARA when EPA published the final rule on October 29, 1999. This amended rule, which became effective on December 31, 1999, sets a 0.1 gram (g) reporting threshold for dioxin and dioxin-like compounds (64 FR 58665, 40 CFR Part 372).

[Sources: EPA website http://www.epa.gov/ and the Chem Alliance regulatory Handbook http://www.chemalliance.org/RegTools/handbook.htm]

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[2] Dioxin is included in the "List of High Risk Pollutants," 40 CFR Part 63, Table 1.

[3] RCRA Section 3001 is the statutory source for designation of furan as a CERCLA hazardous waste.

Table A-2. Management of Dioxins and Furans in the Lake Michigan Basin

Dioxins and Furans						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Section 112(b) hazardous air pollutant; NESHAPS / MACT Standards (40 CFR Parts 61 and 63) **Pulp and Paper Cluster Rule:** Pulp and paper mill emission standards (40 CFR Part 63, 40 CFR Part 261and 40 CFR Part 430)		**SDWA:** Dioxin MCL = 3E-08 mg/L; MCLG = 0 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant**;** Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403) **Pulp and Paper Cluster Rule:** Pulp and paper mill effluent standards (40 CFR Part 63, 40 CFR Part 261and 40 CFR Part 430)	No action level established under FFDCA	**RCRA:** Universal treatment standards for dioxin levels in waste (40 CFR 268.58); furan designated hazardous waste (waste no. U124)	**SARA Section 313:** Reporting threshold = 0.1 g for dioxin and dioxin-like compounds with certain limitations (64 FR 58665; 40 CFR Part 372) **CERCLA Section 103:** Reporting requirements for spills > 1 lb (40 CFR 302.4) Furan designated EHS with a TPQ of 500 lbs
Policy and Programs (nonregulatory actions)	- Remedial Action Plans - Vinyl Institute Dioxin Characterization Program: Quantify potential releases form ethylene dichloride, vinyl chloride monomer, and PVC manufacturing					

A.3.3 DIELDRIN/ALDRIN

The last remaining uses of aldrin and dieldrin have been canceled under FIFRA. Aldrin is no longer found as an active ingredient in any registered pesticides. EPA is currently developing a Pesticides Action Plan, to address dieldrin/aldrin.

Aldrin and dieldrin each have release reporting quantities under CERCLA of 1 pound.[4]

Any aldrin/dieldrin releases to any environmental media that occur as a result of manufacturing, processing, or otherwise using these substances must be reported in the TRI. Under amendments to 40 CFR Part 372 (the implementing regulations for SARA Section 313), reporting thresholds for aldrin releases have been lowered to 100 pounds per year (64 FR 58665 10/29/99). These changes became effective on December 31, 1999. In addition to TRI reporting requirements under EPCRA, Aldrin is listed as an Extremely Hazardous Substance (ENS), with a threshold planning quantity of 500/10,000 pounds (40 CFR Part 355, Appendix A).

Aldrin is also a listed hazardous waste under RCRA, Subtitle C hazardous waste management program (40 CFR 261.33). Pesticide-containing wastes (wastewater and nonwastewater) have land disposal restrictions, including Universal Treatment Standards for aldrin and dieldrin (40 CFR 268.48). Small quantities of dieldrin and aldrin may qualify for partial exclusion from hazardous waste regulations (40 CFR 261.5(e)).

[Sources: EPA website http://www.epa.gov/ and the Chem Alliance Regulatory Handbook http://www.chemalliance.org/RegTools/handbook.htm]

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[4] The statutory sources for listing both aldrin and dieldrin as CERCLA hazardous substances are Sections 307(a) and 311(b)(4) of the CWA and Section 3001 of RCRA.

Table A-3. Management of Dieldrin/Aldrin in the Lake Michigan Basin

Dieldrin						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Not targeted	**FIFRA:** Use and registration restrictions; all uses canceled (40 CFR Subchapter E and USC CH6)	**CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutants with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403) **State Drinking Water Stds:** Illinois 1 μg/L	**FDA:** FFDCA 0.03 ppm action level for fish tissue	**RCRA:** Designated hazardous wastes (aldrin waste no. P004; dieldrin waste no. P037); land disposal restrictions (40 CFR Part 268); groundwater monitoring requirements (40 CFR Part 264)	**SARA Section 313:** Releases reported to TRI by qualifying facilities (40 CFR 372.65); reporting threshold > 100 lbs per year (64 FR 58665; 40 CFR Part 372) **CERCLA Section 103:** Reporting requirements for spills > 1 lb (40 CFR 302.4)
Policy and Programs (nonregulatory actions)	- Superfund Program - Remedial Action Plans - Pesticides Clean Sweeps - BNS Level 1 substance - Level 1 Pesticides Action Plan: Currently being developed by EPA					

A.3.4 CHLORDANE

Chlordane is a member of the class of chlorinated organic pesticides. Regulatory actions related to chlordane use in agriculture began in 1978. All aboveground uses were halted in the United States by 1983. Between 1983 and 1988, the sole registered use of chlordane was for subterranean control of termites. By 1988, all commercial uses of chlordane were canceled. In 1995, Velsicol, the sole U.S. manufacturer, voluntarily canceled its export registration, and by 1997, Illinois completely stopped all production in the United States and abroad and exported all existing stocks (NARAP 1997a).

Chlordane is included in the CAA Title III list of 189 HAPs and will be subject to standards established under Section 112, including MACT standards (40 CFR Parts 61 and 63). It is included on the Clean Air Act "List of High Risk Pollutants" (40 CFR Part 63, Table 1). Chlordane is a designated priority pollutant under the CWA Section 307, and facilities are potentially subject to chlordane effluent limits on their NPDES permits.

Chlordane is listed as a hazardous waste under the RCRA, Subtitle C hazardous waste management program (40 CFR 261.33). Pesticide-containing wastes (wastewater and nonwastewater) have land disposal restrictions, including Universal Treatment Standard levels for chlordane (40 CFR 268.48).

Chlordane is subject to a 1 pound release reporting quantity under CERCLA.[5] Chlordane releases to any environmental media must also be reported in the TRI. Effective December 31, 1999, the TRI reporting thresholds for chlordane releases was lowered to 10 pounds per year (64 FR 58665, 40 CFR Part 372).

[Sources: EPA website http://www.epa.gov/ and the Chem Alliance regulatory Handbook, http://www.chemalliance.org/RegTools/handbook.htm]

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[5] Statutory sources for designation of chlordane as a CERCLA hazardous waste are Sections 307(a) and 311(b)(4) of the CWA and Section 3001 of RCRA.

Table A-4. Management of Chlordane in the Lake Michigan Basin

	Air	Soils / Sediments	Water	Biota	Waste	Reporting Requirements / Spills
Standards and Regulations	**Clean Air Act:** Section 112(b) hazardous air pollutant; NESHAPS/MACT Standards (40 CFR Parts 61 and 63); Designated high risk pollutant (40 CFR Part 63 Table 1)	**FIFRA:** Use and registration restrictions; all uses canceled (40 CFR Subchapter E and USC CH6)	**SDWA:** MCL = 0.002 mg/L; MCLG = 0 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)	**FDA:** FFDCA 0.03 ppm action level for fish tissue	**RCRA:** Designated hazardous waste (No. U036); land disposal restrictions (40 CFR Part 268); groundwater monitoring requirements (40 CFR Part 264)	SARA Section 313: Releases reported to TRI by qualifying facilities (40 CFR 372.65); reporting threshold > 10 lbs per year (64 FR 58665, 40 CFR Part 372); EHS with TPQ 1,000 lbs (40 CFR Part 355) CERCLA Section 103: Reporting requirements for spills > 1 lb (40 CFR 302.4)
Policy and Programs (nonregulatory actions)	- Remedial Action Plans - Clean Sweeps - Velsicol Chemical Corporation voluntary ceased production in 1997. - Council of Great Lakes Industry: Searching for information regarding the export, storage, and use as chemical intermediates of Level I pesticides - BNS Level 1 substance - Level 1 Pesticides Action Plan: Currently being developed by EPA					

A.3.5 DDT AND METABOLITES

DDT is a broad spectrum insecticide previously used on crops, grazing lands, forests, and urban areas to control insects that transmit diseases such as malaria and typhus. All non-health uses were canceled by 1973; the last remaining uses (public health use for control of vector-borne diseases, USDA or military use for health quarantine, and use in prescription drugs for control of body lice) were canceled by October 1989.

While there is no final CERCLA release reporting quantity for the generic class "DDT and metabolites," DDT, DDD, and DDE are all identified separately as CERCLA hazardous substances with reporting quantities of 1 lb each (40 CFR 302.4).[6] DDT and DDD are listed on the RCRA hazardous waste U List.

DDT and its metabolites are not targeted by the Clean Air Act but are subject to ambient water quality criteria, NPDES effluent limitations, and pretreatment standards under the CWA.

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[6] The statutory source for designating DDT and DDD as CERCLA hazardous substances are Sections 307(a) and 311(b)(4) of the CWA and Section 3001 of RCRA. The statutory source for designating DDE as a CERCLA hazardous substance is Section 307(a) of the CWA.

Table A-5. Management of DDT and Metabolites in the Lake Michigan Basin

DDT						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** DDE designated Section 112(b) hazardous air pollutant	**FIFRA:** Use and registration restrictions; all uses canceled (40 CFR Subchapter E and USC CH6)	**CWA:** Section 307(a)(1) toxic pollutants; Section 304(a) priority pollutants with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403) **State Drinking Water Standards:** Illinois = 50 μg/L	**FDA:** FFDCA 5 ppm action level for fish tissue	**RCRA:** DDT and DDD designated hazardous waste (DDT No.U061; DDD No. U060)**;** designated hazardous waste; land disposal restrictions (40 CFR Part 268); groundwater monitoring requirements (40 CFR Part 264)	**CERCLA Section 103:** Reporting requirements for spills > 1 lb (40 CFR 302.4)
Policy and Programs (nonregulatory actions)	**-** Clean Sweeps - Council of Great Lakes Industry BNS Implementation: Searching for information regarding the export, storage, and use as chemical intermediates of Level I pesticides - Remedial Action Plans					

A.3.6 MERCURY

Mercury and mercury compounds are included in the CAA Title III list of HAPs and will be subject to standards established under Section 112, including MACT standards (40 CFR Parts 61 and 63). In addition, mercury is a designated high risk pollutant under the CAA (40 CFR Part 63 Table 1). Other sections of the CAA that may require data on mercury emissions include the electric utility steam-generating units, Section 112(n)(1)(A); the National Institute of Environmental Health Sciences (NIEHS) health effects study, Section 112(n)(1)(B); the mercury report to Congress, Section 112(n)(1)(C); the Great Waters Program, Section 112(m); the National Academy of Sciences (NAS) risk assessment methodology study, Section 112(o)(1); the area source program, Section 112(k); and the solid waste combustion program, Section 129.

Many facilities are subject to mercury effluent limits or monitoring requirements in their NPDES permits, and requirements are not limited to those specific sources listed in the CWA.

Mercury releases are subject to CERCLA reporting requirements when releases exceed 1 lb (40 CFR 302.4).[7]

Mercury is also regulated under the RCRA, Title C, Hazardous Waste Management Program (40 CFR 261.33). All mercury-containing wastes have land disposal restrictions, and the specified treatment for these wastes is incineration or thermal processing (40 CFR 268.42). Under the land disposal restrictions, RCRA establishes Universal Treatment Standards for mercury in wastes, including wastewater and nonwastewater (40 CFR 268.48).

Section 313 of Title III of SARA requires that mercury releases to any environmental media be reported in the TRI. TRI reporting thresholds for mercury emissions were lowered to 10 pounds per year under the final rule, which became effective on December 31, 1999 (64 FR 58665, 40 CFR Part 372). As part of SARA Section 313, EPA provides public access to the annual emissions data.

[Source: Ross & Associates Environmental Consulting, Ltd. *Mercury Sources and Regulations: Background Information for the Virtual Elimination Pilot Project.* September 1994, unless otherwise indicated.]

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[7] The statutory sources for designation of mercury as a CERCLA hazardous substance are the Clean Air Act Section 112, CWA Section 307(a), and RCRA Section 3001.

Table A-6. Management of Mercury in the Lake Michigan Basin

Mercury						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Mercury compounds designated section 112(b) hazardous air pollutant; NESHAPS/MACT standards (40 CFR parts 61 and 63); mercury compounds designated high risk pollutants (40 CFR Part 63 Table 1)	**FIFRA:** Cancellation of phenylmercuric acetate for use as fungicide in plants	**SDWA:** MCL for inorganic mercury = 0.002 mg/L; MCLG for inorganic Hg = 0.002 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403); biosolids rules	**FDA:** FFDCA 1 ppm action level for fish tissue (for methyl mercury)	**RCRA:** Designated hazardous waste; land disposal restrictions (40 CFR Part 268); groundwater monitoring requirements (40 CFR Part 264)	**SARA Section 313:** Releases reported to TRI by qualifying facilities (40 CFR 372.65); Reporting threshold > 10 lbs per year (40 CFR Part 372) **CERCLA 103:** Reporting requirements for spills > 1 lb in organic mercury (40 CFR 302.4)
Policy and Programs (nonregulatory actions)	- Remedial Action Plans - U.S. Automobile Pollution Prevention Project: Reduce PCBs and mercury from automotive manufacturing sector - Clean Sweeps - Chlorine Institute: Committed to reduce mercury use in chlor-alkali industry by 50 percent from 1990 to 1995 levels - Memorandum of Understanding: EPA and the American Hospital Association's commitments to work toward virtual elimination of mercury from hospital waste - Lake Michigan Primary Metals Project: Agreement to reduce mercury in 3 northwest Indiana steel mills, spearheaded by BNS Mercury Workgroup - Workshop on Potential Mercury Reductions at Electrical Utilities: BNS Workgroup's effort to reduce mercury emissions at electric utilities - Action Plan for Mercury: Recently developed by EPA					

A.3.7 METALS

Most metals are regulated pursuant to the CWA, SDWA, RCRA, and CERCLA. All are designated toxic pollutants pursuant to Section 307(a)(1) of the CWA and priority pollutants pursuant to Section 304(a) of the CWA. As priority pollutants, all metals are subject to water quality criteria. On October 29, 1999, EPA issued a notice of intent to revise the aquatic life criteria for lead, cadmium, and copper (64 FR 58409). All are subject to NPDES effluent limitations (40 CFR Part 122) and to general pretreatment standards (40 CFR Part 403). All are also subject to MCLs and goals pursuant to the SDWA (40 CFR Part 141).

The CAA designates lead compounds, cadmium compounds and chromium compounds as HAPs pursuant to Section 112(b). These metals are subject to NESHAPS and MACT standards (40 CFR Parts 61 and 63). In addition, cadmium compounds and chromium compounds are designated high risk pollutants (40 CFR Part 63 Table 1).

All of the metals are designated CERCLA hazardous substances with various reporting quantities. However, reporting under CERCLA is not required if a release of cadmium, copper, zinc, or chromium involves pieces of solid metal that are equal to or greater than 100 micrometers (0.0004 inches) in diameter.

Lead is subject to TRI reporting requirements. EPA recently published a proposed rule to lower the reporting threshold of lead and lead compounds to 10 pounds (64 FR 42221).

Pursuant to RCRA, lead, cadmium, zinc, and chromium are subject to land disposal restrictions (40 CFR Part 261). In addition, lead, cadmium, and zinc are subject to groundwater monitoring requirements (40 CFR Part 264).

Cadmium is a Level II substance under the Binational Toxics Strategy.

Table A-7. Management of Lead in the Lake Michigan Basin

	Lead					
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Lead compounds designated Section 112(b) hazardous air pollutants; NESHAPS/MACT standards (40 CFR Parts 61 and 63)		**SDWA:** MCL lead at tap action level = 0.015 mg/L; MCLG = 0 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with water quality criteria; NPDES effluent limitations (40 CFR Part 122); General pretreatment standards (40 CFR Part 403)		**RCRA:** May be characterized as hazardous waste; land disposal restrictions (40 CFR 261.24); groundwater monitoring requirements (40 CFR Part 264)	**CERCLA Section 103:** Reporting requirements for spills > 10 lbs (40 CFR 302.4)
Policy and Programs (nonregulatory actions)						

Table A-8. Management of Cadmium in the Lake Michigan Basin

Cadmium						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Cadmium compounds designated Section 112(b) hazardous air pollutants; NESHAPS/MACT standards (40 CFR Parts 61 and 63); Cadmium compounds designated high risk pollutants (40 CFR Part 63 Table 1)		**SDWA:** MCL = 0.005 mg/L; MCLG = 0.005 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)		**RCRA:** Characterized as hazardous waste; land disposal restrictions (40 CFR 261.24); groundwater monitoring requirements (40 CFR Part 264)	**CERCLA Section 103:** Spills > 10 lbs must be reported (40 CFR 302.4)[8]
Policy and Programs (nonregulatory actions)	- BNS Level II substance					

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[8] There is no reporting requirement where the diameter of the pieces of solid metal released is greater than or equal to 100 micrometers (0.0004 inches) in diameter.

Table A-9. Management of Copper in the Lake Michigan Basin

Copper						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Not targeted		**SDWA:** MCL at tap action level = 1.3 mg/L; MCLG = 1.3 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)			**CERCLA Section 103:** Reporting requirements for spills > 5,000 lbs (40 CFR 302.4)[9]
Policy and Programs (nonregulatory actions)						

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[9] There is no reporting requirement where the diameter of the solid metal pieces released is greater than or equal to 100 micrometers (0.0004 inches).

Table A-10. Management of Zinc in the Lake Michigan Basin

Zinc						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Not targeted		**SDWA:** Zinc is listed for regulation; Secondary MCL = 5 mg/L for elemental zinc and zinc compounds 40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403) **State Drinking Water Stds:** Illinois_= 5 mg/L		**RCRA:** May be characterized as hazardous waste; land disposal restrictions (40 CFR 261.24); groundwater monitoring requirements (40 CFR Part 264)	**CERCLA Section 103:** Reporting requirements for spills > 1,000 lbs for elemental zinc (40 CFR 302.4)
Policy and Programs (nonregulatory actions)						

Table A-11. Management of Chromium in the Lake Michigan Basin

	Chromium					
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Chromium compounds designated Section 112(b) hazardous air pollutants; NESHAPS/MACT standards (40 CFR Parts 61 and 63); chromium compounds designated high risk pollutants (40 CFR Part 63 Table 1)		**SDWA:** Total chromium MCL = 0.1 mg/L; total chromium MCLG = 0.1 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)		**RCRA:** May be characterized as hazardous waste; Land disposal restrictions (40 CFR 261.24)	**CERCLA Section 103:** Reporting requirements for spills (40 CFR 302.4)
Policy and Programs (nonregulatory actions)						

A.3.8 ARSENIC

Pursuant to CERCLA, several arsenic compounds have been designated as hazardous substances. The owner or operator of any facility that produces, uses, or stores any CERCLA hazardous substance in an amount exceeding the reporting quantity of 1 pound is required to immediately report any release to any environmental media of the substance. Approximately 11 arsenic compounds are designated as “hazardous substances” under Sections 101(4) and 102(a) of CERCLA and must meet the requirements for reporting releases to the environment in accordance with 40 CFR 302.4.

Under EPCRA, several arsenic compounds are designated “extremely hazardous substances” with a threshold planning quantity of 1 pound. Releases of more than 1 pound of arsenic and arsenic compounds into the air, water, or land must be reported annually to the TRI database.

Inorganic arsenic compounds have been identified and listed as HAPs under Section 112(b) of the Clean Air Act. The source categories to which emission standards for arsenic apply include primary copper and lead smelters and glass manufacturing plants.

Under RCRA requirements, a solid waste containing arsenic may be characterized as a hazardous waste when subjected to the Toxicant Extraction Procedure listed in 40 CFR 261.24, and if so characterized, must be managed in accordance with federal and state hazardous waste regulations. For wastewaters identified by the hazardous waste code D004, a universal treatment standard of 1.4 mg/L for arsenic has been established.

To protect the groundwater within the boundaries of hazardous waste treatment, storage, or disposal facilities, the EPA has included arsenic on a list of hazardous constituents to be regulated through permissible concentration limits. The concentration of arsenic in groundwater within the boundaries of a facility must not exceed 0.05 mg/L, as long as the background concentration is below this value.

Pursuant to the CWA, arsenic and arsenic compounds are regulated under effluent limitation guidelines for existing sources, standards for performance for new sources, and pretreatment standards for new and existing sources. The point source categories for which arsenic and arsenic compounds are regulated include inorganic chemical manufacturing, nonferrous metals manufacturing, timber products processing, and electrical and electronic components manufacturing.

Under the SDWA, EPA determined the MCL for arsenic to be 0.05 mg/L. This value is presently undergoing review by the EPA as part of a rulemaking to establish a new MCL for arsenic. The World Health Organization (WHO) has established a provisional guideline value of 0.01 mg/L for arsenic in drinking water.

Arsenic levels in the workplace are regulated by Occupational Safety and Health Administration (OSHA). OSHA has established a maximum permissible exposure limit (PEL) of 10 micrograms per cubic meter ($\mu g/m^3$) for organic arsenic over an 8-hour work shift in various workplaces where arsenic is used. The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to airborne arsenic should not exceed 0.002 milligrams per cubic meter (mg/m^3) for a 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that employee exposure to airborne arsenic should not exceed 0.2 mg/m^3 averaged over an 8-hour work shift.

The FDA issues permissible levels of arsenic in muscle meats, edible meat by-products, and eggs. The permissible level of arsenic in muscle tissue is 0.5 ppm. Bottled water must meet the standards of chemical quality and shall not contain arsenic in excess of 0.05 mg/L.

[Sources: ATSDR website http://atsdr.cdc.gov/; the National Safety Council; Environmental Health Center website http://www.nsc.org/; EPA website http://mail.odsnet.com/TRIFacts/; and USDHHS 1998 Toxicological Profile for Arsenic.]

Table A-12. Management of Arsenic in the Lake Michigan Basin

Arsenic						
	Air	Soils / Sediments	Water	Biota	Waste	Reporting Requirements / Spills
Standards and Regulations	**Clean Air Act:** Arsenic compounds designated Section 112 hazardous air pollutants; NESHAPS / MACT standards for emissions from copper and lead smelters and glass manufacturers (40 CFR Parts 61 and 63); Arsenic compounds designated high risk pollutants (40 CFR Part 63 Table 1) **OSHA:** PEL 10 μm^3 for an 8-hour work shift **NIOSH:** 0.002 mg/m^3 for a 15-minute sampling	**FIFRA:** Many pesticide uses of inorganic arsenicals canceled or restricted	**SDWA:** MCL 0.05mg/L (currently under review) (40 CFR Part 141) **CWA:** Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403) **WHO:** 0.01 mg/L **UTS:** 1.4 mg/L **TSDF Groundwater:** 0.05 mg/L	**FDA:** 0.5 ppm in uncooked muscle tissue and 0.05 mg/L in bottled water	**RCRA:** Designated hazardous waste; land disposal restrictions (40 CFR Part 268); groundwater monitoring requirements (40 CFR Part 264)	**SARA Section 313:** Arsenic releases reported to TRI by qualifying facilities (40 CFR 372.65) **CERCLA Section 103:** Reporting requirements for spills >1 lb (40 CFR 302.4)[10]
Policy and Programs (nonregulatory actions)						

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[10] No reporting of releases required where the diameter of the solid metal pieces released is greater than or equal to 100 micrometers (0.0004 inches).

A.3.9 CYANIDE

Under the Safe Drinking Water Act of 1974, EPA determined the safe level of cyanide in drinking water. The MCLG for cyanide is 0.2 ppm and the enforceable MCL is 0.2 ppm. The regulation for cyanide became effective in 1992. Between 1993 and 1995, EPA required public water suppliers to collect water samples once and analyze them to find out if cyanide exceeded the 0.2 ppm MCL. If cyanide was present above this level, the public water system was required to continue to monitor this contaminant every 3 months. If contaminant levels were consistently above the MCL, the water supplier was then required to take steps to reduce the amount of cyanide to ensure that the MCL was not exceeded. The following treatment methods have been approved by EPA for removing cyanide from drinking water: ion exchange, reverse osmosis, and chlorine.

Hydrogen cyanide is sometimes used to treat food after it is harvested to prevent pest damage. The EPA allows levels of cyanide in food ranging from 25 ppm in dried beans, peas, and nuts to 250 ppm in spices.

Cyanide levels in the workplace are regulated by OSHA. OSHA has a legally enforceable exposure limit of 5 milligrams per cubic centimeter (mg/cm^3) for cyanide and 11 mg/cm^3 (or 10 ppm) hydrogen cyanide in air for an 8-hour workday, 40-hour work week. NIOSH recommends that employee exposure to hydrogen cyanide and cyanide salts not exceed 5 mg/m^3 in air for a 10-minute sampling period.

[Sources: ATSDR website http://atsdr.cdc.gov/ToxProfiles/ ; and EPA website http://www.epa.gov/OGWDW/dwh/c-ioc/cyanide]

Table A-13. Management of Cyanide in the Lake Michigan Basin

	Cyanide					
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Cyanide compounds designated Section 112(b) hazardous air pollutants **OSHA:** 5 mg/cm^3 for cyanide exposure in 8 hr workday, 40 hr work week; 11 mg/cm^3 for hydrogen cyanide exposure in 8 hr workday, 40 hr work week		**SDWA:** MCL = 0.2 mg/L; MCGL = 0.2 mg/L (40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)		**RCRA:** May become characterized as hazardous waste (40 CFR 261.33)	**CERCLA Section 103:** Reporting requirements for spills >10 lb (42 USC 9601 and 40 CFR 302.4); potassium cyanide and hydrogen cyanide are designated EHSs with TPQs of 100 lbs (40 CFR Part 355)
Policy and Programs (nonregulatory actions)						

A.3.10 HEXACHLOROBENZENE

Hexachlorobenzene (HCB) is included in the Title III list of HAPs and will be subject to standards established under Section 112, including MACT standards (40 CFR Parts 61 and 63). Other sections of the Clean Air Act that may require data on HCB emissions include sections of the Great Waters Program. Proposed NESHAPs for the source category of pesticide active ingredient production are expected to reduce emissions of HAPs, including HCB.

HCB is a CWA listed priority pollutant (40 CFR Part 423). Many facilities are subject to HCB effluent limitations or monitoring requirements in their NPDES permits, and requirements are not limited to those specific sources listed in the CWA.

HCB is also regulated under RCRA as a toxic waste under the Subtitle U, Hazardous Waste Management Program (40 CFR 261.33). HCB-containing wastes are subject to land disposal restrictions; the proposed disposal method is incineration or thermal processing (40 CFR 268.40). Under the land disposal restrictions, RCRA establishes Universal Treatment Standards for HCB in wastes (40CFR 268.48).

HCB is subject to Section 313 of Title III of SARA, requiring reporting of HCB releases to air, water, or land to the TRI database. TRI reporting thresholds for HCB emissions have been lowered to 10 lbs per year under a rule finalized on October 29, 1999 (64 FR 58665, 40 CFR Part 372). As part of SARA Section 313, EPA provides public access to the annual emissions data.

EPA is currently developing an HCB Action Plan.

Table A-14. Management of HCB in the Lake Michigan Basin

HCB						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Section 112(b) hazardous air pollutant; NESHAPS / MACT Standards (40 CFR Parts 61 and 63); designated high risk pollutant (40 CFR Part 63 Table 1)	**TSCA:** Use, disposal, and management regulations (40 CFR Part 761) **FIFRA:** Use and registration restrictions; voluntarily canceled (40 CFR Subchapter E and USC CH6)	**SDWA:** MCL = 0.001 mg/L; MCGL = 0 mg/L (40 CFR Part 141) **CWA:** Chlorinated benzenes designated Section 307(a)(1) toxic pollutants; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)	No action level established under FFDCA	**RCRA:** Designated hazardous waste (waste no. U127); land disposal restrictions (40 CFR Part 268); groundwater monitoring requirements (40 CFR Part 264); Small quantity generator exclusion (40 CFR 261.5)	**SARA Section 313:** Releases of greater than 10 lbs reported to TRI by qualifying facilities (64 FR 58665, 40 CFR Part 372) **CERCLA 103:** Reporting requirements for spills > 10 lbs (40 CFR 302.4)
Policy and Programs (nonregulatory actions)	- Binational Toxics Strategy Level 1 substance - Bioaccumulative Chemical of Concern (BCC) under the Great Lakes Water Quality Guidance - Remedial Action Plans - Great Lakes Regional Air Toxic Emissions Inventory Project - Integrated Atmospheric Deposition Network (IADN) - Atmospheric Deposition to Great Lakes and Coastal Waters (Great Waters Program) - HCB Action Plan: Currently being developed by EPA					

A.3.11 TOXAPHENE

All pesticide uses of toxaphene were canceled in 1982, except (1) in emergency situations for controlling livestock ecto parasites, and (2) to control grasshoppers and army worm infestations on cotton, corn, and small grains in the continental United States, and on bananas and pineapple crops in Puerto Rico and the Virgin Islands. The remaining U.S.-registered uses of toxaphene were canceled in 1990. In addition, EPA prohibited the importation of food containing toxaphene residues in 1993.

Toxaphene is included in the Clean Air Act Title III list of 189 HAPs and will be subject to air quality standards established under Section 112, including MACT standards (40 CFR Parts 61and 63).

As toxaphene is a designated priority pollutant under the CWA, facilities may be subject to toxaphene effluent limitations or monitoring requirements in their NPDES permits. In addition, toxaphene is considered a toxic pollutant under CWA Section 307, and as such, has established toxic pollutant effluent standards that may also be incorporated into any NPDES permit (40 CFR Part 129).

Toxaphene is a listed hazardous waste under RCRA, Subtitle C hazardous waste management program (40 CFR 261.33). Toxaphene-containing wastes (wastewater and nonwastewater) have land disposal restrictions, including Universal Treatment Standards (40 CFR 268.48). Toxaphene is also included in groundwater monitoring requirements for disposal facilities (40 CFR 264.94).

Under the recently amended rule, toxaphene releases must be reported in the TRI database when they exceed the reporting threshold of 10 lbs per year (64 FR 58665, 40 CFR Part 372).

Toxaphene is a BNS Level 1 substance and is a targeted pesticide in the Level 1 Pesticides Action Plan currently being developed by EPA.

[Sources: EPA website http://www.epa.gov/ and the Chem Alliance regulatory Handbook http://www.chemalliance.org/RegTools/handbook.htm.]

Table A-15. Management of Toxaphene in the Lake Michigan Basin

	Toxaphene					
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Section 112(b) hazardous air pollutant; NESHAPS / MACT Standards (40 CFR Parts 61 and 63); designated high risk pollutant (40 CFR Part 63 Table 1)	**FIFRA:** Use and registration restrictions; voluntarily canceled (40 CFR Subchapter E and USC CH6)	**SDWA:** MCL = 0.003 mg/L; MCLG = 0 mg/L(40 CFR Part 141) **CWA:** Section 307(a)(1) toxic pollutant; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)	**FDA:** Action level for fish 5.0 ppm established under FFDCA	**RCRA:** Designated hazardous waste (waste no. P123); land disposal restrictions (40 CFR Part 268); groundwater monitoring requirements (40 CFR Part 264)	**SARA Section 313:** Releases in excess of 10 lbs/yr reported to TRI by qualifying facilities (64 FR 58665, 40 CFR 372.65); designated EHS with TPQ 500/10,000 lbs (40 CFR Part 355) **CERCLA Section 103:** Reporting requirements for spills > 1 lb (40 CFR 302.4)
Policy and Programs (nonregulatory actions)	– Binational Toxics Strategy (BNS) Level 1 substance – Bioaccumulative Chemical of Concern (BCC) under the Great Lakes Water Quality Guidance – Remedial Action Plans – Included in the North American Free Trade Agreement Technical Working Group on Pesticides – Integrated Atmospheric Deposition Network (IADN) (at some stations) – Atmospheric Deposition to Great Lakes and Coastal Waters (Great Waters Program under the Clean Air Act) – Level 1 Pesticides Action Plan: Currently being developed by EPA – Pesticides Clean Sweeps Programs					

A.3.12 POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

PAHs are a group of naturally occurring organic chemicals which exist in more than 100 forms. Pure chemical PAHs are used in medicines, dyes, plastics, pesticides, asphalt, crude oil, coal tar pitch, creosote, and roofing tar. The majority of PAH contamination is formed through the incomplete combustion of organic materials and fossil fuels. There are five PAHs listed for commercial or industrial use by the ATSDR: anthracene, acenaphthene, fluorene, phenanthrene, and fluoranthene.

PAHs are regulated under the CWA as designated toxic pollutants (Section 307(a)(1)) and as priority pollutants (Section 304(a)). In addition, they are subject to effluent limitations in NPDES permits and general pretreatment standards. Benz(a)pyrene is regulated under the Safe Drinking Water Act. Qualifying facilities must report releases of PAHs to TRI. There are no known regulations of PAHs in the CAA or RCRA.

Table A-16. Management of PAHs in the Lake Michigan Basin

PAHs						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** No known requirements		**SDWA:** Benz(a)pyrene MCL = 0.002 mg/L; MCGL = 0 mg/L (40 CFR Part 141) **CWA:** Many PAHs designated Section 307(a)(1) toxic pollutants; Many PAHs designated Section 304(a) priority pollutants with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403)		**RCRA:** No known requirements	**SARA Section 313:** Releases reported to TRI by qualifying facilities (40 CFR 372.65) **CERCLA Section 103:**
Policy and Programs (nonregulatory actions)						

A.3.13 ATRAZINE

Atrazine is a chloro-triazine which is widely used as a herbicide for controlling broadleaf and grassy weeds in corn sorghum, rangeland, sugarcane, macadamia orchards, pineapple, turf grass sod, asparagus, forestry, grasslands, grass crops, and roses. It has been widely used in the agricultural regions of the Great Lakes basin since 1959 and was estimated to be the most heavily used herbicide in the U.S. in 1987 to 89. During that time, atrazine was most extensively used for corn and soybeans in Illinois, Indiana, Iowa, Kansas, Missouri, Nebraska, Ohio, Texas, and Wisconsin.

EPA has promulgated maximum contaminant levels for atrazine under the Safe Drinking Water Act. In addition, 40 CFR 180.220(a) establishes tolerances for combined residues of atrazine in raw agricultural commodities. Atrazine is subject to use, disposal, and management regulations under TSCA and releases must be reported to TRI by qualifying facilities under SARA Section 313. Atrazine is not regulated under the CAA or RCRA.

Table A-17. Management of Atrazine in the Lake Michigan Basin

PAHs						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Not targeted	**TSCA:** Use, disposal, and management regulations (40 CFR Part 761) **FIFRA:** Standard tolerances (40 CFR 180.220(b)); labeling requirements	**SDWA:** MCL = 0.003 mg/L; MCLG = 0.003 mg/L (40 CFR Part 141)	Tolerances established for combined residues of atrazine in raw agricultural commodities (40 CFR 180.220(a))	**RCRA:** No known requirements	**SARA Section 313:** Releases reported to TRI by qualifying facilities (40 CFR 372.65) **CERCLA Section 103:** None
Policy and Programs (nonregulatory actions)						

A.3.14 SELENIUM

Several EPA offices regulate selenium as a pollutant under EPCRA, including the Office of Drinking Water, the Office of Water Regulations and Standards, the Office of Emergency and Remedial Response, the Office of Solid Waste, and the Office of Toxic Substances.

Under RCRA, if selenium (D010) is characterized as a hazardous waste when subjected to the Toxicity Characteristic Leaching Procedure (TCLP) listed in 40 CFR 261.24, it must be managed as a hazardous waste in accordance with state and federal regulations.

Section 8(a) of TSCA requires manufacturers of selenium to report to EPA with preliminary assessment information concerning production, use, and exposure. Owners or operators of qualifying vessels or facilities are required to notify the National Response Center when there is a release of selenium in an amount equal to or greater than its reportable quantity of 100 pounds.

The EPA MCL for selenium in drinking water is 0.05 ppm. The FDA has determined that a level of 0.010 ppm selenium is allowable in bottled water. Permissible exposure limits of selenium are regulated by OSHA. The OSHA exposure limit for selenium compounds in workplace air is 0.2 mg/m^3 for an 8-hour day over a 40-hour work week.

[Source: ATSDR website http://atsdr.cdc.gov/tfacts92; and TOXNET http://sis.nlm.nih.gov/sis1/index.html.]

Table A-18. Management of Selenium in the Lake Michigan Basin

Selenium						
	Air	**Soils / Sediments**	**Water**	**Biota**	**Waste**	**Reporting Requirements / Spills**
Standards and Regulations	**Clean Air Act:** Selenium compounds designated Section 112(b) hazardous air pollutants; NESHAPS / MACT Standards (40 CFR Parts 61 and 63) **OSHA:** PEL 0.2 mg/m^3 for 8-hour day 40- hour work week		**SDWA:** MCL = 0.05 mg/L; MCLG = 0.05 mg/L (40 CFR Part 141) **CWA:** Selenium compounds designated Section 307(a)(1) toxic pollutants; Section 304(a) priority pollutant with established water quality criteria; NPDES effluent limitations (40 CFR Part 122); general pretreatment standards (40 CFR Part 403) **FDA:** 0.01 ppm in bottled water		**RCRA:** May be characterized as hazardous (40 CFR 261.24)	**SARA Section 313:** Releases reported to TRI by qualifying facilities for releases > 100 lbs (40 CFR 372.65) **CERCLA:** Reporting requirements for spills > 100 lbs (42 USC 9601 and 40 CFR 302.4)
Policy and Programs (nonregulatory actions)						

APPENDIX B

PHYSICAL AND CHEMICAL PROPERTIES

CONTENTS

TABLES

TABLES (Continued)

B.1 PHYSICAL AND CHEMICAL PROPERTIES OF POLYCHLORINATED BIPHENYLS

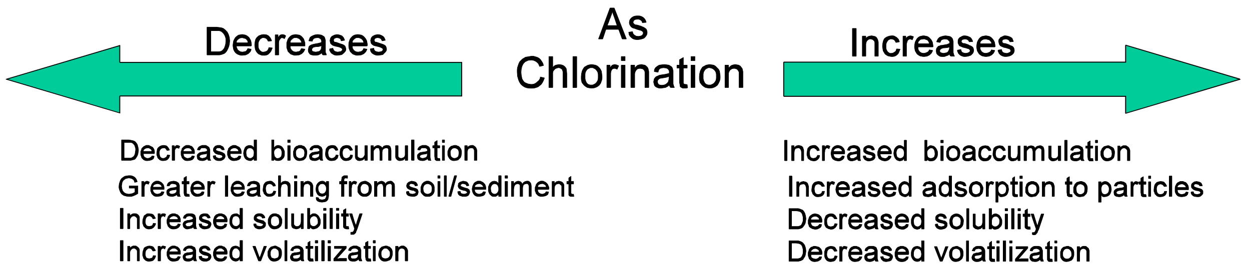
PCBs are a class of compounds in which 1 to 10 chlorine atoms are attached to the biphenyl structure. The 209 chlorobiphenyl congeners are classified according to degree of chlorination of the molecule, and the term isomer is used to identify different compounds with the same degree of chlorination. The mono-, di-, tri-, tetra-, penta-, hexa-, hepta-, octa-, nona-, and decachlorobiphenyl congeners can exist in 3, 12, 24, 42, 46, 42, 24, 12, 3, and 1 isomeric forms, respectively. According to the International Union of Pure and Applied Chemistry (IUPAC) system of nomenclature, the 209 PCB congeners are arranged in ascending numerical order, based on chlorine substitution, and assigned numbers from 1 to 209. Of the theoretical 209 congeners, only about 130 are likely to be found in commercial mixtures (Safe 1990).

From 1930 to 1977, PCBs were marketed in mixtures under the trade name Aroclor. The Aroclors are identified by a four-digit numbering code in which the first two digits indicate that the parent molecule is biphenyl and the last two digits indicate the chlorine content by weight percent. For example, Aroclor 1242 is a chlorinated biphenyl mixture of varying amounts of mono- through heptachlorinated homologs with an average chlorine content of 42 percent.

PCBs are highly stable under most environmental conditions. However, they differ in their properties and physicochemical behaviors depending on the number and pattern of chlorine substitutions in the individual congeners. These properties, such as vapor pressure, water solubility, and susceptibility to degradation, influence both the environmental fate and toxicity of PCBs.

PCBs in general are relatively insoluble in water, sorb strongly to soil and organic matter, and have a high potential for bioaccumulation. As the degree of chlorination increases, PCBs generally become less soluble, less volatile, and more strongly sorbed to soils and sediments. In addition, PCBs are very stable and persistent compounds in various environmental media, and the breakdown of PCBs in water and soil may take several years or even decades. Generally, persistence increases as the number of chlorine atoms increases. Although they are slow processes, volatilization and biodegradation account for the major routes of removal of PCBs from water and soil (Mackay and others 1992).

Recent research *(discussed in EPA 1996)* has found that certain PCB congeners are much more toxic than others with the same degree of chlorination. The most toxic congeners have three properties: (1) they have few ortho-substituted chlorines so the two aromatic rings can be in the same plane, (2) they have four or more chlorines, and (3) when in the coplanar state, the congener molecule appears to other molecules as if it were a 2,3,7,8-substituted tetrachlorodioxin or tetrachlorofuran. Therefore, these congeners behave in mammals and other species much as if they were the highly toxic dioxins and furans. Residual and bioaccumulated PCBs, with relatively more of the highly chlorinated congeners, including the coplanar congeners, will be more toxic than the original mixtures because they contain a higher proportion of the dioxin-like, coplanar PCB congeners.



PCBs in Air

The vapor pressures of PCBs indicate that they should exist primarily in the vapor phase in the atmosphere. Monitoring data indicate that 87 to 100 percent of the PCBs in the atmosphere are present in the vapor phase. The predominant congeners are the less toxic, less chlorinated ones. The atmosphere may effectively disperse PCBs within short distances from sources (Eisenreich and others 1981, Hermanson and Hites 1989). In the atmosphere, removal of vapor-phase PCBs is dominated by the reaction of PCBs with hydroxyl radicals by photolysis.

PCBs in air may also be present as both solid and liquid aerosols that eventually return to the land and water by either settling or washout by snow and rain. Adsorbed to particulates, PCBs can undergo long-range transport in the air. Because the vapor pressure of PCBs generally decreases with an increase in the degree of chlorination, the higher-chlorinated PCBs are more likely to be associated with the particulate-adsorption-phase in air than are the lower-chlorinated PCBs. Physical removal of PCBs from the atmosphere is accomplished by wet and dry deposition; dry deposition occurs only for PCBs associated in the particulate phase (HSDB 2000).

PCBs in Soil and Sediment

As reflected by their low water solubility and high soil (organic carbon) partition coefficients (K_{oc}), PCBs bind strongly to soil and sediments and may persist in this phase for many years. Adsorption of PCBs generally increases as the organic carbon and clay content of the soil and sediment increase. Conversely, evaporation from soil surfaces to air increases as organic matter and clay in soils decrease, due to the weaker sorption of PCBs. Volatilization rates will also be greater in moist soils due to the codistillation of PCBs with water. Leaching of PCBs from soil to groundwater is generally slow. PCBs may, however, leach significantly in the presence of organic solvents, as might occur at a hazardous waste site (Griffin and Chou 1981). The residual mixtures (after volatilization and leaching) will be enriched in the more chlorinated congeners. Storm water runoff will also transport PCBs from soil to surface water, in the water phase and as particulates.

There is no chemical process known to degrade PCBs in sediment and soil. However, biodegradation via dechlorination may occur under anaerobic conditions. Biodegradation rates are highly variable because they depend on a number of factors, including the amount of chlorination, concentration, type of microbial population, available nutrients, and temperature. In general, the rates of PCB dechlorination decrease as (1) the degree of chlorination increases and (2) the organic carbon content of the soil increases (Tiedje and others 1993).

PCBs in Water

In water, adsorption to sediments and suspended particulates is a major fate process that partitions PCBs from water to solid phases. Based on their water solubilities and partition coefficients, PCB solubility decreases with increased chlorination. A small amount of the PCBs may remain dissolved, but most tend to be adsorbed to particles and sediments. PCBs are freely soluble in nonpolar organic solvents and in biological lipids.

In water, transformation processes such as hydrolysis and oxidation do not significantly degrade PCBs. PCB degradation in water is primarily via photolysis, although biodegradation may be more important than photolysis in subsurface water. Biodegradation is also probably the ultimate degradation process for PCBs in sediments.

The values for the estimated Henry's law constants for PCBs indicate that volatilization is also a significant environmental transport process for PCBs dissolved in water. Adsorption to sediments significantly decreases the volatilization rate of highly chlorinated PCBs from the aquatic phase (EPA 1985b, Lee and others 1979).

Sediments containing PCBs at the bottom of a large body of water generally act as a reservoir from which PCBs may be released in small amounts to the water over a long period of time. Although adsorption and subsequent sedimentation may immobilize PCBs for relatively long periods of time in aquatic systems, redissolution into the water column has been shown to occur in the environment. Redissolution and release of PCBs from sediments is favored when PCB concentrations in the aquatic phase are depleted, for example as a result of volatilization. The rate of redissolution of PCBs from sediment to water will always be greater in summer than in winter because of more rapid volatilization from water (Larsson and Soedergren 1987).

PCBs in Plants, Animals, and Food

Accumulation of PCBs in terrestrial vegetation can occur in the following ways: uptake from soil through the root with translocation to the aerial parts of plants; deposition of atmospheric particulates on aerial plant surfaces; and uptake of airborne vapors by aerial plant parts.

PCBs in water bioaccumulate in fish and can reach levels hundreds of thousands of times higher than the levels in water. The bioaccumulation in aquatic animals may also depend on the water zone in which they predominantly reside. For example, because the concentration of PCBs in sediments is several orders of magnitude higher than in water, the bioaccumulation of PCBs in bottom-feeding (benthic) species is also expected to be high. Bioaccumulation is more pronounced in the fatty tissues of aquatic organisms than in the muscle or whole body.

As indicated by the PCB concentrations in higher trophic levels of aquatic organisms, PCBs biomagnify within the food web. There is also evidence that food web biomagnification occurs in several species of birds that feed on fish.

The more chlorinated congeners have higher bioconcentration and bioaccumulation factors, as well as lower biodegradation rates than the less chlorinated congeners. Therefore, the accumulated PCBs will be enriched in the heavier congeners.

By virtue of their large and mobile biomass, their position in food webs, and their biotransformation potential, insects have been suggested as significant contributors to the global transport and transformation of PCBs (Saghir and others 1994).

[Sources: Background information for the preceding section is from USDHHS. 1997. *Toxicological Profile for Polychlorinated Biphenyls* (Update). Agency for Toxic Substances and Disease Registry unless otherwise indicated.]

Table B-1. Origins and Physical and Chemical Properties of PCBs

<table>
<tr><th colspan="6">PCBs</th></tr>
<tr><td>Major Sources / Uses</td><td colspan="5">• Current authorized uses limited to coolants and lubricants in electrical equipment (transformers, capacitors)
• Historically used as an ingredient in hydraulic fluids, plasticizers, carbonless copy paper, fluorescent lamp ballasts, flame retardants, inks, adhesives, and other consumer products. Landfills not designed to handle hazardous wastes may contain these products and serve as PCB sources
• One of the major sources today is environmental cycling of PCBs previously introduced into the environment; PCBs held in soil and sediments are released to water, PCBs in the water and soils volatilize to the atmosphere, PCBs in atmosphere are redeposited in soil and surface waters via wet and dry deposition.</td></tr>
<tr><td rowspan="2">Chemical and Physical Forms</td><td>Water</td><td>Soils and Sediments</td><td>Air</td><td>Biota</td><td>Other Commonly Released Forms</td></tr>
<tr><td>• Primarily as PCBs adsorbed to sediments and suspended particulates</td><td>• Primarily as PCBs adsorbed to soil particles and sediments; PCBs do not readily leach to water</td><td>• Primarily as PCBs in the vapor phase
• Also present as solid and liquid aerosols (airborne particulates)</td><td>• Primarily found in fatty tissues in humans, wildlife, and aquatic organisms</td><td>• There are 209 PCB congeners; the seven principal Aroclors (tradename) included:
Aroclor 1221
Aroclor 1232
Aroclor 1016
Aroclor 1242
Aroclor 1248
Aroclor 1254
Aroclor 1260 (4)</td></tr>
</table>

Source for physical and chemical property data: EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan unless otherwise indicated.

Table B-2. Distribution and Fate of PCBs

	PCBs				
	Transport and Media Partitioning (physical distribution)				
	- Generally PCBs bind strongly to soil and sediments rather than remaining in dissolved phase; transport and deposition of PCBs in water is in the form of suspended particulates. - In air, most PCBs are in the vapor phase, although more highly chlorinated forms may be associated with particulates. Removal from atmosphere and deposition to water and land is by dry and wet deposition.				
	Water (solid/liquid transfers)	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
Distribution and Fate in the Environment	Water Solubility [1] : 0.57 mg/L (Aroclor 1016) or 0.010 mg/L (Aroclor 1254) (5)	Log K_{ow} [2] : 5.4 (Aroclor 1016) or 6.2 (Aroclor 1254)	Vapor Pressure [3] : $7x10^{-4}$ mm Hg (Aroclor 1016) or $9x10^{-5}$ mm Hg (Aroclor 1254) except for photolysis in the atmosphere or shallow water	KH [4] : $4.23x10^{-4}$ atm m^3/mol at 25°C (Aroclor 1016) (5) and $3.79x10^{-3}$ atm m^3/mol at 25°C (Aroclor 1254)	BCF [5] (Aroclor 1242): >100,000 (fathead minnow)[7]
	• Generally insoluble in water (more highly chlorinated[6] forms are least soluble), and are therefore associated primarily with sediments.	• Binds to soils and sediments • Soluble in organic solvents and may leach from landfills where solvents are present	• PCBs bound to soils, sediments, or particles in water are less volatile.	• Volatilization is significant for dissolved PCBs in water.	• Retained in body tissue (bioaccumulative) • More highly chlorinated forms are the most bioaccumulative

Table B-2. Distribution and Fate of PCBs (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	-Biodegradation is major removal route from soils, sediments, and aquatic environments but is a very slow process. No chemical degradation process is known.				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	Half-life: 2 to 6 yrs (b) • Photolysis in surface water layers • Biodegradation in deeper water or where associated with solids	Half-Life: 2 to 6 yrs (b) • Biodegradation via microbial dechlorination	Half-life: 2 to 6 yrs (b) • Biodegradation	Residence time): 1 week to 6 years (b) • Degradation by photolysis	

Sources:
a Revised Draft Lake Michigan Lakewide Management Plan unless otherwise indicated.
b Makay and others 1992.
c USDHHS. 1997. Toxicological Profile for Polychlorinated Biphenyls. (ATSDR)
d EC. 1997. Scientific Justification: Polychlorinated Biphenyls.
e EPA 1998. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

Table B-2. Distribution and Fate of PCBs (continued)

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

[6] The number of chlorine atoms in PCB may range from 1 to 10, with the most commonly released Aroclor mixtures containing between 21 to 60 percent chlorine. The representative mixtures, Aroclor 1016 and Aroclor 1254; contain about 40 and 54 percent chlorine, respectively (EC 1997).

[7] Fathead minnows are a ubiquitous fish species found in Lake Michigan and are commonly used as a marker species in bioaccumulation and toxicity studies.

B.2 PHYSICAL AND CHEMICAL PROPERTIES OF DIOXINS AND FURANS

Dioxins and furans are aromatic hydrocarbons that can have from one to eight chlorine substituents. There are 75 PCDD and 135 PCDF substituted forms (congeners) for a total of 210. The most toxic and consequently the most extensively studied of the dioxins is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). To simplify the assessment of toxicity data for PCDDs and PCDFs, a system has been developed to compare the relative toxicity of the congeners. As it is the most studied, the toxicity of 2,3,7,8-TCDD is used as a reference in relating the toxicity of the other 209 compounds (in terms of equivalent amounts of 2,3,7,8-TCDD). Using this system, the toxicity of airborne mixtures of PCDDs and PCDFs are expressed in terms of 2,3,7,8-TCDD toxic equivalents (TEQ) in mg/m^3 (EPA 1997).

Both the number of chlorine atoms and their positions determine the physical and chemical properties, and therefore, the fate and toxicity of a given substituted form (congener). The most toxic congener (2,3,7,8,-TCDD) is extremely lipophilic, exhibiting a high degree of solubility in fats and is only sparingly soluble in water. The more chlorinated congeners are even more lipophilic and less soluble in water. Limited data also indicated that PCDDs and PCDFs are persistent in soils, sediments, and water. On the basis of the information available, it is concluded that the more highly chlorinated (that is, tetra-CDD/Fs and above) congeners are persistent in the environment (EC 1997).

Dioxins and Furans in Air

Although 2,3,7,8-TCDD has an extremely low vapor pressure it has been shown to be volatile and to occur in air in both the gas phase and particulate phase. In general, most PCDDs and PCDFs are not persistent atmospherically in the vapor phase but are persistent when associated with particulate matter. The physical and chemical properties of PCDDs and PCDFs indicate that most of the more highly chlorinated (tetra-CDD/Fs and above), less volatile PCDDs and PCDFs in the ambient atmosphere will be associated with the particulate phase (Mackay and others 1992). They are susceptible to photodegradation in the presence of ultraviolet light. TCDD may be transported long distances through the atmosphere, and particulates may be physically removed from the atmosphere by wet and dry deposition. There is also evidence that PCDDs and PCDFs are transported long distances in the atmosphere.

Partitioning affects the persistence of PCDDs and PCDFs in the atmosphere. Generally, PCDDs and PCDFs associated with particulate matter will be more persistent and have the potential to be transported long distances in the atmosphere. Atmospheric deposition is one of the major sources of PCDDs and PCDFs measured in the sediments of the Great Lakes (EPA 1994). Persistence of specific congeners, regardless of media partitioning, has also been observed to generally increase with the amount of chlorination of the molecule.

Dioxins and Furans in Soil

In soils, dioxins are generally bound tightly to the solid phase and are thus relatively immobile. Soil adsorption studies and monitoring of various soils contaminated by 2,3,7,8-TCDD have demonstrated that TCDD does not leach to groundwater. In this adsorbed phase, dioxins are also resistant to biodegradation and are relatively persistent in soils. Movement of dioxins from soils to surface waters by surface erosion of contaminated soil particles may be possible. Minor amounts of the more volatile (less chlorinated) dioxins are lost from the soil to the atmosphere through volatilization. TCDD exposed to sunlight on terrestrial surfaces may be susceptible to photodegradation. Volatilization from soil surfaces during warm, summer months may be a major mechanism by which TCDD is removed from soil.

Dioxins and Furans in Water

Photolysis and biological degradation are the key transformation processes affecting the persistence of PCDDs and PCDFs in water. The more highly chlorinated PCDDs and PCDFs are generally resistant to hydrolysis in the environment. The photolysis rates of PCDDs in natural water are enhanced by direct photosensitization or by indirect reactions of chemicals naturally occurring in water. Volatilization may also contribute to some dioxin loss from surface water.

Dioxins and furans, as reflected in high soil-water partition coefficients and low water solubilities, will tend to associate with the particulate phase in aquatic environments and will be removed from the water column by sedimentation. Once in sediments, as in soils, dioxins are resistant to biodegradation and are persistent. Aquatic sediments may be an important, and perhaps ultimate, environmental sink for all global releases of TCDD.

Dioxins and Furans in Plants, Animals, and Food

Although variability in bioaccumulation factors among congeners is significant, in general the more highly chlorinated (tetra-CCD/F and above) congeners of PCDDs and PCDFs accumulate in biota. The presence of dioxins and furans in human breast milk around the world and in animals at the top of the food chain also demonstrates that these substances biomagnify (EC 1997).

[Sources: Background information for the preceding section is from EPA, 1997. *Locating and estimating air emissions from sources of Dioxins and Furans*; and from HSDB 1998 unless otherwise indicated.]

Table B-3. Origins and Physical and Chemical Properties of Dioxins and Furans

	Dioxins and Furans				
Major Sources / Uses	• Dioxins and furans formed as a by-product during the incomplete combustion of materials containing carbon and chlorine compounds, including backyard burn barrels, manufacture of organic compounds (such as chlorinated solvents and pesticides), and chlorine bleaching process used in pulp and paper mills. • Other sources include incinerators, vehicle exhaust, iron and steel manufacturing, cement kilns, crematoria, and chemical waste landfills. • Natural sources include forest fires.				
Physical and Chemical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Adsorbed to suspended solids and sediments	• Associated with solid phase and organic matter	• Highly chlorinated congeners and associated with airborne particulates (tetra-CDDs and above) • Less chlorinated forms also in vapor phase	• Accumulates in fatty tissue of humans and wildlife	• Released as congener mixtures • 75 different polychlorinated (PCDD) dibenzo-p-dioxin congeners • 135 different polychlorinated (PCDF) dibenzofuran congeners • 2,3,7,8 -congeners more harmful (2,3,7,8-tetrachlorodibenzo - p- dioxin most toxic)

Source for physical and chemical property data: EPA. 1993 and Revised Draft Lake Michigan Lakewide Management Plan unless otherwise indicated

Table B-4. Distribution and Fate of Dioxins and Furans

Dioxins and Furans					
Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	• Soils and sediments are primary sink • Also subject to long-range transport as particulates in the atmosphere, with removal by wet and dry deposition				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility[1] (2,3,7,8 -TCDD): 0.419 μg/L (2,3,7,8-TCDF): 0.483 μg/L	Log K_{ow}[2] : TCDD = 6.6 TCDF≅ 6.5	Vapor Pressure[3] : TCDD =3.38 x 10^{-8} mm Hg and TCDF≅=1.50 x 10^{-8} mm Hg	KH[4] : TCDD =1.6 x 10^{-5} atm * m^3/mol and TCDF≅=8.6 x 10^{-6} atm * m^3/mol	BCF[5] : 2, 3, 7, 8-TCDD = 2500 - 9300 (fathead minnow)[6]
	• Low water solubility • Lipophilic	• Immobile in soils • Removal from water column by sedimentation	• Vapor pressure decreases as chlorination increases • Less volatile forms partition to particulates in air	• Air deposition is important source to surface waters	• Bioaccumulates in fatty tissues, especially the more highly chlorinated congeners

Table B-4. Distribution and Fate of Dioxins and Furans (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	• Persistence increases as chlorination increases • Generally not persistent in vapor phase, but generally persistent in soil, sediment, and water phases				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• Half-life: 2 days to 1.62 years (a) • Resistant to hydrolysis	• Half-life: 1 to 3 years, up to 12 years (a) • Generally resistant to biodegradation • Persistent in soils	• Half-life: 4.4 to 6.2 years, up to 30 to 170 years (a) • Persistent in sediment	• Half-life: 1.6 to 10 days (vapor phase) • Breakdown via photodegradation for vapor phase • In particulate phase, photodegradation less important	• Slowly metabolized

Source: Revised Draft Lake Michigan Lakewide Management Plan unless otherwise indicated
(a) Source for water solubility, log K_{ow}, vapor pressure, Henry's Law coefficient EPA 1998
(b) EC. 1997. Scientific Justification: Polychlorinated Biphenyls.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion).
K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

[6] Fathead minnows are a ubiquitous fish species found in Lake Michigan and are commonly used as a marker species in bioaccumulation and toxicity studies.

B.3 PHYSICAL AND CHEMICAL PROPERTIES OF DIELDRIN/ALDRIN

Aldrin in its pure form is a white crystalline solid. Dieldrin in its pure form is a white crystalline solid and in its technical grade is a tan color. The chemical synthesis of dieldrin is by epoxidation of aldrin, and in the environment, aldrin is readily converted to dieldrin through biodegradation. In general, aldrin undergoes photolysis to dieldrin, which in turn may be degraded by ultraviolet radiation or microbial action into the more persistent photodieldrin (USDHHS 1993). Dieldrin is persistent because it is more resistant to biotransformation and abiotic degradation than aldrin, and as a result, it is found in low levels in all media.

Dieldrin/Aldrin in Air

Aldrin and dieldrin are released to the atmosphere through volatilization in the vapor phase from previously treated soil and evaporation from contaminated surface water. Gas-water transfers are strongly dependent on seasons, with net outputs in the summer and net inputs to surface waters typically observed in the winter (EPA 1997). Volatilization of aldrin from soil is more rapid when it is applied to the soil surface rather than incorporated into the soils. Once in the atmosphere, both chemicals may be transported great distances and may be removed by wet or dry deposition (USDHHS 1993). Atmospheric degradation of aldrin, by epoxidation by sunlight to photoaldrin, dieldrin, or photodieldrin, prevents accumulation of aldrin in the air. The estimated lifetime of dieldrin in the atmosphere, based on reactions with atmospheric hydroxyl radicals, is approximately 1 day. However, dieldrin may be more stable than implied by this lifetime if it is associated with particulate matter in the atmosphere. Under these conditions, wet and dry deposition may be more important loss processes (Bidleman and others 1990).

Dieldrin/Aldrin in Soil

Possible releases of aldrin and dieldrin to soil may come from the improper disposal of old stocks at landfill sites or as a result of the historical use of these compounds as insecticides. Because aldrin is converted to dieldrin so rapidly, aldrin concentrations in soils tend to be much lower than dieldrin concentrations, despite the fact that aldrin was applied more frequently (USDHHS 1993). Losses of dieldrin from soils may occur by volatilization to the atmosphere, by runoff to surface waters (as dieldrin-contaminated soil particles), or by degradation. The major degradation pathways include epoxidation of aldrin to dieldrin, biodegradation, and photodecomposition of dieldrin to photodieldrin. Dieldrin is much more resistant to biodegradation than aldrin and is relatively persistent in soil.

In general, aldrin/dieldrin are unlikely to leach appreciably from soil to water. Dieldrin is extremely nonpolar and, therefore, has a strong tendency to adsorb tightly to soil particles. Volatilization is the principal route of loss of dieldrin from soil; however, the process is relatively slow because of the low vapor pressure of dieldrin. Volatilization of aldrin is more rapid when it is applied to the soil surface rather than incorporated into the soil, and relatively rapid loss of both aldrin and dieldrin attributed to volatilization has been observed from soil during the first few months after the pesticide application.

Dieldrin/Aldrin in Water

Aldrin and dieldrin may be released to surface waters as a result of suspended solid transport in runoff from contaminated soils. Losses of dieldrin from water may occur by volatilization to the atmosphere, removal from the water column by sedimentation, or in small amounts by degradation. Due to their hydrophobic nature, aldrin and dieldrin can be expected to accumulate in sediments. Dieldrin is persistent in water.

Dieldrin/Aldrin in Plants, Animals, and Food

Aldrin is readily and rapidly converted to dieldrin, not only in the environment but also in plant and animal tissues (USDHHS 1993). Dieldrin readily bioaccumulates and biomagnifies. Dieldrin is extremely nonpolar and, therefore, has a strong tendency to adsorb tightly to lipids such as animal fat and plant waxes. Dieldrin bioconcentrates and biomagnifies through the terrestrial and aquatic food webs.

[Sources: Background information from USDHHS 1993. *Toxicological Profile for Aldrin/Dieldrin* (Update). Agency for Toxic Substances and Disease Registry unless otherwise indicated.]

Table B-5. Origins and Physical and Chemical Properties of Dieldrin/Aldrin

<table>
<tr><th colspan="6">Dieldrin/Aldrin</th></tr>
<tr><td>Major Sources / Uses</td><td colspan="5">• Organochloride pesticide
• Used on crops and as a termiticide
• Used for locust and mosquito control and as a wood preservative
• Most uses canceled in 1974, with last remaining use canceled in 1989
• Primary degradation product of aldrin (a related pesticide, canceled for all uses by 1991)</td></tr>
<tr><td rowspan="2">Physical and Chemical Forms</td><td>Water</td><td>Soils and Sediments</td><td>Air</td><td>Biota</td><td>Other Commonly Released Forms</td></tr>
<tr><td>• Primarily bound to particulate phase, little in dissolved phase</td><td>• Bound to soil solid phase and sediments</td><td>• May be in vapor phase or associated with particulate matter</td><td>• Accumulates in fatty tissue
• Dieldrin also present as aldrin metabolite</td><td>• Aldrin readily converts to dieldrin in the environment</td></tr>
</table>

Source for physical and chemical property data: EPA BNS *Great Lakes Pesticide Report* unless otherwise indicated.

Table B-6. Distribution and Fate of Dieldrin/Aldrin

	Dieldrin/Aldrin				
Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	• Will reach surface water via particulate phase runoff • Airborne particulates subject to long-range transport • Removed from the atmosphere by wet and dry deposition				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility[1] = 140 μg/L at 20°C	Log K_{oc}[2] = 4.41	Vapor Pressure[3] = 1.31 x 10^{-9} mm Hg @ 25°C	KH[4] = 3.51 x 10^{-9} atm m^3/mol a 25°C	BCF[5] : 100 to 10,000 for various aquatic species (a)
	• Hydrophobic • Adsorbs strongly to sediments	• Adsorbs strongly to sediments • Immobile in most soils	• Tendency to associate with particulates, some found in vapor phase	• Gas transfer from water strongly dependent on seasons (temperature dependent)	• Bioconcentrates in fish

Table B-6. Distribution and Fate of Aldrin/Dieldrin (continued)

Dieldrin/Aldrin					
Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• Hydrolysis not important • Persistent in water (associated with particulate phase)	• Half-life: 1 month to 5 years • Epoxidation of aldrin to dieldrin • Biodegradation (Dieldrin is much more resistant to biodegradation than aldrin)	• Epoxidation of aldrin to dieldrin • Dieldrin relatively persistent in sediments (dieldrin is much more resistant to biodegradation than aldrin)	• Epoxidation of aldrin to dieldrin • Photodecomposition of dieldrin to photodieldrin	• Aldrin converted to dieldrin in plant and animal tissues

(a) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.4 PHYSICAL AND CHEMICAL PROPERTIES OF CHLORDANE

Chlordane is an organochlorine pesticide chemically related to aldrin, dieldrin, heptaclor, and endosulfan. However, it is more volatile than the others and was once used as a fumigant.

Chlordane in Air

When released to the atmosphere, chlordane exists predominately in the vapor phase and is susceptible to rapid photodegradation in this state. Chlordane degrades in the atmosphere by both photolysis and oxidation. The amount of chlordane bound to particulates in the atmosphere relative to the amount in the vapor phase is temperature dependent (more is present in the particulate phase in colder, arctic regions). Although chlordane exists primarily in the vapor phase, the small amount bound to particles appears to be significant in terms of long-range atmospheric transport of chlordane

Even though there has been no recent use of chlordane for termite control, studies have detected chlordane in the indoor air of homes treated for termites up to 15 years after application.

Chlordane in Soil

When released to soil, chlordane persists for long periods, although only limited degradation information is available. Chlordane has been found in soils for up to 20 years after application. Chlordane, like many of the persistent chlorinated hydrocarbons, persists much longer in heavy soils with high organic content when compared to loamy sandy soil (USDHHS 1994). It has been suggested that chlordane is very slowly biotransformed in the environment, which is consistent with the long persistence periods observed under field conditions.

Chlordane in Water

When released to water, chlordane does not significantly undergo hydrolysis, oxidation, or direct photolysis. As a result, chlordane is highly persistent in aquatic ecosystems. Based on the low solubility and high K_{ow} of chlordane, any chlordane present in the water column is likely bound to particles and can be assumed to partition to sediments.

Chlordane in Plants, Animals, and Food

Although chlordane is very bioaccumulative, long-term monitoring studies have indicated a decline in the concentrations of chlordane in fish from the mid-1970s through the early 1990s. Studies of herring gull eggs have reported a slightly different trend. Chlordane levels in herring gull eggs increased or remained constant from the mid-1970s to 1980 before dropping dramatically.

[Sources: Some background information for the preceding section is from USDHHS. 1994. *Toxicological Profile for Chlordane* (Update). Agency for Toxic Substances and Disease Registry unless otherwise indicated.]

Table B-7. Origins and Physical and Chemical Properties of Chlordane

	Chlordane				
Major Sources / Uses	• Pesticide used on field crops and later under restricted use as a termiticide • All commercial uses canceled since 1988 • Current sources from historical use and hazardous waste sites				
Primary Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Isomer mixtures • Primarily bound to soils or water-borne particulates	• Isomer mixtures bound to solid phase	• Exists predominantly in vapor phase • Particulate phase binding is temperature dependent (more adsorption in colder regions)	• Chlordane is metabolized to oxychlordane in fish	• Technical grade chlordane is mixture of >140 related compounds • Major constituents: cis-(α-chlordane) and trans-(γ-chlordane) chlordane

Source for physical and chemical property data: EPA 1998. *Great Lakes Binational Toxics Strategy Pesticide Report*. December unless otherwise indicated.

Table B-8. Distribution and Fate of Chlordane

Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	• Physical and chemical properties differ among isomers and uncertainty exists regarding transport of specific compounds • Adsorption to sediments is the major fate process				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility^1 = 550 µg/L @25°C	Log K_{oc}^2 = 4.71	Vapor Pressure^3 = 2.7 x 10^{-5} mmHg	KH^4 = 2.6 x 10^{-5} atm m^3 / mol at 25°C	BCF^5 : 38,000 (fathead minnow^6 at 32 days) (a)
	• Low solubility	• Partitions to soil and sediments • Generally immobile	• Vapor pressures change as the more volatile compounds in the mixture volatilize • Volatility is temperature dependent		• Strongly bioaccumulated in fish and other aquatic organisms

Table B-8. Distribution and Fate of Chlordane (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	• Physical and chemical properties differ amongst isomers and therefore there is uncertainty regarding degradation of specific compounds • Generally resistant to both chemical and biological degradation				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• Hydrolysis, oxidation, direct photolysis not significant • Very persistent in adsorbed state	• Mean half-life: • 3.3 years (a) • Very persistent • Very slowly biotransforms	• Very persistent	• Half-life: 1.3 to 6.2 hours (vapor phase), • 1.3 days (other phases) • Degrades by photolysis and oxidation	• Metabolized to oxychlordane

(a) EPA. 1993. *Revised Draft Lake Michigan Lakewide Management Plan*

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

[6] Fathead minnows are a ubiquitous fish species found in Lake Michigan and are commonly used as a marker species in bioaccumulation and toxicity studies.

B.5 PHYSICAL AND CHEMICAL PROPERTIES OF DDT AND ITS METABOLITES

DDT is normally found associated with DDD and DDE. The latter two are impurities in the newly synthesized DDT and products of degradation, including on-column transformations during analysis and metabolism. All three compounds have substantially similar chemical, physical, and biological properties. DDT remains in use in public health work in many countries but not the United States or Canada.

DDT in Air

DDT may be present in the atmosphere as a result of volatilization from soil and water. DDT remains in the air only a short time. Once in the atmosphere, DDT will eventually photooxidize to carbon dioxide, hydrochloric acid, and hydroxyl radicals. Cortes and others (1998) report atmospheric half-lives at Sleeping Bear Dunes (IADN monitoring station for Lake Michigan) as 2.3 years for DDT and 2.6 years for DDE and DDD. Small particles that carry DDT or its degradation products may also be distributed through the atmosphere. Both wet and dry deposition are significant mechanisms of removal of DDT and its metabolites from the atmosphere.

DDT in Soil

DDT is persistent in soil and does not leach or move easily to groundwater. Routes of loss and degradation include runoff, volatilization, photolysis and biodegradation (aerobic and anaerobic). These processes generally occur very slowly. DDE and DDD are the initial breakdown products of DDT in the soil environment. Both sister compounds are also highly persistent and have chemical and physical properties similar to DDT. Due to its extremely low solubility in water, DDT will be retained to a greater degree by soils and soil fractions with higher proportions of organic matter. DDT residues in surface soils are much more likely to be broken down or otherwise dissipated than in subsurface deposits.

Volatilization losses of DDT from soil depends on the amount of DDT applied, the proportion of soil organic matter, proximity to the soil-air interface, and the amount of sunlight. Volatilization of DDT, DDE, and DDD is known to account for considerable losses of these compounds from soil surfaces. Their tendency to volatilize from the soil surface can be predicted by their relatively high vapor pressures.

DDT in Water

DDT reaches surface waters primarily by runoff, atmospheric transport, drift, or by direct application (for example, to control mosquito-borne malaria). DDT, DDE, and DDD are only slightly soluble in water. The main degradation and loss pathways in the aquatic environment are volatilization, photodegradation, adsorption to water-borne particulates (including sedimentation), and uptake by aquatic organisms that accumulate DDT and DDT metabolites in their tissues. Volatilization of DDT, DDE, and DDD is known to account for considerable losses of these compounds from the water surface.

DDT in Plants, Animals, and Food

DDT, DDE, and DDD are highly lipophilic, which combined with an extremely long half-life, has resulted in bioaccumulation (that is, levels in organisms exceed those levels occurring in the surrounding environment). In aquatic systems, DDT and its metabolites are bioconcentrated in aquatic organisms and biomagnify in the food web. The evaluation of DDT trends in wildlife is complicated by the fact that some studies report total DDT (DDT and the sum of metabolites), whereas other studies may report DDT, DDE, and DDD separately (DHHS 1994).

A study of the biomagnification of polychlorinated biphenyls (PCB), toxaphene, and the DDT family of metabolites in southeastern Lake Michigan found that DDE was the most strongly biomagnified compound, increasing 28.7 times in average concentration from plankton to fish. The same study determined that DDE is the predominant form of DDT in the Lake Michigan ecosystem, accounting for more than 75 percent of total DDT. (Evans and others 1991)

Table B-9. Origins and Physical and Chemical Properties of DDT

	DDT				
	Water	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
Physical and Chemical Forms	• DDT and metabolites primarily bound to water-bourne particles and sediments	• DDT and metabolites bound to solid phase	• Gaseous, vapor phase	• Primarily found in fatty tissues and eggs of fish-eating birds	• Technical DDT: p,p-DDT (85 percent) o,p-DDT (15 percent) DDE as trace contaminant

Source for physical and chemical property data: EPA 1998. *Great Lakes Binational Toxics Strategy Pesticide Report*. December, unless otherwise indicated.

Table B-10. Distribution and Fate of DDT

<table>
<tr><th colspan="6">DDT</th></tr>
<tr><th rowspan="6">Distribution and Fate in the Environment</th><th colspan="5">Transport and Media Partitioning (physical distribution)</th></tr>
<tr><td colspan="5">• Major processes for transfer are air-water exchange and sorption in biota and sediments</td></tr>
<tr><th rowspan="2">Water</th><th rowspan="2">Soils and Sediments
(solid/liquid transfers)</th><th colspan="2">Air</th><th rowspan="2">Living Organisms
(bioaccumulation)</th></tr>
<tr><th>Volatility</th><th>Gas/Liquid transfers</th></tr>
<tr><td>Water Solubility^1 = 3.4 μg/L @ 25 °C</td><td>Log $K_{oc}{}^2$ = 5.83</td><td>Vapor Pressure^3 = 3.9 x 10^{-7} torr at 20 °C</td><td>KH^4 = 5.37 x 10^{-5} atm m^3/mol @ 25 °C</td><td>BCF^5 : 317,000 (largemouth bass) (a)</td></tr>
<tr><td>• Highly insoluble in water
• Soluble in most organic solvents</td><td>• Adsorbs to soil and water-borne particulates</td><td>• Semivolatile
• Will partition to atmosphere</td><td>• Air-water exchange significant process in deposition to surface water</td><td>• Very lipophilic
• Readily bioaccumulates</td></tr>
</table>

Table B-10. Distribution and Fate of DDT (continued)

Distribution and Fate in the Environment (Continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	• In general, very persistent and resistant to degradation • Major degradation products are DDE and DDD, both of which are highly persistent and have physical and chemical properties similar to those of DDT.				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• Half-life: • 7-350 days (b) • Mainly photolysis	• Half-life: 2-15 yrs (b) • Very persistent • Slow degradation by photolysis and biodegradation (aerobic and anaerobic)	• Half-life: 16.6 days - 31.3 years (b) • Slow biodegradation	• Half-life: 17.7 hours to 7.4 days (b) • Will photo oxidize to CO_2 and hydroxyl radicals	• Very persistent

(a) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.6 PHYSICAL AND CHEMICAL PROPERTIES OF MERCURY

Mercury is an element, a metal that occurs naturally in the environment in several forms. Most of the mercury found in the environment is inorganic mercury, in the form of metallic mercury and inorganic mercury compounds.

In its metallic or elemental form (Hg^0), mercury is a shiny, silver-white, odorless liquid. Some evaporation of metallic mercury occurs at room temperature to form mercury vapor, a colorless, odorless gas. In the ionic form, mercury exists in one of two oxidation states (or valences): Hg^{+1}, or the mercurous ion, and Hg^{+2}, or the mercuric ion. Of the two states, the higher oxidation state (Hg^{+2}) is the more stable. Ionic mercury combines with other elements, such as chlorine, sulfur, or oxygen, to form inorganic mercury compounds or “salts.”

Mercury can also form a chemical bond with carbon to create the organomercurial compounds methylmercury, dimethylmercury, phenylmercury, and thimerosal (Merthiolate). It is customary to refer to mercury with bonds to carbon as “organic” mercury. Like the inorganic mercury compounds, both methylmercury and phenylmercury exist as “salts” (for example methylmercuric chloride or phenylmercuric acetate). The most common forms of mercury naturally found in the environment are metallic mercury, mercuric sulfide, mercuric chloride, and methylmercury.

Environmental cycling of mercury includes conversion between inorganic and organic forms, as well as phase transfers between the gaseous (atmospheric); solid (soils, sediments, and airborne particulates); and aqueous (dissolved and sediment bound) states.

The natural global biogeochemical cycling of mercury is characterized by degassing of the mineral mercury from soils and surface waters, long-range transport in the atmosphere, wet and dry deposition of mercury back to land and surface waters, and sorption of the compound to soil or sediment particulates.

The form of mercury found in the environment can be changed slowly by microorganisms and natural processes. Particulate-bound mercury can be transformed and mobilized by biotic and abiotic oxidation and reduction and can be converted to insoluble mercury compounds and precipitated. Inorganic mercury can also be methylated by microorganisms indigenous to soils and fresh water. This bioconversion between inorganic and organic forms is mediated by various microbial populations under both aerobic and anaerobic conditions. Overall, these transformations may convert mercury into more volatile or soluble forms that reenter the atmosphere or are taken up by biota and bioaccumulated in terrestrial and aquatic food webs.

The specific state (that is, solid, liquid, or gas) and form (for example, inorganic or organic) in which the compound is found in an environmental medium depends on several factors, including pH, temperature, aerobic or anaerobic condition, and microbial activity.

Mercury in Air

Over 95 percent of the mercury found in the atmosphere is elemental mercury (Hg^0), which is gaseous. This is the form involved in long-range atmospheric transport of the compound. Approximately 5 percent of atmospheric mercury is associated with particulates, which have a shorter atmospheric residence time, are removed by dry or wet deposition, and may show a regional or local distribution pattern (Nater and Grigal 1992). Metallic mercury released to the atmosphere in vapor form can be transported long distances before wet and dry deposition processes return the compound to land and water surfaces.

Wet deposition is the primary method of removal of mercury from the atmosphere and may account for virtually all of the mercury content in remote lakes that do not receive inputs from other sources (such as industrial effluents) (Hurley and others 1991, Swain and others 1992). Most inert mercury (Hg^{+2}) in precipitation is bound to aerosol particulates, which are relatively immobile when deposited on soil or water. In addition to wet and dry deposition processes, mercury may also be removed from the atmosphere by sorption of the vapor form to soil or water surfaces (EPA 1984b)

The primary form of atmospheric mercury, metallic mercury vapor (Hg^0), is oxidized by ozone to other forms (such as Hg^{+2}) in the removal of the compound from the atmosphere by precipitation. Other mercury compounds vary in stability and susceptibility to chemical transformation. The main atmospheric transformation process for organomercurials appears to be photolysis (EPA 1984b).

Mercury in Soil and Sediment

Mercury compounds in soils may undergo the same chemical and biological transformations described below for surface waters. Mercuric (Hg^{+2}) mercury usually forms various complexes with chloride and hydroxide ions in soils, and the specific complexes formed depend on the pH, salt content, and composition of the soil solution. Formation and degradation of organic mercurials in soils appear to be mediated by the same types of microbial processes occurring in surface waters and may also occur through abiotic processes (Anderson 1979).

In general, mercury in soil is stable for long periods of time, usually stays on the surface of the sediments or soil, and does not move through the soil to groundwater. Inorganic mercury sorbed to particulate material is not readily desorbed. Thus, freshwater and marine sediments are important repositories for inorganic forms of the compound, and leaching is a relatively insignificant transport process in soils. This strong adsorption of mercury to particulate matter also means that the transport of mercury-contaminated particulates carried in surface runoff is an important mechanism for moving mercury from soil to water.

Mercury in Water

Mercury cycling occurs in freshwater lakes with the concentrations and speciation of the mercury depending on limnological features and water stratification. The top water layer may be saturated with volatile elemental mercury, although sediments are the primary source of the mercury in surface waters.

Mercury in water can exist in the +1 and +2 valence states as a number of complex ions with varying water solubilities. Mercuric mercury, present as complexes, is probably the predominant form of mercury present in surface waters. The transport and partitioning of mercury in surface waters and soils is influenced by the particular form of the compound. Highly insoluble salts, such as mercury sulfide, are the most stable and least mobile form of mercury.

Volatile forms of mercury (such as metallic mercury and dimethylmercury) evaporate to the atmosphere, whereas solid forms partition to particulates in the soil or water column and are transported downward to the sediments in the water column.

The most important transformation process in the environmental fate of mercury in surface waters is biotransformation. Any form of mercury entering surface waters can be microbially converted to methylmercuric ion given favorable conditions. Methylmercury is the usual organic form of mercury created by these natural processes. It is soluble, mobile, and quickly enters the aquatic food chain. Methylmercury is accumulated to a greater extent in biological tissue than are inorganic forms of mercury, and it can accumulate in certain fish to levels that are many times greater than in the surrounding water.

Transformation of methylmercury compounds back to volatile elemental mercury may also occur as a result of microbial demethylation. Anaerobic conditions, as may be found in sediments, favor the demethylation of methylmercury. Abiotic reduction of mercuric mercury to metallic mercury in aqueous systems can also occur. This reduction process is enhanced by light and occurs under both aerobic and anaerobic conditions.

Mercury in Plants, Animals, and Food

Methylmercury in surface waters is rapidly accumulated by aquatic organisms. The biomagnification potential for methylmercury in fish is influenced by the pH and dissolved oxygen content of the water. The biological half-life of methylmercury in mussels is estimated to be 1,000 days (Cossa 1989) Bioaccumulation of methylmercury in aquatic food webs is of interest because it is generally the most important source of nonoccupational human exposure to the compound (EPA 1984b).

[Sources: Background information in the preceding section is from USDHHS. 1993. *Toxicological Profile for Mercury* (Update). Agency for Toxic Substances and Disease Registry unless otherwise indicated.]

Table B-11. Origins and Physical and Chemical Properties of Mercury

	Mercury				
Major Sources / Uses	• Naturally occurring substance. • Used in batteries, thermometers, electric switches, fluorescent lamps, and as a catalyst in oxidation of organic compounds. • Other anthropogenic releases include combustion of fossil and other fuels, mining, smelting, manufacturing, and past agricultural use. • Environmental cycling of historically released mercury compounds is an important source of mercury loadings to Lake Michigan.				
Physical and Chemical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Inorganic salts (chelates and complexes) and methyl mercury • Associated with solid phase (particulates and sediments)	• Elemental (Hg°) (gaseous) • Inorganic mercury salts (Hg^{+1}, Hg^{+2}) (solids: such as mercuric sulfide, mercuric chloride) bound to solid phase	• Most is elemental mercury (Hg°) gas • Small amount associated with solid phase (air-borne particulates)	• Hg metabolized to methyl-mercury (organic Hg) by microorganisms • Accumulates as methyl-mercury	• Phenylmercuric (organic) acetate formerly used as fungicide • Methyl-mercury compounds formerly man-made for use as fungicides

Source for physical and chemical property data: USDHHS 1993. Toxicological Profile for Mercury. ATSDR unless otherwise indicated.

Table B-12. Distribution and Fate of Mercury

	Transport and Media Partitioning (physical distribution)				
	• Major transport mechanisms include outgassing of the element from soils and surface waters, long-range transport in the atmosphere, wet and dry deposition, sorption to soils and sediment particles, and bioaccumulation.				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
Distribution and Fate in the Environment	Water Solubility[1] = 0.056 mg/L (inorganic element)	Log K_{oc}[2] = additional information needed	Vapor Pressure[3]: inorganic = .002 mmHg at 25°C organic = .0085 mmHg at 25°C	KH[4] = 7.1 X 10^{-3} atm-m^3/mol (inorganic element)	BCF[5] : inorganic = 1,800- 4,994 organic = 10,000-81,670 (b)
	• Water solubility varies among inorganic complexes. • Methyl-mercury is soluble.	• In general, the dominant transport process is sorption of nonvolatile forms to soils and sediments with little resuspension to the water column. • Methyl-mercury is mobile in soils.	• More volatile forms evaporate to atmosphere	• More volatile forms (Hg° and dimethyl-Hg) evaporate to atmosphere	• Very bioaccumulative

Table B-12. Distribution and Fate of Mercury (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	- Mercury (as an element) cannot be further broken down. - Other forms are converted by biotic and abiotic oxidation and reduction, bioconversion between organic and inorganic forms, and photolysis of organic compounds.				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• Bioconversion is most important (methylation).	• Bioconversion and abiotic reduction (especially in the presence of organic matter)	• Same as soils and surface waters	• Hg° oxidized by ozone to Hg^{+1} and Hg^{+2} • Particulate-bound is more stable	• Methyl-mercury is persistent. • May be transformed back to elemental-mercury in tissues

Sources:
(a) USDHHS. 1993. Toxicological Profile for Mercury. ATSDR unless otherwise indicated.
(b) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.7 PHYSICAL AND CHEMICAL PROPERTIES OF LEAD

Natural lead is found in many minerals, with the highest concentrations in sulfides. Since it is the ultimate, stable product of natural radioactive decay, lead is also found in minerals derived from such compounds. Virtually all natural lead is in the plumbous (Pb^{+2}) oxidation state.

Most manmade lead is in the metallic (Pb^0) state or the plumbous state. There are also a few plumbic (Pb^{+4}) compounds. Environmental transformations between oxidation states are rare, and occur slowly. However, the forms have generally similar characteristics, including minimal to negligible water solubility and volatility. A few compounds (acetate, nitrate, chloride, others) are fairly soluble in water, but these will be rapidly precipitated as the sulfate, carbonate, or similar insoluble salt. Synthetic organolead compounds, such as tetraethyl lead, are volatile, but are relatively unstable and are converted to inorganic salts within years. Since these organolead compounds have been phased out over the last few decades, they are now of minimal importance.

Lead in Air

Lead in air is in the particulate phase, entering as airborne dust, and then washed out if it does not settle out first. Relatively soluble compounds may be transformed to the oxide, or carbonate salts, but no other changes are expected.

Lead in Soil and Sediment

Lead in soil is relatively stable and immobile. Therefore, deposits from airborne lead will form a highly contaminated surface layer over a minimally contaminated mass. Deposits of the metal will corrode, forming the more insoluble salts, such as the sulfate, phosphate, sulfide, and oxide depending on the exact soil chemistry.

Lead in Water

Almost all of the lead in water will be in the sediment phase, since most compounds have low solubility and the lead in the soluble compounds will be precipitated by the anions in the water. Minimum soluble concentrations occur at pH 5 to pH 6. Lead metal will dissolve, especially at low pH, move some distance, and then be precipitated.

In addition, there are reports that some lake sediment microorganisms can transform inorganic lead compounds to methyl lead compounds. However, this occurs with only some sediments and the rate is measurable only if the lead is initially present as a soluble compound.

Lead in Plants, Animals, and Food

Lead is passively absorbed by plants and animals. Once absorbed, it will then be deposited wherever the organisms deposits calcium. Therefore, plants will not have very much lead. However, mammals, birds, fish, and other animals will accumulate lead in their skeletons and oysters, mussels, snails, and similar animals will accumulate lead in their shells. Older individuals will have more than younger ones. In aquatic communities, the benthic organisms and the algae will generally have the highest concentrations.

Table B-13. Origins and Physical and Chemical Properties of Lead

	Lead				
Major Sources / Uses	• Widely distributed metal, in sulfide and other minerals • The largest single use for lead is in storage batteries • Lead metal and alloys are used in cable sheaths, solder, type metal, bearings, bullets, radiation shielding, and so on. • Lead oxide and other compounds are used in optical glass, ceramics, pigments, and other uses. Tetraethyl lead as a gasoline additive and lead pigments in household paints are now obsolescent.				
Physical and Chemical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Inorganic salts associated with the solid phase (particulates and sediments)	• Inorganic salts bound to, or part of, the mineral matrix	• Inorganic salts in the solid phase (particulates)	• Bioaccumulated in calcium-containing organs, such as bones and shells	• Older tetraethyl lead releases are now probably mineralized to inorganic lead.

Source for physical and chemical property data: USDHHS 1993. *Toxicological Profile for Lead*. ATSDR unless otherwise indicated.

Table B-14. Distribution and Fate of Lead

Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility[1] = 10 mg/L (litharge form of Pb0)	Log K_{oc}[2] = additional information needed	Vapor Pressure[3]: 10 mmHg at 1,025°C (litharge)	KH[4] = additional information is needed	log BCF[5] : = 42 (fish) = 536 (oysters) = 2,570 (mussels) but some species much higher, such as 726 (rainbow trout) and 6,600 (eastern oyster)
	- Other salts are generally similar				

Table B-14. Distribution and Fate of Lead (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• Generally relatively immobile in the solid phase	• Generally relatively immobile in the solid phase	• Generally relatively immobile in the solid phase	• Generally relatively immobile in the solid phase	

Sources:

(a) USDHHS. 1993. Toxicological Profile for Mercury. ATSDR unless otherwise indicated.
(b) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.8 PHYSICAL AND CHEMICAL PROPERTIES OF CADMIUM

Cadmium is a naturally occurring element in the earth's crust. Pure cadmium is a soft, silver-white metal; however, cadmium is not usually found in the environment as a metal. It is usually found as a mineral combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate, cadmium sulfide). These compounds are solids that may dissolved in water but do not evaporate or disappear from the environment. All soils and rocks, including coal and mineral fertilizer, have some cadmium in them. Cadmium is often found as part of small particles present in air. You cannot tell by smell or taste that cadmium is present in air or water because it does not have any definite taste or odor.

Cadmium and cadmium compounds have negligible vapor pressures, but may exist in air as suspended particulate matter derived from sea spray, industrial emissions, combustion of fossil fuels, or the erosion of soils. Cadmium emitted to the atmosphere from combustion processes is usually associated with very small particulates that are in the respirable range (less than 10 μm) and are subject to long-range transport. These cadmium pollutants may be transported from 100 to a few thousand km and have a typical atmospheric residence time of about 1 to 10 days before deposition occurs. Larger cadmium-containing particles from smelters and other pollutant sources are also removed from the atmosphere by gravitational settling, with substantial deposition in areas downwind of the pollutant source. Cadmium deposition in urban areas is about one order of magnitude higher than in rural areas of the United States.

Cadmium is more mobile in aquatic environments than most other heavy metals, such as lead. In natural waters, most cadmium will exist as the hydrated ion ($Cd(+2)\ 6H_2O$). Cadmium complexed with humic substances is also an important form of cadmium in polluted waters. Cadmium concentration in water is inversely related to the pH and the concentration of organic material in the water. Because cadmium exists only in the +2 oxidation state, aqueous cadmium is not strongly influenced by the oxidizing or reducing potential of the water. However, under reducing conditions, cadmium may form cadmium sulfide which is poorly soluble and tends to precipitate.

Precipitation and sorption to mineral surfaces and organic materials are the most important removal processes for cadmium compounds. Sediment bacteria may also assist in the partitioning of cadmium from water to sediments. Both cadmium-sensitive and cadmium-resistant bacteria reduced the cadmium concentration in the water column from 1 ppm to between 0.2 and 0.6 ppm, with a corresponding increase in cadmium concentration in the sediments that is at least one order of magnitude higher than in the overlying water. However, cadmium may also re-dissolve from sediments under varying ambient conditions of pH, salinity, and redox potential. Cadmium is not known to form volatile compounds, so partitioning from water to the atmosphere does not occur.

Cadmium in soils may leach into water, especially under acidic conditions. Cadmium-containing soil particles may also be entrained into the air or eroded into water, resulting in dispersion of cadmium into these media.

Cadmium in Air

Little information is available on the atmospheric reactions of cadmium. The common cadmium compounds found in air (oxide, sulfate, chloride) are stable and not subject to photochemical reactions. Cadmium sulfide may photolyze to cadmium sulfate in aqueous aerosols. Transformation of cadmium among types of compounds in the atmosphere is mainly by dissolution in water or dilute acids.

Cadmium in Soil and Sediment

Transformation processes for cadmium in soil are mediated by sorption from and desorption to water, and include precipitation, dissolution, complexation, and ion exchange. Important factors affecting transformation in soil include the cation exchange capacity, the pH, and the content of clay minerals, carbonate minerals, oxides, organic matter, and oxygen.

Cadmium in Water

In fresh water, cadmium is primarily present as the cadmium(+2) ion, although at high concentrations of organic material, more than half may occur in organic complexes. In reducing environments, cadmium precipitates as cadmium sulfide. Photolysis is not an important mechanism in the aquatic fate of cadmium compounds, nor is biological methylation likely to occur.

Cadmium in Plants, Animals, and Food

Aquatic and terrestrial organisms bioaccumulate cadmium. Cadmium concentrates in freshwater and marine animals to concentrations hundreds to thousands of times higher than in the water. Reported bioconcentration factors (BCFs) range from 113 to 18,000 for invertebrates and from 3 to 2,213 for fish. Bioconcentration in fish depends on the pH and humus content of the water.

The data indicate that cadmium bioaccumulates in all levels of the food chain. Cadmium accumulation has been reported in grasses and food crops, and in earthworms, poultry, cattle, horses, and wildlife. However, since cadmium accumulates primarily in the liver an kidneys of vertebrates, biomagnification through the food chain may not be significant. Although some data indicate increased cadmium concentrations in animals at the top of the food chain, comparisons among animals at different trophic levels are difficult, and the data available on biomagnification are not conclusive. Uptake of cadmium from soil by feed crops may result in high levels of cadmium in beef and poultry (especially in the liver and kidneys). This accumulation of cadmium in the food chain has important implications for human exposure to cadmium, whether or not significant biomagnification occurs.

Table B-15. Origins and Physical and Chemical Properties of Cadmium

<table>
<tr><th colspan="6">Cadmium</th></tr>
<tr><td rowspan="1">Major Sources / Uses</td><td colspan="5">• Naturally occurring substance
• Used for nickel-cadmium batteries and metal plating
• Releases result from combustion of fossil fuel, incineration of municipal or industrial wastes, or land application of sewage sludge or fertilizer.</td></tr>
<tr><td rowspan="2">Physical and Chemical Forms</td><td>Water</td><td>Soils and Sediments</td><td>Air</td><td>Biota</td><td>Other Commonly Released Forms</td></tr>
<tr><td>• Generally found as hydrated ion (Cd(+2) $6H_2O$), complexed with humic substances is also an important form.</td><td>• Usually found adsorbed onto soil</td><td>• Found only as solid particles</td><td>• Bioaccumulates in all levels of the food chain</td><td></td></tr>
</table>

Table B-16. Distribution and Fate of Cadmium

	Transport and Media Partitioning (physical distribution)				
			Air		
	Water	**Soils and Sediments** (solid/liquid transfers)	**Volatility**	**Gas/Liquid transfers**	**Living Organisms** (bioaccumulation)
Distribution and Fate in the Environment	Insoluble	Log Koc[2] = Not available	Vapor pressure[3] = 1 mmHg at 394° C	KH[4] = Not available	BCF[5] = Not available
	Primarily present as the cadmium (+2) ion, although at high concentrations of organic material, more than half may occur in organic complexes.	May leach into water, especially under acidic conditions.	Cadmium and cadmium compounds have negligible vapor pressures.	Particulates may dissolve in atmospheric water droplets and be removed from air by wet deposition.	Bioaccumulates in all levels of the food chain.
Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	In reducing environments, cadmium precipitates as cadmium sulfide.	Transformation processes are mediated by sorption from and desorption to water.	Bacteria may assist in partitioning from water to sediments.	Found only in the particulate (solid) form	Accumulated, but does not biomagnify

Source: USDHHS. 1993. *Toxicological Profile for Cadmium*, April.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

Table B-16. Distribution and Fate of Cadmium (continued)

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.9 PHYSICAL AND CHEMICAL PROPERTIES OF CHROMIUM

Chromium has a rather complicated chemistry with three common and several uncommon oxidation states. Natural chromium is found in the chromic (Cr^{+3}) form, generally in association with iron. Highest concentrations are in basic and ultrabasic igneous rocks, with much lower concentrations in granitic (siliceous) igneous rocks. Chromium ore is converted to either the metal (Cr^{0}) or the chromate (Cr^{+6}) form. Most chromium is used as the metal in stainless steel and many other alloys. Some of the chromite (Cr^{+3}) ore is refined and used in refractories. A small part of the total chromium is converted to chromate (Cr^{+6}) and other chromium compounds. These are used primarily as pigments (Cr^{+3} and Cr^{+6}); leather tanning (Cr^{+3}); metal finishing (Cr^{+6}); and wood preserving (Cr^{+6}); as well as a wide array of minor uses.

Environmentally, the three oxidation states have quite different chemical properties. Chromium metal is practically inert, as one would expect from its use in stainless steel. Salts in the chromic state (Cr^{+3}) are relatively insoluble, so they are almost inert; however, chromate salts (Cr^{+6}) are relatively water soluble. Dissolved chromate is an oxidizing material, which will react in time to produce a chromic chemical and the oxidized substrate. Thus Cr^{+3} is the ultimate form of environmental chromium. However, this process takes a considerable period of time, so the environmental processes of chromate are significant.

Chromium in Air

Airborne chromium is found in the solid phase. Natural sources include dust and volcanic emissions. The major manmade source is combustion of fuels; other sources include emissions from cement kilns and from cooling towers that use chromium water treatments. Chromium in air remains in the solid phase. The only likely reactions involve chromate (Cr^{+6}), which can oxidize organic matter and other material that it contacts.

Chromium in Soil

Chromium metal and chromic (Cr^{+3}) salts are stable in soil. Chromate (Cr^{+6}) salts are slowly reduced to the chromic state, with the reaction proceeding faster in acidic soils. In shallow soils, the chromate typically reacts with organic carbon. In deeper soils, where conditions are anaerobic, the chromate will react with sulfide (S^{-2}) or ferrous (Fe^{+2}) iron. The chromate salts can move by dissolution in water and movement with the water. However, chromic salts are found in practically insoluble salts and organic complexes and are, therefore, immobile.

Chromium in Water

The properties of chromium in water are substantially similar to those in soil. The chromic and metallic chromium is part of the solid phase, sediment and particulate, while much of the chromate is dissolved. There may be some chromic-organic complexes which are soluble and stable. The chromate then reacts with a suitable substrate and is reduced to an insoluble chromic salt.

Chromium in Plants, Animals, and Food

In plants, chromium is taken up with water and remains in the plant after evapotranspiration of the water. Since chromate is much more soluble, it is the predominant species entering the plant, but it is readily reduced to the chromic form.

Chromium is a necessary component of some metabolic enzymes in mammals as well as other animals. Therefore, uptake and excretion of surplus chromium are under active control. However, the net result of animal chromium metabolism is substantially similar to the passive processes in plants.

Table B-17. Origins and Physical and Chemical Properties of Chromium

Chromium					
Major Sources / Uses	- Chromium salts are widely distributed, especially with iron salts. - The main use of chromium is the metal as a component in stainless steel and other alloys. - Chromium salts are used in refractories, pigments, leather tanning, wood preserving, and other fields.				
Physical and Chemical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	- Inorganic salts are generally insoluble, associated with the solid phase (particulates and sediments)	- Part of the mineral matrix	- Part of the solid phase (airborne particulates)	- Limited uptake	

Source for physical and chemical property data: USDHHS 1993. *Toxicological Profile for Chromium*. ATSDR unless otherwise indicated.

Table B-18. Distribution and Fate of Chromium

Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	• The major mechanisms are dissolution and precipitation				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility[1] = Chromic ($^{+3}$) oxide = practically insoluble Chromium ($^{+6}$) trioxide = 671 g/L	Log K_{oc}[2] = additional information needed	Vapor Pressure[3]: Negligible	KH[4] = additional information needed	log BCF[5] : = 1 (trout), 86 to 192 (mollusks)
	• Other salts have similar solubilities		• Chromium is expected to remain in the solid phase		

Table B-18. Distribution and Fate of Chromium (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• The primary processes are dissolution of Cr^{+6}, reduction to Cr^{+3}, and precipitation	• Cr^{+6} will dissolve and act as in water. Cr^{+3} has minimal mobility	• Same as soils	• Remains part of solid phase	Once absorbed, converted to Cr^{+3} and excreted.

Sources:
(a) USDHHS. 1993. Toxicological Profile for Mercury. ATSDR unless otherwise indicated.
(b) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material’s tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry’s Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry’s law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry’s law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.10 PHYSICAL AND CHEMICAL PROPERTIES OF COPPER

Copper is one of the first metals used by man. Most of the copper used by man is found as the pure metal (electrical wiring, pipe, and son on) or as alloys (brass, bronze, bell metal, German silver, and many others). However, most natural copper and some manufactured copper is found in salts, including chlorides, sulfides, carbonates (the green coating seen on copper roofing), and complex salts. Cuprous salts (Cu^{+1}) are known, but the cupric salts (Cu^{+2}) are more common. When cuprous salts are dissolved in water, they generally disproportionate into the metal and the cupric form.

Copper in Air

Neither copper metal nor any of its salts has a readily measured vapor pressure. Therefore, copper will be found in air as part of the particulates (solid phases). The primary source of natural airborne copper is windblown dust. Other sources include volcanoes, decaying vegetation, and forest fires. Manmade sources include metal production (iron and steel and various other metals, in addition to copper), waste incineration, coal combustion, and others. The combustion sources (including most metal production processes) generally release cupric oxide, while the other sources do not change the chemical species. In all cases, the particulates, including their copper, are eventually deposited on soil, water, or vegetation.

Copper in Soil

Most environmental copper is present in the soil; where traces of copper (typically tens of parts per million) are found in many rocks and in the soils derived from those rocks. Manmade copper is initially found on surface deposits from airborne deposition.

Copper in soil is relatively immobile. There is little, if any, mobilization at pH >3 except for the few soluble salts such as copper sulfate. Dissolved copper from such soluble salts generally precipitates as copper carbonate (if exposed to air), binds to the organic matter in the soil, or is bound by other ions. Therefore, in ordinary conditions, copper in soil will move only as a component of a particle.

Copper in Water

Metallic copper will dissolve in water especially in relatively soft, acidic water. Such “aggressive water” will rapidly erode copper pipes and fittings, producing a solution of cupric oxide. Dissolved copper in surface water precipitates rapidly, becoming part of the solid phase, both sediment and suspended matter. Once in that state, the copper behaves as in soil, with minimal dissolved cupric ions. The exact nature of the chemical state varies with the nature of the solid phase. Some will be bound to humic acid and similar material while other copper will be part of a mineral matrix.

Copper in Plants, Animals, and Food

Some copper is taken up by all plants and animals. In plants, uptake seems to be passive. That is, copper in the water the plant takes in will be distributed about the plant and then precipitated when the water is lost by evapotranspiration. Most plants are not affected by copper. Therefore, if high concentrations of copper exist in the water from deposition, deliberate (such as use as a pesticide) or otherwise, plants may contain so much copper that animals eating them are poisoned.

Copper is an essential micronutrient for mammals and other animals. Terrestrial animals (including humans) have mechanisms that take up enough copper from food and reject or excrete the surplus.

Therefore, toxicity is rare except for extremely high concentrations. However, aquatic animals are much more susceptible to copper toxicity, leading to the use of copper salts as molluscicides. In addition, many microorganisms, both terrestrial and aquatic, are also susceptible to copper toxicity, leading to its use as fungicide and algicide in fields, orchards, lakes, and streams.

Table B-19. Origins and Physical and Chemical Properties of Copper

	Copper				
Major Sources / Uses	• Naturally occurring substance, as metal and (especially) salts • Metal very widely used in electrical wiring and plumbing • Salts have been used for pigments in paints and ceramics, and as pesticides of various types, especially antifouling points, algicides, and fungicides. Copper salts are also used in nutritional supplements with many alloys used for coins and various machinery parts.				
Physical and Chemical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Inorganic salts • Associated with solid phase (particulates and sediments)	• Inorganic salts bound to solid phase • Element may be present in particulate form	• Bound to solid phase (air-borne particulates)	• Essential micronutrient in animals	• Salts have been used on algicides in streams and reservoirs.

Source for physical and chemical property data: USDHHS 1990. Toxicological Profile for Copper. ATSDR unless otherwise indicated.

Table B-20. Distribution and Fate of Copper

Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	• Data are for copper sulfate, a common, soluble commercial salt				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility[1] = 143 g/L	Log K_{oc}[2] = additional information needed	Vapor Pressure[3]: Very low organic = .0085 mmHg at 25°C	KH[4] = Additional information needed	BCF[5] : Not available
	• Water solubility varies considerably among salts; most are much less soluble	• Dominant transfer process is sorption to soils and sediment with little resuspension in water column due to density.			

Table B-20. Distribution and Fate of Copper (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**

Sources:

(a) USDHHS. 1993. Toxicological Profile for Mercury. ATSDR unless otherwise indicated.
(b) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.11 PHYSICAL AND CHEMICAL PROPERTIES OF ZINC

Natural zinc is found as bivalent compounds, especially as sulfides, carbonates, and oxides. The major use of zinc is as the metal. The primary useful property of the metal is its corrosion resistance, so chemical transformations are relatively unimportant.

Zinc in Air

Zinc is in air in the particulate phase. It is removed by wet and dry deposition.

Zinc in Soil and Sediment

In soil, zinc is part of the mineral matrix. Due to its solubility in water, it will slowly leach with the water phase. The rate of this movement depends on the local environmental conditions, especially the anions present and the pH.

Zinc in Water

The nitrate, chloride, and similar salts of zinc are very soluble, but soon precipitate as the oxide, sulfide, carbonate, or other slightly soluble species. The amount of zinc in the dissolved phase will depend on pH (least dissolved at near-neutral pH7), the presence of organic molecules that can bind the zinc ion, and the concentrations of precipitating anions. Regardless, the bulk of the zinc will be in the solid phase.

Zinc in Plants, Animals, and Food

Zinc is an essential mineral for essentially all life, so it can be found in most tissues. Aquatic organisms will have zinc concentrations considerably above the concentration of the dissolved zinc. However, the organisms control mechanisms generally prevent biomagnification up the food chain. Terrestrial organisms do not bioconcentrate zinc.

Table B-21. Origins and Physical and Chemical Properties of Zinc

<table>
<tr><th colspan="6">Zinc</th></tr>
<tr><td>Major Sources / Uses</td><td colspan="5">• Zinc is widely distributed in the earth’s crust, primarily as the sulfide, carbonate and oxide salts.
• The main use of zinc is as a protective coating for other metals, as in “galvanized iron.” Zinc alloys include brass, bronze, and current penny coins.
• Zinc compounds have many uses, from smoke bombs through batteries and wood preservatives to food supplements and drugs.</td></tr>
<tr><td rowspan="2">Physical and Chemical Forms</td><td>Water</td><td>Soils and Sediments</td><td>Air</td><td>Biota</td><td>Other Commonly Released Forms</td></tr>
<tr><td>• Inorganic salts primarily in the solid phase (particulates and sediments)</td><td>• Inorganic salts, relatively immobile</td><td>• Part of the solid phase</td><td>• Essential element to all biota. Some accumulation can occur.</td><td></td></tr>
</table>

Source for physical and chemical property data: USDHHS 1994. *Toxicological Profile for Zinc* (update). ATSDR unless otherwise indicated.

Table B-22. Distribution and Fate of Zinc

<table>
<tr><td rowspan="6">Distribution and Fate in the Environment</td><td colspan="5">Transport and Media Partitioning (physical distribution)</td></tr>
<tr><td colspan="5">• Major transport mechanisms include outgassing of the element from soils and surface waters, long-range transport in the atmosphere, wet and dry deposition, sorption to soils and sediment particles, and bioaccumulation.</td></tr>
<tr><td rowspan="2">Water</td><td rowspan="2">Soils and Sediments (solid/liquid transfers)</td><td colspan="2">Air</td><td rowspan="2">Living Organisms (bioaccumulation)</td></tr>
<tr><td>Volatility</td><td>Gas/Liquid transfers</td></tr>
<tr><td>Water Solubility[1] = 6.5 mg/L (zinc oxide)</td><td>Log K_{oc}[2] = additional information needed</td><td>Vapor Pressure[3]: 1 mmHg at 487 °C (metal). Salts are even less volatile</td><td>KH[4] = Addition^{al} information needed</td><td>BCF[5] : Typical numbers are 1,000 for plants and fish and 10,000 for invertebrates.</td></tr>
<tr><td>• Most other salts have similar solubility, but zinc sulfide is essentially insoluble.</td><td></td><td></td><td></td><td>• Very bioaccumulative</td></tr>
</table>

Table B-22. Distribution and Fate of Zinc (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	• The concentration of zinc in water depends on the other ions present. Sulfide decreases water concentrations while high pH and high organic concentrations will increase dissolved zinc.	• Generally bound to the mineral mass	• Generally bound to the mineral mass	• Generally bound to the mineral mass	• Zinc is an essential part of several essential enzymes. Most organisms have mechanisms to control zinc concentrations, but these can be overwhelmed by high environmental concentrations.

Sources:

(a) USDHHS. 1993. Toxicological Profile for Mercury. ATSDR unless otherwise indicated.

(b) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material’s tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry’s Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry’s law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry’s law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.12 PHYSICAL AND CHEMICAL PROPERTIES OF ARSENIC

Arsenic is a silver-gray, brittle, crystalline, metallic-looking substance that exists in three allotropic forms: yellow, black, and gray. It is odorless and nearly tasteless. Arsenic is naturally occurring in the environment at low levels. It is found mostly in compounds with oxygen, chlorine, and sulfur, which form inorganic arsenic compounds. Arsenic in plants and animals combines with carbon and hydrogen to form organic arsenic compounds. Organic arsenic is usually less harmful than inorganic arsenic. Arsenic has several oxidation states. The most common are As^{+3} (arsenous), which includes arsenite (AsO_2^-) salts, and As^{+5} (arsenic), which includes arsenate (AsO_4^{3-}) salts.

Arsenic exists in both the gas and particulate matter phases. The majority of atmospheric arsenic is highly respirable inorganic arsenic particulate matter smaller than 2.5 micrometers. Heating of most arsenic-containing compounds in the presence of air results in the oxidation of the arsenic bound in the mineral, producing primarily arsenic trioxide. Conditions in the ambient atmosphere favor oxidation, so inorganic arsenic compounds are generally expected to predominate in unimpacted ambient air.

The inorganic arsenic compounds are solids at normal temperatures and are not likely to volatilize. In water, they range from quite soluble (sodium arsenite and arsenic acid) to practically insoluble (arsenic trisulfide). Arsenic is soluble in nitric acid, cold hydrochloric acid, and sulfuric acid. It is insoluble in water and nonoxidizing acids. Arsenic compounds are generally nonvolatile except for gaseous arsine and arsenic trioxide. Arsenic trioxide is a solid at room temperature but sublimes at 193 °C.

Some organic arsenic compounds are gases or low-boiling point liquids at normal temperatures. Poisonous gas is produced by arsenic in a fire. Arsenic near acid or acid mist can release arsine, a very deadly gas.

Synonyms for arsenic are arsenic-75, metallic arsenic, arsenic black, arsenicals, and colloidal arsenic.

Transport and partitioning of arsenic depends upon its chemical form. The major transport fate for arsenic is sorption or complexation to soils and sediments. Suspended particulates reach surface waters by wet and dry deposition.

Arsenic as a free element is rarely encountered in natural waters. Soluble inorganic arsenate predominates under normal conditions because it is thermodynamically more stable in water than arsenite.

Arsenic in Air

Because arsenic is naturally occurring in the environment, low levels of arsenic are present in the air. Levels in air are usually about 0.02 to 0.10 micrograms per cubic meter. The atmospheric lifetime of inorganic, particulate-phase arsenic is typically 5 to 15 days due to wet and dry deposition.

Combustion and high-temperature processes are the major sources of inorganic arsenic emissions to the atmosphere. Manufacturing of copper and other metals often releases inorganic arsenic into the air, as does the burning of most fossil fuels, which frequently contain low levels of arsenic. There are also low levels of arsenic in cigarette smoke.

Natural processes that release inorganic arsenic to the air include volcanoes and the weathering of arsenic-containing minerals and ores.

Arsenic in Soil and Sediment

Low levels of arsenic are naturally present in all media, although soil usually contains the highest quantities, with average levels of about 5,000 parts per billion. Elevated levels of arsenic in soil and sediment are due either to natural mineral deposits or to contamination from anthropogenic activities.

Arsenic in Water

Arsenic is naturally occurring in water in amounts of about 2 parts per billion. Arsenic and its salts have low solubility in water. Concentrations of less than 1 milligram will mix with a liter of water. Arsenic is persistent in water, with a half-life of more than 20 days.

Natural mineral deposits in some geographic areas contain large quantities of arsenic, which may result in elevated levels of inorganic arsenic in water. Some chemical waste disposal sites also contain large quantities of arsenic. If the material is not properly stored or contained at the site, arsenic may leach into the water. Widespread application of pesticides may lead to water or soil contamination.

Arsenic in Plants, Animals, and Food

Except where soil arsenic contact is high (around smelters and where arsenic-based pesticides have been applied heavily), arsenic does not accumulate in plants to toxic levels. Where soil arsenic content is high, growth and crop yields can be decreased. Arsenic has a high chronic toxicity to aquatic life and moderate chronic toxicity to birds and land animals.

The concentration of arsenic found in fish tissue is expected to be somewhat higher than the average concentration of arsenic in the water from which the fish was taken. Fish and shellfish build up organic arsenic in their tissues, but most of the arsenic in fish is not toxic. Mammals, including man, excrete arsenic by depositing it in the dermis (for example, the skin, hair, and nails).

[Sources: Information for parts of the preceding section are from the Environmental Defense Fund website http://www.scorecard.org/; National Safety Council; Environmental Health Center website http://www.nsc.org/; the EPA website http://mail.odsnet.com/TRIFacts/; and USDHHS 1998. Toxicological Profile for Arsenic; ATSDR website http://atsdr.cdc.gov/; the National Safety Council, Environmental Health Center website http://www.nsc.org/; and the Environmental Defense Fund website http;//www.scorecard.org/.]

Table B-23. Origins and Physical and Chemical Properties of Arsenic

Arsenic					
Major Sources / Uses	• Naturally occurring substance • Used on lead and other alloys, glass, semiconductors, pesticides, and herbicides • Other releases include combustion of coal and tobacco, mining and smelting, manufacturing, and past agricultural use				
Physical and Chemical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Generally found as dissolved arsenates; some precipitates may be found	• Usually found on arsenates adsorbed onto soil	• Found only as solid particles	• Found in trace concentrations in most biota. Mammals excrete arsenic in hair.	

Source:
NLM. 2000. Hazardous Substances Databank (HSDB). Downloaded February 4, 2000.

Table B-24. Distribution and Fate of Arsenic

Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	Data are for arsenic pentoxide, parent compound of arsenic acid and arsenate salts				
	Water	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water solubility[1] = 1,500,000 mg/L	Log Koc[2] = Not available	Vapor pressure[3] = Not available	KH[4] = Not available	BCF[5] = 0 to 7
	Solubility varies considerably among compounds. Arsenite compounds are generally less soluble, and less common in the environment than the corresponding arsenates.	Arsenite compounds are generally transformed to arsenates. Arsenates are well adsorbed on hydrous oxides of aluminum and iron.	Except for the reactive gas arsine, arsenic compounds are essentially nonvolatile solids.	Deposition of particulates is the only significant process.	Most plants and animals readily absorb soluble compounds. Biomagnification does not occur.
Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Only major transformation is arsenite to arsenate in all environments except extremely reducing ones.				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	Oxidation to arsenate and dissolution occur.	Oxidation to arsenate, adsorption to soils, and dissolution in waste occur.	Oxidation to arsenate, adsorption to sediments, and dissolution in waste occur.	Found only in the particulate (solid) form	Accumulated and excreted, but does not biomagnify

Source: NLM. 2000. Hazardous Substances Databank (HSDB). Downloaded February 4, 2000.

Table B-24. Distribution and Fate of Arsenic (continued)

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.13 PHYSICAL AND CHEMICAL PROPERTIES OF CYANIDE

Hydrogen cyanide, HCN, is a colorless or pale blue liquid or gas with a strong, irritating, bitter almond odor. Its boiling point is 25.6 °C. It is miscible and soluble in water. When it is exposed to heat, flame, or oxidizers, a very dangerous fire hazard can occur. Potassium cyanide, KCN, is a white granular powder. Sodium cyanide, NaCN, is a nonflammable, white crystalline powder. Both potassium cyanide and sodium cyanide have a slight, bitter, almond odor (www.glc.org/air/scope/ 1995). Some plants produce toxic cyanide-containing organic compounds, such as amygdalin in almonds and some fruit pits, as well as cyanide itself in cassava (manioc).

Cyanide in Air

The single largest source of cyanide in air is vehicle exhaust. Other sources of release to the air may include emissions from chemical processing industries, steel and iron industries, metallurgical industries, metal plating and finishing industries, and petroleum refineries. Cyanides may also be released from public waste incinerators, from landfills, and during the use of cyanide-containing pesticides. Cyanides are also released in high concentrations when nitrogen-containing plastics, silk, wool, paper, and other materials are burned (ATSDR 1989).

The usual atmospheric form is gaseous hydrogen cyanide. This is relatively stable and can be transported long distances before it is removed by wet deposition.

Cyanide in Soil

Cyanides are generally not persistent when released to water or soil and are not likely to accumulate in aquatic life. They rapidly evaporate and are broken down by microbes. They do not bind to soils and may leach to groundwater. In water and soil, cyanide compounds generally form hydrogen cyanide that goes into the air and remains there for several years (EPA 1998).

The largest sources of cyanide released to soil are primarily from the disposal of cyanide wastes in landfills and the use of cyanide-containing road salts (EPA 1986).

Cyanide in Water

The major sources of cyanide releases to water are publicly owned wastewater treatment works, iron and steel production plants, and metal finishing and organic chemical industries. Much smaller amounts of cyanide may enter water through stormwater runoff in locations where cyanide-containing road salts are used. Groundwater can be contaminated by the movement of cyanide through soil from landfills (ATSDR 1989).

Because hydrogen cyanide is a weak acid, the fate of cyanide depends on pH. However, when the pH is less than 9.2, the cyanide is primarily in the mobile, volatile acid form. Only a higher pH will produce major concentrations of the less volatile salt form.

Cyanide in Plants, Animals, and Food

Cyanides compounds are not accumulated in fish. Cyanide occurs naturally as cyanoglycosides or as the free ion in a variety of fruits, vegetables (such as cassava), and grains. In the United States, only low levels of cyanide are taken in from eating because foods with high cyanide levels are not a major part of the American diet.

Table B-25. Origins and Physical and Chemical Properties of Cyanide

	Cyanide				
Major Sources / Uses	• Found in some plants (cherries, peaches, apricots, apples, and pears) as cyanoglycosides in the seeds • Product of incomplete combustion of nitrogen-containing material, such as wool, tobacco, and some plastics • Used as chemical intermediates, electroplating, and pesticides. Cyanamides were formerly used as fertilizers.				
Chemical and Physical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	Usually found as inorganic salts or as organic cyanides (nitriles). At pH ≤ 9.2, much will volatilize as HCN.	Usually found as inorganic salts. At pH ≤ 9.2, much will volatilize as hydrogen cyanide.	Found as hydrogen cyanide gas	Usually metabolized to thiocyanate and excreted	

Source: NLM. 2000.

Table B-26. Distribution and Transport of Cyanide

Cyanide					
Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	Water (solid/liquid transfers)	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility [1] : Miscible (1,000,000 mL/L)	Log K_{ow} [2] : -0.25	Vapor Pressure [3] : 630 mm Hg at 20°C	KH [4] : 1.33×10^{-4} atm-m^3/mol at 25°C	BCF [5]: None known to occur
	Transformations and Degradation/Persistence (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	- Half-life: NA	Half-Life: NA	Half-life: NA	Half-life: 1 year	Usually rapidly degraded

Data are for hydrogen cyanide (NLM 2000).

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.14 PHYSICAL AND CHEMICAL PROPERTIES OF HEXACHLOROBENZENE

Hexachlorobenzene (HCB) is a halogenated aromatic hydrocarbon also known as pentachlorophenyl chloride, perchlorobenzene, and perchloryl phenyl. Former trade names of HCB include Anticarie, Bunt-Cure, No Bunt, and Sanocide. HCB exists as either a white, crystalline solid or a clear liquid and is practically insoluble in water. When heated to decomposition, HCB emits toxic fumes of chlorides. HCB is a persistent environmental chemical due to its chemical stability and resistance to biodegradation. A moderate rate of volatilization, as expected from the Henry's law constant value, makes this a significant mechanism of transfer from water, plant, and soil surfaces.

HCB in Air

In the atmosphere, HCB can exist in the vapor phase and in association with particulates. Degradation is very slow (estimated half-life with hydroxyl radicals is 2.6 years). Physical removal of HCB from the atmosphere occurs by both wet and dry deposition, although the compound is hydrophobic and therefore somewhat resistant to wet deposition, unless sorbed to particles. Atmospheric pathways are a major transport mechanism for HCB and can operate over large distances (possibly hemispheres).

HCB in Soil

HCB persists in soils for extended periods of time as indicated by the reported half-life of more than 6 years. This persistence is due to the strong adsorption to soil. HCB generally does not leach to water. Transport to groundwater is slow but varies with the organic makeup of the soil, as HCB tends to bind more strongly to soils with high organic content. Where bioremediation methods are proposed at waste disposal sites to reduce carbon-containing contaminants, the lipid content of remedial bacteria may cause HCB absorbed to soils to repartition to the bacteria and move into groundwater.

HCB in Water

HCB has a moderate vapor pressure and a very low solubility in water. If released to water, HCB will significantly partition from the water column to sediment and suspended matter, and it may build up in bottom sediments. Volatilization from the water column is rapid; however, the strong adsorption to sediment can result in long periods of persistence.

HCB in Plants, Animals, and Food

Bioconcentration and biomagnification of HCB in aquatic species are expected to be important on the basis of a high octanol/water partition coefficient (K_{ow}) value. Biological concentration factor (BCF) values of 16,200 for fathead minnows; 21,900 for green sunfish; and 5,500 for rainbow trout exposed to HCB. Biomagnification of HCB was also reported within aquatic food webs, with catfish (the highest trophic level species) accumulating over 10 times more HCB than the next highest trophic level investigation (snails); snail species accumulated 1.5 to 2 times more HCB than the lowest trophic level species in the food web.

Root crops and other plants (sugar beets, carrots, turnips, wheat, and pasture grass) have been shown to accumulate HCB from the soil. Concentrations of HCB in plants and agricultural crops can be directly transferred to humans by direct consumption and can be indirectly transferred to humans via consumption of dairy products or meat from animals consuming contaminated pasture grass.

Table B-27. Origins and Physical and Chemical Properties of HCB

<table>
<tr><th colspan="6">HCB</th></tr>
<tr><td>Major Sources / Uses</td><td colspan="5">• Currently released to the environment as a by-product from the manufacture and use of chlorinated solvents, pesticides and tires; it is also formed and released from diverse combustion and incineration processes.
• Prior to 1985 HCB was used as a fungicide for seeds, although those uses have been voluntarily canceled and it is no longer produced as a pesticide in the United States. However, HCB is known to be a minor contaminant in several currently used pesticides, such as dacthal, picloram, pentachlorophenol, and chlorothalonil.
• Long-range transport and subsequent deposition from within the United States and from other continents contribute to the environmental burden in geographically diverse aquatic systems.</td></tr>
<tr><td rowspan="2">Chemical and Physical Forms</td><td>Water</td><td>Soils and Sediments</td><td>Air</td><td>Biota</td><td>Other Commonly Released Forms</td></tr>
<tr><td>• Readily volatilizes from the surface of water and adsorbs to sediments and suspended particulates</td><td>• Adsorbs to soil particles and sediments and generally does not leach to water; subject to volatilization at the soil surface</td><td>• May undergo slow photolytic degradation or be transported and removed from air via wet and dry deposition</td><td>• Primarily found in fatty tissues in humans, wildlife, and aquatic organisms</td><td></td></tr>
</table>

Source for physical and chemical property data: EPA 1993. Revised Draft Lake Michigan Lakewide Management Plan, unless otherwise indicated.

Table B-28. Distribution and Fate of HCB

<table>
<tr><th colspan="6">HCB</th></tr>
<tr><td rowspan="10">Distribution and Fate in the Environment</td><td colspan="5">Transport and Media Partitioning (physical distribution)</td></tr>
<tr><td colspan="5">• Volatilization from water to air and sedimentation of adsorbed particulates are the major removal processes from water. HCB will also volatilize from the surface of soil, but it will accumulate and become trapped by overlying sediments.
• Subject to long-range transport in the atmosphere, with removal by wet and dry deposition</td></tr>
<tr><td rowspan="2">Water
(solid/liquid transfers)</td><td rowspan="2">Soils and Sediments
(solid/liquid transfers)</td><td colspan="2">Air</td><td rowspan="2">Living Organisms
(bioaccumulation)</td></tr>
<tr><td>Volatility</td><td>Gas/Liquid transfers</td></tr>
<tr><td>Water Solubility ^{1} : 0.0086 mg/L</td><td>Log K_{oc} ^{2} : 4.90
Log K_{ow}: 5.50</td><td>Vapor Pressure ^{3} : 1.23 x 10^{-5} mm Hg</td><td>KH ^{4} : 5.35 x 10^{-4} atm m^3/mol at 25°C (a)</td><td>BCF ^{5}: 106,840 (worm); 24,800 (freshwater algae); 1,254 to 20,000 (trout)</td></tr>
<tr><td>• Low water solubility enhances volatilization from water</td><td>• Binds to soils and sediments; volatilizes from surface
• Soluble in organic solvents, may desorb from resuspended bottom sediments</td><td>• Adsorbed particulates will be removed via wet and dry deposition</td><td>• Partitions between vapor and solid phases</td><td>• Retained in body tissue (bioaccumulative)
• Studies indicate that HCB biomagnifies through the food web (b)</td></tr>
<tr><td colspan="5">Transformations and Degradation/Persistence (chemical changes and distribution)</td></tr>
<tr><td colspan="5">- Chemical and biological degradation are not considered to be important removal processes from water or sediments</td></tr>
<tr><td>Water</td><td>Soils</td><td>Sediments</td><td>Air</td><td>Biota</td></tr>
<tr><td>Half-life: 2.7-6 years (c)</td><td>Half-Life): > 6 years (d)
• Aerobic degradation</td><td>Half-life: > 6 years (d)
• Aerobic degradation</td><td>Half-life: 2-6 years (d)
• Degradation by photolysis and photo-oxidation</td><td>• Additional information needed</td></tr>
</table>

(a) EPA, 1993. Revised Draft Lake Michigan Lakewide Management Plan, unless otherwise indicated.
(b) USDHHS. 1998. Toxicological Profile for Hexachlorobenzene (ATSDR).
(c) Oliver, B.G., and A.J. Niimi. 1988. Environ. Sci. Technol. Volume 22. Pages 388 to 397.

Table B-28. Distribution and Fate of HCB (continued)

(d) Mackay and others. 1992. Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals. Volume I. Lewis Publishers.   Chelsea, Michigan.   Howard and others. 1991. Handbook of Environmental Degradation Rates. Ed. H. Taup. Lewis Publishers. Chelsea, Michigan. Mackay and others. 1992.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.15 PHYSICAL AND CHEMICAL PROPERTIES OF TOXAPHENE

Toxaphene, usually found as a solid or gas, is a mixture of more than 175 chlorinated components. These components, produced by the chlorination of camphene (a compound found in turpentine and many essential oils), result in a mixture averaging 67 to 69 percent chlorine by weight.

Because toxaphene is a mixture of polychlorinated camphene derivatives of varying physical and chemical properties and environmental behaviors, the environmental fate of toxaphene is complicated. However, in general, toxaphene is persistent in air, water, soil, and sediment, and is a bioaccumulative substance. It tends to partition to the solid phase in terrestrial and aquatic systems, although loss to the atmosphere via evaporation is also a significant process. Once volatilization has occurred, numerous studies indicate that the atmosphere is the most important environmental medium for toxaphene transport. Information on the environmental fate of toxaphene in various media is summarized below.

Toxaphene in Air

Due to its volatility and persistence, toxaphene is widely distributed in the atmosphere. In addition, it can be transported long distances, as evidenced by the presence of toxaphene in Canadian air masses that had originated in the southern United States (EPA 1997). Atmospheric toxaphene has been observed to exist predominantly in the apparent gas phase (greater than 90 percent) (Hoff and others 1992a), although some may be associated with airborne particulates (USDHHS 1998). In addition, toxaphene concentrations in the air, like many pesticides, tend to vary seasonally, with summer concentrations approximately 4 times higher than winter concentrations (Hoff and others 1992a). Although wet and dry deposition of toxaphene may occur, research indicates that loading of toxaphene by gas exchange may be more than one order of magnitude higher than the input by wet or dry deposition (USDHHS 1998).

Toxaphene in Soil

Toxaphene is relatively immobile in soil, due to its low water solubility and strong absorption. In ordinary conditions, it is relatively stable, with a long half-life. However, biodegradation is faster in anaerobic saline marsh soils and during the summer in inland areas.

Toxaphene in Water

Aquatic toxaphene is strongly sorbed to sediments. No significant hydrolysis and photolysis occur. However, it can be biodegraded in anaerobic sediments and it will volatilize from shallow streams.

Toxaphene in Plants, Animals, and Food

Toxaphene readily bioaccummulates in aquatic organisms, with bioconcentration factors of 3,000 to 33,000 for various fish species. The accumulated toxaphene is mostly in the fatty tissues. No major accumulation is known in plants, but one study reports a bioaccumulation factor of 5 in chickens given dosed feed.

Table B-29. Origins and Physical and Chemical Properties of Toxaphene

Toxaphene					
Major Sources / Uses	• Insecticide used to control insect pests on cotton and livestock and biocide used to kill unwanted fish in lakes. • Most United States uses canceled in 1982, with remaining uses canceled in 1990. • Long-range atmospheric transport from environmental reservoirs is an important source of toxaphene in Lake Michigan.				
Chemical and Physical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Primarily bound to water-borne particulates and sediments	• Bound to solid phase	• Exists predominantly in vapor phase (some as air-borne particulates)	• Found in fatty tissue	• Manufactured insecticide containing over 175 congeners (majority contain 6 to 10 chlorines) • Also known as chlorinated camphene, polychlorocamphene, and camphechlor

Source for physical and chemical property data: EPA. 1998. *Great Lakes Binational Toxics Strategy Pesticide Report*, unless otherwise indicated.

Table B-30. Distribution and Fate of Toxaphene

Toxaphene					
Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	• Long-range atmospheric transport and loading via gas absorption is the major pathway of toxaphene in Lake Michigan. • Non-atmospheric sources (for example, tributaries) may also be important in northern Lake Michigan.				
	Water (solid/liquid transfers)	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility [1] : 3 mg/L at 25C	Log K_{oc} [2] : 2.5 - 5.0 Log K_{ow} = 3.3	Vapor Pressure [3] : 5×10^{-6} mm Hg at 20C	KH [4] : 0.005-0.21 atm m^3/mol at 25 C	BCF [5]: 37,000 to 69,000 (fathead minnow)[6] (b)
	• Slightly soluble in water	• Sorbed to solid phase	• Volatile; evaporation from soils to atmosphere is an important transport process	• Air-water exchange is important transport process	• Lipophilic • Bioconcentrates in fatty tissue

Table B-30. Distribution and Fate of Toxaphene (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Persistent in air, water, soil, and sediment Bioaccumulative				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	Half-life: > 200 days • Resistant to hydrolysis and photolysis • Biodegradation occurs relatively rapidly in anaerobic sediments, but not in aerobic sediments or surface waters	Half-Life: 1 to 14 years • Persistent under aerobic conditions • Biodegradation occurs relatively rapidly under anaerobic conditions (for example, in flooded soils)	Half-life: information needed • Biodegradation occurs relatively rapidly in anaerobic sediments	• Very resistant to degradation by direct photolysis • Degraded (vapor phase) by photochemically produced hydroxyl radicals (half-life: 4 to 5 days)	• Bioaccumulative

(a) EPA. 1998. *Great Lakes Binational Toxics Strategy Pesticide Report* unless otherwise indicated.
(b) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan.
(c) USDHHS. 1998. Toxicological Profile for Toxaphene.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material’s tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry’s Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry’s law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry’s law is generally accepted as a good approximation.

Table B-30. Distribution and Fate of Toxaphene (continued)

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

[6] Fathead minnows are a ubiquitous fish species found in Lake Michigan and are commonly used as a marker species in bioaccumulation and toxicity studies.

B.16 PHYSICAL AND CHEMICAL PROPERTIES OF PAHs

Polynuclear aromatic hydrocarbons (PAH) are the primary products of the incomplete combustion of organic materials. PAHs are principle constituents of soot, automobile and diesel exhaust, creosote (coal tar), tobacco smoke, asphalt, and similar mixtures. Benzo(a)pyrene (B[a]P) is the best-studied of the PAHs and, as far as is known, the most toxic. Its chemical and physical properties are similar to those of other commonly found PAHs. Therefore, B[a]P will be used as a prototype PAH in this discussion**.**

PAHs in Air

Atmospheric PAH concentrations consist, in great part, of lower molecular weight forms that can account for greater than 90 percent of the total atmospheric load. The balance of the load then is accounted for by the higher molecular weight forms bound to sediment particles. Essentially all PAHs are found in the particulate phase. B[a]P, and many other forms of PAHs are subject to long-range transport, depending on particle size and climactic conditions, which in turn determine the rates of wet and dry deposition. See http://www.epa.gov/grtlakes/bns/baphcb/stepbap.html for more information.

Photooxidation of gas phase PAHs caused daytime atmospheric concentrations of PAHs to be 75 percent less than nighttime concentrations, introducing a diurnal fluctuation. Furthermore, atmospheric PAH concentrations exhibit a seasonal fluctuation. According to concentrations observed as part of the Atmospheric Exchange Over Lakes and Oceans (AEOLOS) Project, PAH levels were highest during July and lowest during January. PAH levels are frequently higher during the winter months due to greater fossil fuel combustion for heating.

PAHs in Soil and Sediment

PAHs are found in nearly all soils. They are tightly bound to the soil and sediment particles and have little mobility. It is believed that PAHs in soils are a result of local or long-range air transport and subsequent deposition. Background PAH levels are generally the highest in urban soils and adjoining nearshore sediment due to the presence of large concentrations of anthropogenic activity in the urban corridors. Other, more direct sources of PAHs in soils include sludge disposal from public wastewater treatment plants, automotive exhaust, irrigation with coke oven effluent, leachate from bituminous coal storage sites, and use of contaminated soil compost and fertilizers. Soils directly adjacent to highways are susceptible to contamination from vehicle exhaust and wearing of tires and asphalt. Finally, the soils in or near landfill sites and industrial sites, such as creosote producing, wood-preserving, coking, and former gas manufacturing plants, all have the potential for high PAH levels.

PAHs in surface water sediments are widespread and are the main source of contamination in most surface waters, because PAHs adhere to soil particles and do not easily dissolve in water. In the National Sediment Quality Survey, PAHs were among four contaminants detected the most often at levels with probable adverse human health effects.

PAHs in Water

As stated above, the main source of PAH contamination in surface water is in the sediment. PAHs released to surface waters generally tend to remain in the sediments near their sites of deposition. Therefore, lakes, rivers, estuaries, and coastal environments near industrial or urban centers will contain the greatest amount of PAH contamination.

PAHs in Plants, Animals, and Food

PAHs can accumulate in plants and aquatic and terrestrial organisms. Plants take up PAHs from the soil with their roots or from the air through their foliage. Uptake rates are species-specific, but the biomagnification rates are generally low. Aquatic organisms ingest PAHs through water, sediments, and food, but they are generally able to metabolize PAHs and excrete the by-products. Some aquatic organisms such as molluscs do not metabolize PAHs as readily as other fish and crustaceans. Biomagnification was not observed among increasing trophic level aquatic organisms. Terrestrial animals may ingest PAHs through the food web or by direct soil ingestion, but biomagnification was not observed.

Table B-31. Origins and Physical and Chemical Properties of PAHs

	PAHs				
Major Sources / Uses	• Product of incomplete combustion of carbon-containing material (such as coal, biomass, forest fires, and natural gas) • Only uses are as a component of coke and similar fuels and of asphalt				
Chemical and Physical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	Adsorbed to suspended sediment	Adsorbed, especially in organic carbon	On particulates, especially those from combustion	Metabolized in mammals to more toxic forms	

Source: NLM. 2000.

Table B-32. Distribution and Fate of PAHs

	Transport and Media Partitioning (physical distribution)				
Distribution and Fate in the Environment	• Soils and sediments are the primary sink. • Also subject to long-range transport as particulates in the atmosphere, with removal by wet and dry deposition. • All figures below given for B(a)P, a commonly regulated form of PAH.				
	Water (solid/liquid transfers)	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility [1] : 0.0019 mg/L • Low water solubility	Log K_{ow} [2] : 6.13 • Immobile in soils • Removal from water column by sedimentation	Vapor Pressure [3] : 4.89×10^{-9} mm Hg at 20 °C	KH [4] : 8.36 x 10^{-7} atm-m^3/mol • Air deposition is important source to surface waters.	BCF [5]: 10 to 10,000 • Biomagnification is not significant in plants and aquatic or terrestrial organisms.
	Transformations and Degradation/Persistence (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	Half-life: NA	Half-Life: 1 to 8 years	Half-life: 12 to 300 weeks	Residence time: NA	NA

Note: All information from ATSDR 1995 unless otherwise noted.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

Table B-32. Distribution and Fate of PAHs (continued)

[4] KH (Henry’s Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry’s law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry’s law is generally accepted as a good approximation.

B.17 PHYSICAL AND CHEMICAL PROPERTIES OF ATRAZINE

The chemical structure of atrazine with its triazine nucleus, two amine groups, and single chloro group, is very different from the organochlorine pesticides (such as aldrin, DDT, and toxaphene) and similar compounds (PCBs, dioxins, and furans). Atrazine’s structure leads to different physical properties, such as relatively high water solubility and distinct patterns of partitioning among phases.

In recent years, atrazine has been the most heavily used pesticide in the United States. The primary usage is as a pre-and early post-emergence herbicide for corn, pastures, trees, and non-crop areas.

Atrazine in Air

Atrazine exists in both the vapor and particulate phases. The vapor part will be degraded rapidly by photochemically-produced hydroxyl radicals. In contrast, particulate atrazine is quite stable and will remain until removed by wet or dry deposition. Long-range atmospheric transport is known to occur, and atrazine has been detected hundreds of kilometers from the nearest site of use.

Atrazine in Soil

Atrazine has a wide range of mobility in soil, depending on the soil characteristics. Volatility is negligible, but the atrazine is susceptible to dissolution and leaching. The extent of the dissolution depends on the soil particle size and organic content.

Atrazine will biodegrade, especially in moist soils. However, chemical degradation, primarily hydrolysis, is a more important process. The rate of hydrolysis is minimal in neutral conditions but increases rapidly under both acidic and basic conditions. Laboratory studies using only variations on pH have produced hydrolysis half-lives ranging from hours to centuries. Low moisture, high clay content, and high organic matter content also increase hydrolysis rates. Photolysis can occur in surface soils, but is rarely significant.

Atrazine in Water

The high solubility and low vapor pressure of atrazine result in no volatilization from water. Some atrazine, but not all, is adsorbed on sediments. There is minimal potential for biodegradation, so chemical degradation is more important. The primary process is the same acid- and base-catalyzed hydrolysis discussed for soil.

Atrazine in Plants, Animals, and Food

Little bioaccumulation and no biomagnification occur with atrazine. In fact, many measured bioconcentration factors are less than 1. Some uptake into plants does occur, so atrazine has been detected, at quite low concentrations, in market-basket food analyses. Corn and some other plants can completely metabolize atrazine.

Table B-33. Origins and Physical and Chemical Properties of Atrazine

Atrazine					
Major Sources / Uses	• Released into the environment via effluents at manufacturing sites and at points of application where it is employed as a herbicide				
Chemical and Physical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	• Not expected to adsorb strongly to sediments • Volatilization is not environmentally important	• Moderately to highly mobile in soils with low clay or organic matter content	• Initially found in both vapor and gas phases, but vapor phase is rapidly degraded	• Absorbed mainly through plant roots, but also foliage, and it accumulates in new leaves	Irritating hydrogen chloride and toxic oxides of nitrogen may be formed upon combustion

Source for physical and chemical property data: EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan, unless otherwise indicated.

Table B-34. Distribution and Fate of Atrazine

Atrazine					
Distribution and Fate in the Environment	**Transport and Media Partitioning** (physical distribution)				
	Despite its mild solubility in water, atrazine has a high potential for groundwater contamination				
	Water (solid/liquid transfers)	**Soils and Sediments** (solid/liquid transfers)	**Air**		**Living Organisms** (bioaccumulation)
			Volatility	**Gas/Liquid transfers**	
	Water Solubility [1] : 30 mg/L	Log K_{ow} [2] : 2.61 Log K_{oc} : 1.7 to 3.1 (measured)	Vapor Pressure [3] : 2.78×10^{-7} mm Hg at 25 °C	KH [4] : 2.63×10^{-9} atm m^3 mol^{-1}	log BCF [5]: -0.1 to 0.3 (fathead minnow); 0.5 (whitefish)
	• Moderately soluble in water	• High potential for groundwater contamination	• Rapidly degraded in vapor phase		• Not expected to bioconcentrate

Table B-34. Distribution and Fate of Atrazine (continued)

	Transformations and Degradation/Persistence (chemical changes and distribution)				
	Chemical hydrolysis, followed by biodegradation, may be the most important removal route in soils and aquatic environments.				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
Distribution and Fate in the Environment (continued)	Half-life: varies depending upon conditions (such as, pH, organic carbon content) Hydrolyzes rapidly under acidic or basic conditions but slowly at neutral pH	Half-Life: 60 to >100 days (longer in cold or dry conditions) Highly persistent in soil May hydrolyze in either acidic or basic soils yet is fairly resistant to hydrolysis at neutral pH; addition of organic material increases the rate of hydrolysis	Half-life: *additional information needed*	Atmospheric half-life: 2.6 hour at an atmospheric concentration of $5x10^5$ hydroxyl radicals/cm^3 Reactions with photochemically produced hydroxyl radicals in the atmosphere may be important.	In plant species, atrazine increases arsenic uptake. May also inhibit photosynthesis or be metabolized.

(a) EPA. 1993. Revised Draft Lake Michigan Lakewide Management Plan unless otherwise indicated
(b) USDHHS. 1997. Toxicological Profile for Atrazine

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material's tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry's Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry's law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry's law is generally accepted as a good approximation.

Table B-34. Distribution and Fate of Atrazine (continued)

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

B.18 PHYSICAL AND CHEMICAL PROPERTIES OF SELENIUM

In nature, selenium is found in the -2 (selenide), 0 (selenium), +4 (selenite), and +6 (selenate) oxidation states. Selenium has sorptive affinity for hydrous metal oxides, clays, and organic materials. Speciation is determined by pH and potential of the solution. Elemental selenium is favored by low pH and reducing conditions. Selenium chemistry is similar to sulfur chemistry. Natural selenite is usually a component of sulfide minerals.

Selenium in Air

Selenium is present in coal and fuel oil and is emitted in flue gas and fly ash during combustion. When released to the atmosphere, selenium is expected to exist predominantly in the particulate phase. Particulate-phase selenium is physically removed from the atmosphere by wet and dry deposition.

Selenium in Soil and Sediment

In soils, the behavior of selenium is affected by oxidation-reduction conditions, pH, hydrous oxide content, clay content, organic materials, and the presence of competing anions. In sediments, reduced and tightly bound selenium will remain relatively immobile unless the sediments are chemically or biologically oxidized (TOXNET 1999).

Selenium in Water

Selenium occurs in water as a result of the natural weathering of soils and rocks and from the mining and smelting of certain ores. When released into water, selenium is expected to form oxyanions and exhibit anionic chemistry. Selenium and its compounds have water solubilities ranging from low to moderate. Concentrations up to 1,000 milligrams will mix with a liter of water. Selenium is highly persistent in water, with a half-life greater than 200 days (EPA 1986).

Selenium in Plants, Animals, and Food

Trace amounts of selenium are essential for plants and animals. Plants easily take up selenate compounds from water and change them to organic selenium compounds such as selenomethionine. The toxicity of selenium depends on whether it is in the biologically active oxidized form, such as occurs in alkaline soils. These conditions can increase plant uptake of the metal. Plants grown in soils that contain high levels of selenium and selenium compounds can accumulate selenium and may be toxic to grazing livestock (1997). However, such plants are usually found only in semi-arid to arid alkaline soils, so they are not relevant to the Great Lakes area.

Selenium can collect in animals that live in water containing high levels of it. The concentration of selenium found in fish tissues is expected to be somewhat higher than the average concentration of selenium in the water from which the fish were taken (ATSDR 1997).

Table B-35. Origins and Physical and Chemical Properties of Selenium

Selenium					
Major Sources / Uses	• Widely found in sulfide ores and fossil fuels and is released during smelting, burning, and similar operations. • Uses include in photoelectric cells, in semiconductors, in ceramics, in pigments, a few metal alloys, and as an insecticide, a topical drug, and a feed additive.				
Physical and Chemical Forms	**Water**	**Soils and Sediments**	**Air**	**Biota**	**Other Commonly Released Forms**
	Generally found as selenite ion. Other oxidation states may occur.	Found as insoluble heavy metal selenides or as soluble alkali selenites and selenates.	Most found in particulate form. Selenium dioxide (from fuel combustion) is reduced to elemental selenium.	Some bioorganisms will convert to dimethyl selenide, a gas. Higher organisms treat it like sulfur.	The varied chemistry of selenium compounds controls its partitioning among media.

Source: NLM. 2000.

Table B-36. Distribution and Fate of Selenium

<table>
<tr><th rowspan="6">Distribution and Fate in the Environment</th><th colspan="5">Transport and Media Partitioning (physical distribution)</th></tr>
<tr><td colspan="5">Data are given for selenium dioxide, parent of selenious acid and the selenites. Other known environmental forms include all the common oxidation states, including gases and solids</td></tr>
<tr><th rowspan="2">Water</th><th rowspan="2">Soils and Sediments
(solid/liquid transfers)</th><th colspan="2">Air</th><th rowspan="2">Living Organisms
(bioaccumulation)</th></tr>
<tr><th>Volatility</th><th>Gas/Liquid transfers</th></tr>
<tr><td>Water soluble[1] = 4,000,000 g/L</td><td>Log Koc[2] = NA</td><td>Vapor presence[3] = NA
Sublimes at 340 to 350 °C</td><td>KH[4] = NA</td><td>BCF[5] = NA</td></tr>
<tr><td>Most common compounds are relatively soluble in water.</td><td>Except for insoluble heavy metal selenides, it is highly mobile due to its water solubility, and for dimethyl selenide, its volatility.</td><td>Most compounds are nonvolatile, but some oxides and organic species are gases.</td><td>Depends on chemical form</td><td>Some plants bioaccumulate, creating highly toxic forage.</td></tr>
</table>

Table B-36. Distribution and Fate of Selenium (continued)

Distribution and Fate in the Environment (continued)	**Transformations and Degradation/Persistence** (chemical changes and distribution)				
	Water	**Soils**	**Sediments**	**Air**	**Biota**
	Half-life = NA	Half-life = NA	Half-life = NA	Half-life = NA	Half-life = NA

Source for physical and chemical property data: NLM. 2000.

Footnote Information:

[1] Water Solubility: the maximum concentration of a chemical that dissolves in pure water.

[2] Log K_{oc} (Organic Carbon Partitioning Coefficient) or Log K_{ow} (Octanol-water partition coefficient): both measure a material’s tendency to adsorb to soil/organic matter/sediment. High K_{oc} values indicate a tendency for the material to be adsorbed by the solid phase rather than remain dissolved in solution. Strongly adsorbed molecules will not leach or move unless the soil particle to which they are adsorbed moves (as in erosion). K_{oc} values <500 indicate little or no adsorption and a potential for leaching.

[3] Vapor Pressure: a measure of volatility. Organic compounds with vapor pressures $>10^{-4}$ mm Hg should exist almost entirely in the vapor phase in the atmosphere, while organic compounds with vapor pressures $<10^{-8}$ mm Hg should exist almost entirely in the particulate phase.

[4] KH (Henry’s Gas Law Coefficient): reflects the physical solubility of a given gas. Defined as the ratio of the aqueous phase concentration of a chemical in moles per liter (mol/L) to the partial pressure of the substance in the gas phase in atmospheres (atm). Soluble gases have large Henry’s law coefficients. When considering the behavior of atmospheric gases in equilibrium with large natural bodies such as lakes, Henry’s law is generally accepted as a good approximation.

[5] BCF (Bioconcentration Factor): A measure of the tendency for a chemical to accumulate in tissues of an organism (such as fish) to levels that are greater than that in the medium (such as water). Defined as the ratio of the concentration of the substance in the living organism in milligrams per kilogram (mg/kg) to the concentration of the substance in the surrounding environment in milligrams per liter (mg/L).

APPENDIX C

HUMAN HEALTH

Lake Michigan Lakewide Management Plan: Human Health Appendix

April 2000

.Lake Michigan Lakewide Management Plan (LaMP): Human Health Appendix

Table of Contents

Lake Michigan Lakewide Management Plan (LaMP): Human Health Appendix

1.0 Introduction

1.1 Great Lakes Water Quality Agreement and the Lakewide Management Plan

The purpose of the Great Lakes Water Quality Agreement of 1978, a binational agreement between the United States and Canada, “is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem” (IJC 1994). The Agreement calls for the establishment of Lakewide Management Plans (LaMPs) for open lake waters. These plans are “. . .designed to reduce loadings of Critical Pollutants in order to restore beneficial uses” (IJC 1994), in the form of fish and drinking water consumption, and recreational water use. In addition, the LaMPs are required to define [describe] the threat to human health from Great Lakes Critical Pollutants (substances that may cause impairment of beneficial uses). The International Joint Commission (IJC), which assists in the implementation of the Agreement, has identified 11 Great Lakes Critical Pollutants (IJC 1998). They are alkylated lead, benzo[a]pyrene, DDT [1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane] and metabolites, dieldrin, dioxins, furans, hexachlorobenzene, methylmercury, mirex, PCBs (polychlorinated biphenyls), and toxaphene (Table 1). In addition, the broader Agreement calls for recreational waters to be substantially free from bacteria, fungi, and viruses, and also calls for control of contaminated groundwater (drinking water).

1.2 Health Objectives of the Lake Michigan LaMP Human Health Appendix

The health objectives are to support the human health requirements of the Great Lakes Water Quality Agreement by 1) defining (describing) the potential adverse human health effects arising from exposure to Critical Pollutants and other contaminants found in Lake Michigan and other connecting Great Lakes and waterways, 2) examining societal responses (i.e., implementation strategies), such as health advisories for fish consumption to minimize exposure to contaminants found in fish from Lake Michigan and other Great Lakes, and 3) making recommendations for continued research in areas such as chemical mixtures effect and endocrine disruptors (Table 2).

Table 1: International Joint Commission's Critical Pollutants

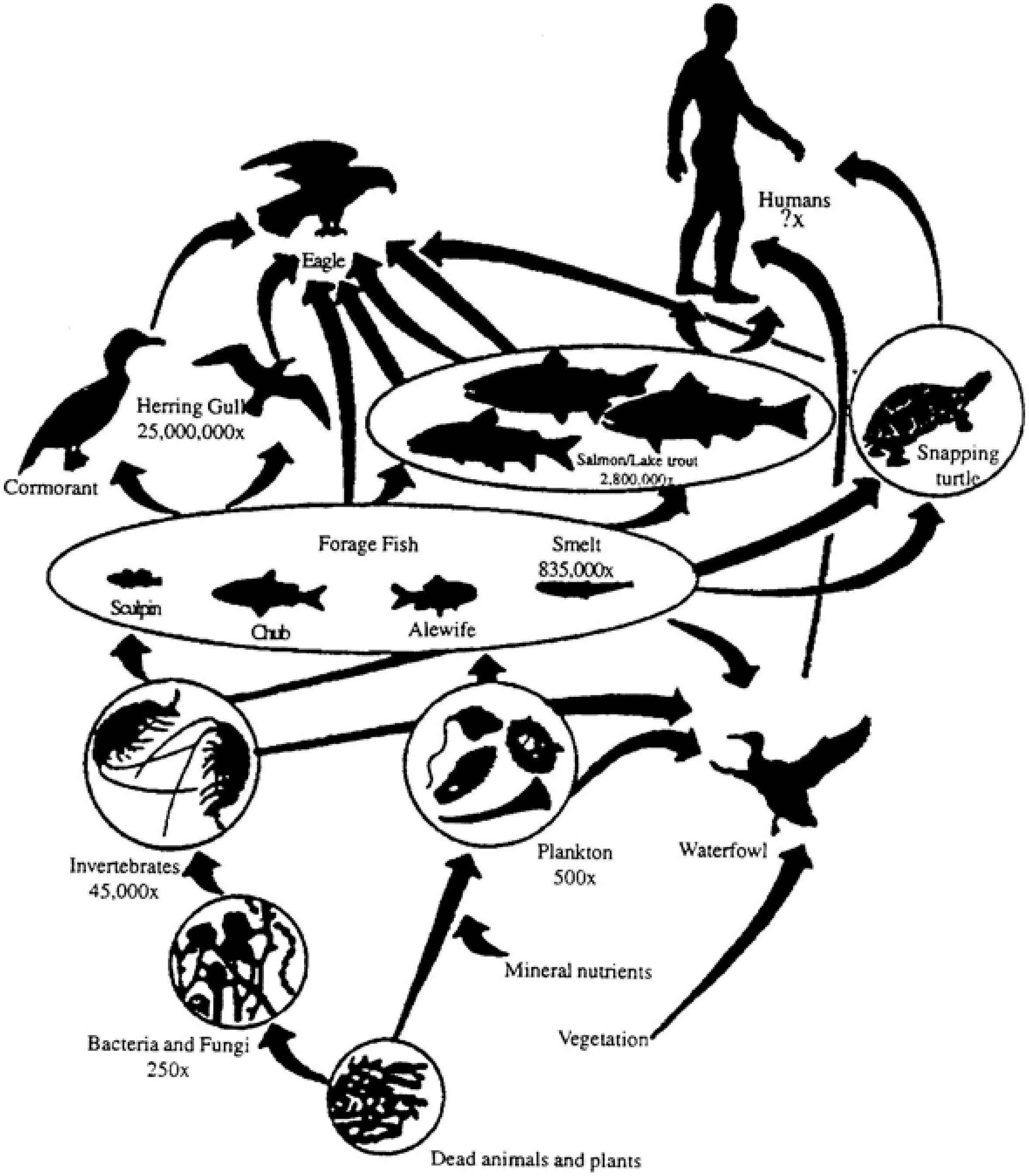
Organic Compounds	**Metals**
Benzo{a}pyrene	Alkylated Lead
DDT and metabolites	Mercury
Dieldrin	
Dioxins	
Furans	
Hexachlorobenzene	
Mirex	
PCBs	
Toxaphene	

Adapted from IJC 1998.

1.3 Pathways of Exposure and Human Health

The chemical pollutants of concern in Lake Michigan include substances such as organochlorines and heavy metals that are known to cause adverse health effects in animals and humans (Table 3). Organochlorines are highly lipophilic and biomagnify in the aquatic food chain, making them available to humans and other higher forms of life, as shown in Figure 1. Lipophilic substances found in the Great Lakes basin include PCBs, hexachlorobenzene, DDT and metabolites, dioxin (2,3,7,8-TCDD), mirex, dieldrin, toxaphene, and furans (Johnson et al. 1999). In addition, alkylated lead and mercury also tend to bioaccumulate in human tissue and are known to cause harmful health effects (Johnson et al. 1999). Recent findings indicate that populations continue to be exposed to persistent toxic substances within the Great Lakes and St.

Figure 1: Great Lakes Food Web



Great Lakes food web. Heavy metals and many synthetic chemicals are absorbed by organisms and bioaccumulate, with concentrations reaching toxic levels if exposure is great enough. The concentration is magnified at each step of the food web as large organisms eat many small ones. Numbers = Biomagnification of PCBs in Lake Ontario.
Source: Johnson et al. 1999.(reprinted with permission)

Lawrence River basins and that health consequences are associated with these exposures (Johnson et al. 1999).

Although the contaminant levels in the Great Lakes are declining, in general, recent trends suggest that concentrations for some pollutants may be leveling off. Low or declining levels may be associated with health consequences. For example, Jacobson and coworkers (1984) found that chronic, low-level prenatal exposure to PCBs was associated with neurobehavioral deficits in infants whose mothers consumed contaminated Lake Michigan fish. These results are supported by the recent work by Lonky and coworkers (1996) in newborns.

The three major routes that chemical and microbial pollutants enter the human body are by ingestion (water, food, soil), inhalation (airborne particles), and dermal contact. The human health goals for the Lake Michigan LaMP are driven by improvements in beneficial uses that are related to these exposure pathways. For example, restrictions on fish and wildlife consumption, restrictions on drinking water consumption, or beach closings prevent populations in the Lake Michigan area from enjoying the beneficial uses of the lake. An awareness of the underlying causes of these restrictions (e.g., chemical and microbial contaminants) and their associated health consequences will allow public health agencies to develop societal responses protective of public health. The human health goals for the Lake Michigan LaMP are outlined in Table 2.

Table 2: Human Health Goals for Lake Michigan LaMP and Pathways of Exposure

Human Health Goal	Pathway of Exposure
We can all eat any fish	Ingestion of food (fish)
We can all drink the water	Ingestion of water
We can all swim in the water	Dermal contact, inhalation, ingestion

1.4 Chemical Pollutants and Microbial Pollutants

The Lake Michigan LaMP has also established lists of Critical Pollutants, Pollutants of Concern, and Emerging Pollutants (Table 3). The Lake Michigan Critical Pollutants are chemicals that violate the most stringent Federal/State water quality standard or criteria, exceed the U.S. Food and Drug Administration (FDA) action levels in Lake Michigan fish, or are associated with lakewide use impairments. They are chlordane, DDT and metabolites, dieldrin, dioxins, furans, PCBs (polychlorinated biphenyls), and mercury. The Lake Michigan Pollutants of Concern are defined as toxic substances associated with local or regional use impairments, or those for which there is evidence that loadings to or ambient concentrations in the Lake Michigan watershed are increasing. They are arsenic, cadmium, chromium, copper, cyanide, hexachlorobenzene, lead, PAHs (polycyclic aromatic hydrocarbons), toxaphene, and zinc. The Lake Michigan Emerging Pollutants are toxic substances that, while not presently known to contribute to impairments or to show increasing loadings/concentrations, have characteristics that indicate a potential to impact the physical or biological integrity of Lake Michigan. They are atrazine, PCB substitute compounds, such as DHEP (di(2-ethylhexyl)phthalate) and TCBT (tetrachlorobenzyltoluene), and selenium. In addition to examining the chemical pollutants, the Lake Michigan LaMP Human Health Appendix will also examine microbial pollutants in recreational waters and drinking water.

Table 3: Lake Michigan Pollutants

Critical Pollutants	Pollutants of Concern	Emerging Pollutants
Chlordane	Arsenic	Atrazine
DDT & Metabolites	Cadmium	Selenium
Dieldrin	Chromium	PCB Substitute Compounds
Dioxins	Copper	DEHP (see text)
Furans	Cyanide	TCBT (see text)
PCBs	Hexachlorobenzene	
Mercury	Lead - alkylated	
	PAHs (see text)	
	Toxaphene	
	Zinc	

1.5 Weight of Evidence Approach

The weight of evidence approach will be used to describe the wildlife and laboratory studies supporting existing humans studies which demonstrate the potential human health impact from exposure to chemical pollutants (Johnson et al. 1998). The objectives of the Lake Michigan LaMP Human Health Appendix will be accomplished by utilizing peer-reviewed reports published by the Agency for Toxic Substances and Disease Registry (ATSDR) and other organizations.

2.0 Lake Michigan Pollutants

Toxicological summaries for Lake Michigan Critical Pollutants, Pollutants of Concern, and Emerging Pollutants are provided below.

2.1 Toxicology of Chemical Pollutants

2.11 Critical Pollutants

1. *Chlordane* (ATSDR 1995a)

   Chlordane is a manufactured chemical that was used as a pesticide in the United States from 1948 to 1988. In 1983, the U.S. Environmental Protection Agency (USEPA) banned all uses of chlordane except to control termites. In 1988, USEPA completely banned all uses. Chlordane adheres strongly to soil and is not likely to enter groundwater. Chlordane most commonly leaves soil by evaporation into the air. It builds up in the tissues of fish, birds, and mammals. Chlordane affects the nervous system, the digestive system, and the liver in animals and humans. Headaches, irritability, confusion, weakness, vision problems, vomiting, stomach cramps, diarrhea, and jaundice have occurred in persons who breathed air containing high concentrations of chlordane or accidentally swallowed small amounts of chlordane. Large amounts of chlordane taken by mouth can cause convulsions and death in humans. Mice fed low levels of chlordane in food developed liver cancer. Studies of workers who made or used chlordane do not show that exposure to chlordane is related to cancer, but the information is not sufficient to know for certain. The International Agency for Research on Cancer has determined that chlordane is not classifiable as to its carcinogenicity to humans.

2. *DDT, DDE, and DDD* (ATSDR 1995c)

DDT [1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane] is a manufactured chemical widely used to control insects on agricultural crops and insects that carry diseases like malaria and typhus. It does not occur naturally in the environment. Because of adverse health effects to wildlife and the potential harm to human health, the use of DDT was banned in the United States. DDT is still used in other countries. Two similar metabolites of DDT are DDE [1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene] and DDD [1,1-dichloro-2,2-bis(p-chlorophenyl)ethane]. DDD was also used to kill pests, but its use has also been banned. DDT adheres strongly to soil and does not move quickly to underground water. It is broken down quickly in air. DDT in soil usually breaks down to form DDE or DDD. DDT builds up in plants and in the fatty tissues of fish, birds, and animals. DDT affects the nervous system. Persons who accidentally swallowed large amounts of DDT have developed excitability, tremors, and seizures. These effects disappeared after the exposure ceased. Persons administered 6 mg DDT per kilogram of body weight orally by capsule generally demonstrated no neurological illness. Long-term occupational exposures to DDT have resulted in reversible changes in the levels of liver enzymes that influence the liver function. In animals, short-term exposure to large amounts of DDT in food affected the nervous system. In animals, long-term exposure to DDT has affected the liver. Animal studies suggest that short-term exposure to DDT in food may have a harmful effect on reproduction. The U.S. Department of Health and Human Services has determined that DDT may reasonably be anticipated to be a human carcinogen. The USEPA has determined that DDE and DDD are probable human carcinogens.

3. *Dieldrin* (ATSDR 1993a)

Aldrin and dieldrin are insecticides having similar chemical structures. Sunlight and bacteria convert aldrin to dieldrin, so that dieldrin is found more frequently in the environment than aldrin. In 1974, USEPA banned the use of aldrin and dieldrin, due to the potentially harmful effect to human health and the environment. Since the ban, very little dieldrin has been found in most foods; however, fish, seafood, dairy products, fatty meats, and root crops from contaminated water or soil, may still have higher levels of dieldrin. The potential effects from low levels of exposure to aldrin and dieldrin are not known. However, headaches, dizziness, vomiting, irritability, and uncontrolled muscle movements have been observed in occupational pesticide applicators. Ingestion of moderate levels of these substances may accumulate in the body and cause convulsions. Exposure to very high levels due to accidental or intentional ingestion of aldrin and dieldrin may lead to convulsions and death. Although mice exposed to high levels of dieldrin are reported to develop liver cancers, no such evidence has been documented in humans. The International Agency for Research on Cancer has determined that aldrin and dieldrin are not classifiable as to their carcinogenicity to humans.

4. *Dioxins* (ATSDR 1999a)

Chlorinated dibenzo-p-dioxins (CDDs) are a family of 75 chemically related compounds, commonly known as dioxins. Of these, 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) is the most toxic and the most studied. Dioxins, particularly 2,3,7,8-TCDD, are formed in paper and pulp manufacture, during chlorination of waste and drinking water, and in the manufacture of organic chemicals. However, dioxins as a byproduct of chlorination have not been found in Michigan drinking water (Communication from Michigan Department of Community Health 3/24/00). Air releases occur from solid waste and industrial incineration. CDDs escape from waste water and are broken down by sunlight, evaporate into the air, but generally adhere to soil and become part of the water sediment. CDDs can be found at measurable concentrations in animals within the food chain due to bioaccumulation. More than 90% of the intake of CDDs in the general population comes from consumption of meat, dairy products, and fish. Chloracne (acne-like skin lesions) of the face and upper body occurs from exposure to large amounts of 2,3,7,8-TCDD, and other skin effects are also seen (i.e., skin rash, discoloration, and body hair). Blood and urine changes may be an indication of liver damage. Exposures to high concentrations of CDDs may result in long-term changes in glucose metabolism and subtle changes in hormonal levels. Animal studies have also demonstrated an increased risk of cancer from 2,3,7,8-TCDD. Studies in humans suggest that 2,3,7,8-TCDD exposure increases the risk of several types of cancer. The U.S. Department of Health and Human Services has determined that 2,3,7,8-TCDD is known to cause cancer.

5. *Chlorodibenzofurans* (CDFs) (ATSDR 1995b)

CDFs are a family of chemicals (135) containing 8 chlorine atoms attached to the parent chemical dibenzofuran. The CDFs with chlorine atoms at the 2,3,7,8-positions are particularly harmful. CDFs are by-products of paper and pulp manufacture and incineration. They are generally found in air as solid particles and vapors. Snow and rain can remove the vaporized CDFs from air. They attach to soil, sediments in lakes and rivers, and may bioaccumulate in fish at levels much greater than detected in water or sediment. CDFs can also bioaccumulate in animals, birds, and humans through ingestion of contaminated foods. Ninety-percent (90%) of the daily exposure comes from consumption of contaminated food (e.g., meat, fish, milk). Inhaling air or drinking water, and contact with contaminated soil are other sources of exposure. Most of the data on human health comes from studies of accidental exposure to foods contaminated with CDFs. The concentration of CDFs, in these cases, exceeded the amounts from environmental or dietary exposure. CDFs exposures resulted in skin and eye irritation (e.g., acne, skin discoloration, swollen eyelids), vomiting and diarrhea, anemia, lung infections, numbness, nervous system effects, and mild liver changes. It is unknown if CDFs cause human cancer. The U.S. Department of Health and Human Services has not classified CDFs for carcinogenicity.

6. *PCBs* (polychlorinated biphenyls) (ATSDR 1997c)

PCBs are organic chemicals consisting of 209 individual congeners. Some commercial mixtures in the United States have the industrial trade name of Aroclor. PCBs have been used as coolants and lubricants in transformers, capacitors, and other electrical equipment. PCBs manufacture ceased in 1977 due to accumulation of PCBs in the environment and potential adverse health effects. Today, PCBs can be discharged into the environment from hazardous waste sites containing PCBs, illegal dumping, and leaks from transformers. PCBs can travel in air. In water, most PCBs adhere to organic particles and sediments with a small amount dissolved in the water. Fish and marine mammals may bioaccumulate PCBs in excess of the amounts found in water. Human exposure may result from eating food (e.g., fish, meat, dairy products), drinking well water contaminated with PCBs, breathing air near hazardous waste sites, or leaks of PCBs from appliances. PCBs have been associated with birth defects and reproductive problems in human studies. Inhalation of PCBs results in irritation of the nose and lungs, and skin irritations. PCBs cause liver cancer in animals, but it is not known if PCBs are a human carcinogen. The U.S. Department of Health and Human Services has determined that PCBs may reasonably be anticipated to be carcinogens.

7. *Mercury* (ATSDR 1999b)

Mercury is a metal found naturally in the environment. It can be found in the metallic, liquid form; as inorganic mercury compounds (salts) with chlorine, sulfur, or oxygen; and as organic mercury in combination with carbon. Methylmercury is the most common organic mercury. Metallic mercury is utilized in the production of chlorine gas and caustic soda, and is used in thermometers, dental fillings, and batteries. Mercury salts have been used in skin lightening creams and as antiseptic creams and ointments. Inorganic mercury is found in air from mining, burning of coal and waste, and from industry, and can also be found in water or soil as natural deposits, waste disposal, and volcanic activity. Methylmercury is produced by the action of microscopic organisms in water and soil. It can bioaccumulate in fish with the larger and older fish having the highest levels of mercury. Exposure to methylmercury may occur from consuming contaminated fish or shellfish; inhalation of vapors from spills, incinerators, and industry; or inhaling contaminated air or skin contact in the workplace. The nervous system is susceptible to all forms of mercury. Because methylmercury and metallic mercury vapors can affect the brain, they are more harmful than other forms of mercury. Exposure to high levels of metallic, inorganic, or organic mercury can permanently injure the brain, kidneys, and developing fetus. Mercury in mother’s breast milk may be passed to the nursing infant. Nervous system effects include irritability, shyness, tremors, changes in vision or hearing, and memory problems. Short-term exposure to metallic mercury vapors at high concentrations may produce lung damage, nausea and vomiting, diarrhea, rise in blood pressure or heart rate, skin rashes, and eye irritation. Effects of fetal exposure include incoordination, blindness, seizures, and inability to speak. Children exposed to mercury may exhibit effects on the nervous and digestive systems and to the kidney. Animal studies have shown tumor development from exposure to mercuric chloride and methylmercury. The data on cancer effects is inadequate for human exposure to mercury. USEPA has concluded that mercury chloride and methylmercury are possible human carcinogens. The U.S. Department of Health and Human Services and the International Agency for Research on Cancer have not classified mercury as to its human carcinogenicity.

2.12 Pollutants of Concern

1. *Arsenic* (ATSDR 1993b)

Arsenic is present in the environment in two forms, organic and inorganic. Organic arsenic is formed by combining with carbon and hydrogen and is less harmful than inorganic arsenic compounds, which are formed in combination with oxygen, chlorine, and sulfur. Inorganic arsenic is used most often in the production of wood preservatives, insecticides, and weed killers. Although arsenic bioaccumulates in fish and shellfish, it is generally in the less harmful organic form. Human exposure may occur by breathing sawdust or burning smoke from arsenic-containing wood; by breathing workplace air where arsenic is detected; and by ingesting contaminated water, soil, or air at waste sites or places with high detected levels of arsenic. Inorganic arsenic is a human poison. Ingesting high levels of inorganic arsenic in food or water can be fatal. Other health effects from high-level exposure include damage to tissues, and development of a sore throat and irritated lungs. Low-level exposure may lead to nausea, vomiting, diarrhea, decreased production of red and white blood cells, abnormal heart rhythm, blood vessel damage, and “pins and needles” sensations in the hands and feet. Inhaling inorganic arsenic increases the risk of lung cancer. Ingestion increases the risk of skin cancer and tumors of the bladder, kidney, liver, and lung. The U.S. Department of Health and Human Services has determined arsenic to be a known carcinogen.

2. *Cadmium* (ATSDR 1993c)

Cadmium may be found naturally in the earth's crust, usually combined with other elements. It can be found in water and soil from waste disposal, spills, or leaks from hazardous waste sites. Fish, plants, and animals take in cadmium from the environment. Human exposure may result from inhalation of cadmium in the workplace or from municipal waste sites, or cigarette smoke. It can also result from ingestion of contaminated water, fish, plants, and animals. Low level, long term exposures from air, food, or water may result in kidney disease. High level inhalation exposure can result in severe lung damage and death. Ingestion of very high levels in food or drinking water may result in vomiting and diarrhea. Based upon weak human and strong animal evidence, the U.S. Department of Health and Human Services has determined that cadmium and its compounds may be carcinogenic.

3. *Chromium* (ATSDR 1993d)

Chromium is a naturally occurring element found in most mineral and organic substances. It is used in the production of steel and other alloys, bricks, dyes and pigments, and for chrome plating, leather tanning, and wood preserving. Chromium enters the environment when these products, or fossil fuels, are burned. Dissolved chromium is not common, as the element tends to remain bound to particles in the water column. Fish and other aquatic life do not bioaccumulate chromium. Chromium can be toxic at high levels. Human exposure occurs mainly through breathing air or sawdust from industries which manufacture chromium-containing products, or at waste sites where chromium exists at high levels. Ingesting food or water contaminated with chromium from soil (near such sites) could also lead to exposure. High levels of chromium ingestion can be fatal, or could lead to stomach upsets, ulcers, convulsions, kidney and liver damage. Breathing high levels of chromium can cause damage or irritation to the nose, lungs, stomach, and intestines. Long-term exposure to high levels of chromium leads to nose and lung damage. In addition, the risk of non-cancer lung diseases increases with exposure level. The U.S. Department of Health and Human Services has determined that certain chromium compounds are carcinogens.

4. *Copper* (ATSDR 1990)

Copper may be found naturally in the earth's crust, water, air as well as in plants and animals. This common environmental element is essential for all living organisms. It can be found in mixtures of metals, natural occurring minerals and man-made chemicals. Mined and processed extensively in the U.S., copper is used in the manufacture of metals, industry, agriculture, and as a preservative for wood, leather and fabrics. Exposure may result from ingestion, inhalation and dermal contact. Individuals living or working near copper mines or processing facilities may breathe higher levels of copper containing dust. Individuals in households with copper pipes and brass faucets may be exposed to high levels of copper in drinking water. However, copper found in lakes and rivers does not easily enter the body since it strongly adheres to existing particles in lake and river water. Copper may be deposited in soil from copper production facilities, mining, and sewage treatment plant sludge. It adheres strongly to soil. Although copper is essential for good health, high levels of copper may be harmful. Long-term exposure may result in irritation of the nose, mouth, and eyes and can cause headaches, dizziness, nausea, and diarrhea. Drinking water with high levels (greater than 1.3 ppm) of copper may cause vomiting, diarrhea, stomach cramps, and nausea. Liver and kidney damage and death may result if high levels (greater than 2-3 milligrams for adults) of copper are intentionally consumed. Copper has not been classified as a carcinogen.

5. *Cyanide* (ATSDR 1997a)

Cyanide is a chemical produced naturally and as a by-product of electroplating, metallurgy, chemical production, photographic development, plastic production, ship fumigation, and some mining processes. Cyanide and the chemicals containing cyanide enter the environment through natural and industrial processes. Airborne cyanide exists as a gas, or adhered to fine dust particles. Cyanide in surface water typically evaporates as hydrogen cyanide. High concentrations of cyanide in the soil, however, can pass through to groundwater. Once in the water column, cyanide will not accumulate in fish or other aquatic organisms. Human exposure to cyanide occurs by breathing contaminated air such as cigarette smoke, smoke from fires, air near a hazardous waste site, or air inside an industrial facility which produces cyanide as a by-product. Cyanide may also be ingested by eating contaminated foods, or touching contaminated soil or other surfaces. Short-term exposure to high levels of cyanide in the air can adversely affect the heart and brain, and can cause coma and death. Low level, long-term cyanide exposure can lead to difficulty breathing, heart pain, vomiting, blood changes, headaches, and thyroid gland enlargement. According to the USEPA, cyanide has not been classified as a human carcinogen.

6. *Hexachlorobenzene* (ATSDR 1997b)

Hexachlorobenzene is a compound which does not occur naturally in the environment. Rather, it is formed as a by-product of chemical production processes, and may be found in the waste streams of chloralkali and wood-preserving plants, and when burning municipal waste. Hexachlorobenzene is found in the environment, most often, bound to soil particles, as it does not dissolve easily in water. It does accumulate in plants such as wheat and grasses as well as organisms including fish, birds, lichens and mammals which feed on lichens. Exposure to hexachlorobenzene can be harmful to humans. Human exposure generally occurs by ingesting contaminated food such as fish, milk, dairy products, meat from cattle which grazed on contaminated pastures, breast milk from exposed mothers, or water, or through breathing contaminated air or touching soil or other contaminated substances. Ingestion of hexachlorobenzene may lead to damage of the liver, thyroid, nervous system, bones, kidneys, blood, and immune and endocrine systems. The U.S. Department of Health and Human Services has determined that hexachlorobenzene may reasonably be expected to be a carcinogen.

7. *Lead* (ATSDR 1993f)

Lead is a metal found naturally occurring in the earth’s crust. It enters the environment through mining, the burning of fossil fuels, and manufacturing batteries, ammunition, metal products, roofing, and devices to shield x-rays. Lead binds to soil particles and remains in the air after emission until the particles fall to the ground or water. Lead in urban soil can also be attributed to landfills and leaded paint. Acidic water can cause lead to dissolve into the water column from contaminated sediments. Almost every organ and system in the human body may be affected by lead. Humans are exposed to lead by breathing contaminated air from industry, tobacco smoke, or hobbies, and, also, ingesting lead-based paint chips, food grown on contaminated soil or food covered with contaminated dust, and drinking water from lead pipes or pipes with lead soldering. The central nervous system is particularly sensitive, and the kidneys and immune system are at risk as well. Children and fetuses are particularly sensitive to high level exposure, with dangers of premature births, low birth weights, decreased mental abilities, learning difficulties, and reduced growth. Adults may suffer decreased reaction times, weakness, anemia, and reproductive disorders when exposed to high levels of lead. The U.S. Department of Health and Human Services has determined that lead acetate and lead phosphate may reasonably be anticipated to be carcinogenic.

8. *Polycyclic Aromatic Hydrocarbons* (PAHs) (ATSDR 1996)

PAHs consist of over 100 chemicals which are formed during the incomplete combustion of fossil fuels, municipal waste, and other organic substances. Some PAHs are manufactured for use in coal and roofing tar, crude oil, dyes, plastics, and pesticides. PAHs enter the environment through the combustion of fossil fuels as well as from volcanoes and forest fires. Generally, PAHs bind to soil particles, so are found in airborne particles as well as in sediment in the water column. Plants and animals do accumulate PAHs, and the concentration in these organisms may be much greater than the concentration in surrounding water or soil. PAHs are considered harmful to human health. Humans may be exposed to PAHs by breathing contaminated air from industrial processes or contaminated smoke; having physical contact with air, water, or soil near hazardous waste sites; eating contaminated foods or drinking contaminated water or milk; and breast milk for infants of mothers exposed to PAHs. No harmful effects have been proven in humans, although animal studies have shown adverse effects on the reproductive cycle, skin, body fluids, and the ability to fight disease. The U.S. Department of Health and Human Services has determined that some PAHs may reasonably be expected to be carcinogens.

9. *Toxaphene* (ATSDR 1997e)

Toxaphene is used as an insecticide and is a mixture of over 670 chemicals. Its usual state is as a solid or gas. Prior to its cancellation (1982) and ban (1990), toxaphene had a high-volume use as an insecticide. One of its uses was the destruction of unwanted fish in lakes. Toxaphene may be found in the environment from migration near hazardous waste sites and may evaporate into the air. Since it does not dissolve easily in water, it is generally found in soil or sediment at the bottom of lakes or streams, or in the air. Toxaphene deteriorates slowly in the environment and bioaccumulates in fish and mammals. Exposure may also result from inhalation of contaminated air near hazardous waste sites, or may be ingested by children eating contaminated soil. Exposure may also result from consuming fish and shellfish, or well water contaminated with toxaphene. Inhalation or consumption (eating or drinking) high levels of toxaphene may result in injury to the lungs, nervous system, and kidneys, and may be fatal. Human health studies are not available. However, animal studies have shown developmental effects in newborns, whose mothers received exposure to toxaphene during pregnancy. The U.S. Department of Health and Human Services has determined that toxaphene may reasonably be anticipated to be a human carcinogen.

10. *Zinc* (ATSDR 1995d)

Zinc is an element found in the earth's crust. Most zinc is released into the environment through mining, steel production, coal burning, and burning of waste. Zinc exists in the air bound to particles, but dissolves easily in water. Zinc does accumulate in fish and other organisms but not in plants. Although zinc is an essential component in the human diet, it can be harmful to human health in large quantities. Humans are exposed to zinc through drinking water contaminated at manufacturing or waste sites; water or other liquids stored in, or transported through, zinc-coated pipes or containers; breathing zinc particles at manufacturing sites; or eating too many zinc dietary supplements. High levels of zinc consumption can cause stomach cramps, nausea, and vomiting. Long-term zinc over-consumption can lead to anemia, pancreas damage, and low levels of high density lipoprotein cholesterol. Breathing high levels of zinc can cause a short-term disease called metal fume fever which affects the lungs and body temperature. The U.S. Department of Health and Human Services, the International Agency for Research on Cancer, and the USEPA have not classified zinc for carcinogenicity.

2.13 Emerging Pollutants

1. *Atrazine* (EPA 1999a; Sittig 1991)

Atrazine is one of a group of chemically similar triazine herbicides. They include cyanazine, propazine, and simazine, as well as atrazine. At present, atrazine is one of the two most utilized U.S. agricultural pesticides. Exposure may result from ingesting food and drinking water contaminated with the triazines, or occupationally in the application of pesticides. Harmful health effects include dermatitis and eye irritation. High exposure levels may affect the nervous system. USEPA has classified atrazine and the other triazines as possible human carcinogens.

2. *PCB Substitutes:*

DEHP (ATSDR 1993e)

DEHP [di(2-ethylhexyl)phthalate] is a manufactured chemical used in the production of polyvinyl chloride plastic products. It is also found in inks, pesticides, cosmetics, and vacuum pump oil. Because of its use in plastics, it is ubiquitous in the environment. It can dissolve in water more quickly in the presence of gas, oil, or paint removers, and adheres well to soil particles. Microorganisms in water or soil help to break down DEHP into harmless compounds. This break down does not occur easily in soil, or in lake or river bottoms. DEHP can be found in plants, fish, and other animals; however, animals high on the food chain have the ability to break down DEHP, avoiding accumulation in the body tissues. Exposure, usually at low levels, may occur from plastic medical products and food wrap, in well water near waste sites, occupational exposure, or tubing for kidney dialysis. Evidence does not show that DEHP causes serious human health effects. In animals, airborne exposure did not produce serious health effects. Very high exposure of animals in food or water caused sperm damage which was reversed when the exposure ceased. Longer exposure caused reproductive and birth defects in male and female animals. Long-term, high level exposures caused kidney damage to animals, similar to that seen in long-term dialysis patients. Dermal effects are unlikely because it is not absorbed through the skin. The U.S. Department of Health and Human Services has determined that DEHP may reasonably be anticipated to be a human carcinogen.

TCBT

TCBT (tetrachlorobenzyltoluene) is a PCB substitute that induces toxicological changes similar to PCBs with pathological effects to the liver and thyroid in mice (Murk et al. 1991). Hepatic toxicity was also observed in rats with introduction of TCBT by gavage (Bouraly and Millischer 1989). Rats exposed to a single high oral dose (300 mg/kg) had a marked rise in the liver's cytochrome-P-450c dependent reactions (von Meyerinck et al. 1990).

3. *Selenium* (ATSDR 1997d)

Metallic selenium is usually found in rocks and soil. Selenium in rock is usually combined with sulfide minerals or with silver, copper, lead, and nickel minerals. It is also found combined with oxygen. Selenium sulfide is found in anti-dandruff shampoos. Selenium acid, formed from selenium dioxide, is used to clean guns. Selenium can be found in air or in irrigation drainage water from agricultural fields. It can accumulate in animals residing in areas where water is contaminated with selenium. Exposure may result from inhaling contaminated air or by consuming food, water, or dietary supplements containing selenium. Exposure to high levels has produced dizziness, fatigue, irritation, fluid in the lungs, and severe bronchitis. The exact levels causing these effects is not known. Skin contact may result in rashes, swelling, and pain. Dietary levels higher than 5-10 times the daily requirement can be harmful. Excessive doses can be life threatening, result in brittle hair and deformed nails, and also loss of feeling and control in the arms and legs. Animal studies have reported liver and lung tumors in animals at high doses. The U.S. Department of Health and Human Services has determined that selenium sulfide is reasonably anticipated to be a carcinogen.

2.2 Recreational Waters

In 1972, the US Congress passed the Clean Water Act to improve the polluted condition of the nation's waters (EPA 1998). Although the Act's original intent was to have "fishable and swimmable" water, presently, its main objective is to preserve the "chemical, physical and biological integrity of water". The most significant source of water pollution is polluted runoff (e.g., oxygen depleting substances, metals, pesticides, organic chemicals). Control of pollution from point sources, such as factories and city sewers has helped to reduce contamination. In addition, the Act has been responsible for the twofold increase in waterways that are safe for swimming and fishing. However, assessments by states indicate that 40 % of the nation's waterways are still not safe for fishing and swimming.

Beaches, rivers, and lakes are the destinations most utilized by Americans as vacation sites (NRDC 1999) . During these trips, Americans will swim, fish, go boating, or relax. Swimming involves full body contact with the water, and may involve ingestion or inhalation exposure to pollutants in water.

The Great Lakes Water Quality Agreement (IJC 1994) calls for recreational waters to be substantially free from bacteria, fungi, and viruses. These microbial organisms of fecal origin have the potential for causing relatively mild illnesses (e.g., gastroenteritis) to more serious illnesses (e.g., hepatitis, typhoid fever) from a single episode of exposure. The risk of illness is dependent upon the degree of water pollution, the individual's level of exposure, immunization status (e.g., polio), and the general health of the individual. For this reason, the protection of the public's health is directed at controlling microbial pollutants in recreational waters. See Table 4 for the swimming associated illnesses.

As a result of the Clean Water Act, the USEPA has established guidelines on the maximum level of pollution acceptable for fresh water use. The USEPA recommends enterococcus or E. coli as indicators because the detection of these organisms provides a reliable estimate of the presence of disease-causing bacteria or viruses in the water (NRDC 1999). Most states utilize the fecal coliform or total coliform counts to monitor recreational waters. For Great

Table 4: Pathogens and Swimming-Associated Illnesses

Pathogenic Agent	**Disease**
Bacteria	
E. coli	Gastroenteritis
Salmonella typhi	Typhoid fever
Other salmonella species	Various enteric fevers (often called paratyphoid), gastroenteritis, septicemia (generalized infections in which organisms multiply in the bloodstream)
Shigella dysenteriae and other species	Bacterial dysentery
Vibrio cholera	Cholera
Viruses	
Rotavirus	Gastroenteritis
Norwalkvirus	Gastroenteritis
Poliovirus	Poliomyelitis
Coxsackievirus (some strains)	Various, including severe respiratory diseases, fevers, rashes, paralysis, aseptic meningitis, myocarditis
Echovirus	Various, similar to coxsackievirus (evidence is not definite except in experimental animals)
Adenovirus	Respiratory and gastrointestinal infections
Hepatitis	Infectious hepatitis (liver malfunction), also may affect kidneys and spleen
Protozoa	
Cryptosporidium	Gastroenteritis
Giardia lambia	Diarrhea (intestinal parasite)
Entamoeba histolytica	Amoebic dysentery, infections of other organisms
Isopora belli and Isopora hominus	Intestinal parasites, gastrointestinal infection
Balantidium coli	Dysentery, intestinal ulcers

Source: NRDC 1999.

Lakes swimming (fresh waters), the EPA-recommended standard is a geometric mean of 33 enterococcus bacteria per 100 ml (milliliters), or 126 E. coli bacteria per 100 ml of water (EPA 2000). Of the eight Great Lakes states, Indiana, Michigan, and Ohio utilize the E. coli indicator to determine bacterial quality in freshwater. Illinois, Minnesota, New York, Pennsylvania, and Wisconsin use the fecal coliform as an indicator. New York also employs the total coliform count, as well as fecal coliform, as an indicator of fecal contamination.

In 1998, sewage spills and overflows, polluted runoff and stormwater, and rain were the major causes of pollution causing U.S. beach closings and health advisories (NRDC 1999). The eight Great Lakes states have monitoring and notification programs for alerting the public about polluted recreational waters. Illinois, Indiana, Ohio, and Pennsylvania have established comprehensive monitoring programs for most (or all) of their beaches and the means to notify the public of the results. Michigan, Minnesota, Wisconsin, and New York have regular monitoring and notification of the public for some of their recreational beaches. Indiana, Illinois, Ohio, and Pennsylvania close beaches when bacterial water-quality standards have been exceeded.

Because of the serious nature of some of the microbial diseases and the fact that 40% of the U.S. waterways are not safe for fishing and swimming, comprehensive monitoring and notification programs are needed to protect the public health.

2.3 Drinking Water

In 1974, Congress passed the Safe Drinking Water Act to regulate the US public drinking water supply (EPA 1999b). The Amendments of 1986 and 1996 mandated actions to protect public drinking water and its sources (i.e., rivers, lakes, reservoirs, springs, and ground water wells). The Great Lakes Water Quality Agreement (IJC 1994) also calls for the control of contaminated ground water.

The USEPA has been authorized by the Act to establish national health-based standards for drinking water to protect the public from man-made and naturally-occurring contaminants in drinking water (EPA 1999b). These standards are based on a health goal that has a risk basis for the general public and sensitive groups. Sensitive groups such as infants, children, pregnant women, the elderly, and immuno-compromised persons are considered when setting these health goals. When the standards (i.e., legal limit of a contaminant in drinking water) are being established, they are set as close to the health goal as possible. The current standards for inorganic and organic chemicals, radionuclides, and microorganisms, and for Great Lakes pollutants can be found at the USEPA web site (http://www.epa.gov/safewater/mcl.html). The Act also requires water suppliers to notify the public about serious problems with water quality. USEPA also prepares an annual report on water system compliance. States are also required to produce and disseminate reports on water systems.

Although the USEPA works with states and water systems to ensure that these standards are being met, substances from various sources may pollute drinking water making it unfit to consume. These sources include improperly disposed chemicals, animal and human waste, pesticides, waste permeating underground, and natural substances (EPA 1999b). Other sources of drinking water contamination may include improper treatment or disinfection, or a faulty distribution system.

One example of improper treatment or disinfection of water occurred in Milwaukee Wisconsin in the spring of 1993. A water treatment plant failure resulted in the contamination of the city's water supply with Cryptosporidium parvum, a parasitic organism of fecal origin. An estimated 403,000 Milwaukee residents developed gastrointestinal illness due to the water contamination (Oswe et al.1996). The immuno-compromised seemed particularly vulnerable with high death rates (Hoxie et al. 1997). During the outbreak, the media succeeded in disseminating health information to the public (Cordell et al. 1997).

At present, the USEPA is assessing health risks from microbial contaminants (e.g., Cryptosporidium), byproducts of drinking water disinfection (i.e., trihalomethanes), radon, arsenic, and vulnerable ground water sources (EPA 1999b). These measures, the regulatory standards, and the notification of the public regarding serious problems are measures to ensure the safety of the nation's public drinking water.

3.0 Weight of Evidence Approach

The purpose of this section is to review the wildlife, laboratory, and human studies that demonstrate the public health risk from exposure to persistent toxic substances found in the

Great Lakes basin. Because of the ethical issue of exposing humans to toxic substances and factors such as a small sample size and presence of multiple chemicals, human studies are often limited in their ability to establish a causal relationship between exposure to chemicals and potential adverse human health effect. The weight of evidence approach utilizes the available information from wildlife and controlled animal experiments to support the results of human studies. The use of wildlife data supposes that animals can act as sentinels for adverse effects observed in humans (Johnson and Jones 1992).

3.1 Wildlife Populations

Reproductive impairments have been described in avian, fish, and mammalian populations in the Great Lakes. For example, egg loss due to egg shell thinning has been observed in predatory birds, such as the bald eagle, within the Great Lakes (Menzer and Nelson 1980). After feeding on Great Lakes fish for two or more years, immigrant birds (eagles) were shown to have a decline in reproductive success (Colburn et al. 1993). Developmental effects in the form of congenital deformities (e.g., crossed mandibles, club feet) have also been reported in the avian population within the Great Lakes basin (Stone 1992).

Effects to the endocrine system and tumor formations have been detected in fish populations. Researchers have reported enlarged thyroids in all of the 2 to 4 year-old Great Lakes salmon stocks that were examined (Leatherland 1992). Tumors associated with exposure to high levels of polyaromatic hydrocarbon compounds have also been detected in brown bullhead fish in the Great Lakes area (Baumann et al. 1982).

Effects on the immune system have also been a notable finding. At a number of Great Lakes sites, a survey of herring gulls and Caspian terns demonstrated a suppression of T-cell-mediated immunity following prenatal exposure to organochlorine pollutants particularly PCBs (Grasman et al. 1996). For more examples of these effects in wildlife, see Table 5.

Table 5: Effects of Toxic Contamination on Fish and Wildlife in the Great Lakes

Species	Population decrease	Effects on Reproduction	Eggshell thinning	Birth defects	Behavioral changes	Biochemical changes	Mortality
Mink	✓	✓	NA	NE	NE	NE	✓
Otter	✓		NA	NE	NE	NE	S
Double-crested cormorant	✓	✓	✓	✓		✓	S
Black-crowned night heron	✓	✓	✓	✓		✓	S
Bald eagle	✓	✓	✓	NE		NE	NE
Herring gull		✓	✓	✓	✓	✓	✓
Ring-billed gull				✓		NE	✓
Caspian tern		✓		✓	NE	NE	
Common tern		✓	✓	✓		✓	
Forster’s tern		✓		✓	✓	✓	
Snapping turtle	NE	✓	NA	✓	NE	NE	NE
Lake trout		✓	NA			✓	
Brown bullhead			NA			✓	
White sucker			NA	✓		✓	

Source: USEPA’s National Water Quality Inventory: 1992 Report to Congress.

Notes: NA = not applicable
NE = not examined
S = suspected

3.2 Animal Experiments

Toxicology evidence in animals is mounting that supports the association between exposure to persistent toxic substances and adverse health effects. Animal experiments have demonstrated a wide range of health outcomes from exposure to PCBs, mercury and chlorinated dibenzo-p-dioxins (CDD).

PCBs (polychlorinated biphenyls): Animals exposed orally to PCBs developed effects to the hepatic, immunological, neurological, developmental and reproductive systems. Effects have also been reported in the gastrointestinal and hematological systems (ATSDR 1998). Animal ingestion studies strongly support the finding that higher chlorinated PCB mixtures (i.e., 60% chlorine by weight) are carcinogenic to the livers of rats, while the lower chlorinated PCBs are weaker animal carcinogens (i.e., lower incidence of total tumors and more benign tumors) (Buchmann et al. 1991, Sargent et al. 1992). A General Electric Company sponsored study demonstrated the carcinogenicity of Aroclor-1016, Aroclor-1242, Aroclor-1254, and Aroclor-1260 in rats receiving dietary exposure to PCBs. As an example, liver tumors were observed in female rats, and thyroid cancers were reported in male rats (Brunner et al. 1996).

A number of animal studies have demonstrated immune effects following exposure to PCBs (Arnold et al. 1995, Tryphonas 1995, Ross et al. 1996). In a laboratory study, habour seals were administered a diet of Baltic sea herring contaminated with organochlorine compounds and other pollutants (Ross et al. 1996). When compared with seals given a diet of relatively uncontaminated Atlantic Ocean fish, the seals ingesting the contaminated sea herring were found to have impaired natural killer cell activity and T-lymphocyte function.

Neurobehavioral effects have been seen in monkeys, exposed orally from birth to 20 weeks, to a PCB congener mixture representative of the PCB mixture found in the breast milk of Canadian women (Rice 1997). The monkeys were subsequently tested at 2.5 and 5 years of age, and found to have deficits in learning and difficulty in learning complex tasks when compared to controls.

Mercury: Long-term, high level animal ingestion exposure to mercury has been associated with cardiovascular (Arito and Takahashi 1991), developmental (Fuyuta et al. 1978, 1979; Nolen et al 1972; Inouye et al 1985), gastrointestinal (Mitsumori et al. 1990), immune

(Ilback 1991), renal (Yasutake et al. 1991; Magos et al. 1985; Magos and Butler 1972; Fowler 1972) and reproductive effects (Burbacher et al. 1988; Mitsumori et al.1990; Mohamed et al. 1987). The studies also indicate that the nervous system is particularly sensitive to mercury exposure by ingestion (Fuyuta et al. 1978; Inouye and Murakami 1975; Magos et al.1980, 1985). In addition, growth of kidney tumors has been reported in animals administered methylmercury in drinking water or diet for extended periods (Mitsumori et al. 1981, 1990).

CDDs (chlorinated dibenzo-p-dioxins): In specific species (e.g., guinea pig), very low levels of 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) have resulted in the death of the exposed animal after a single ingestion dose (NTP 1982). At nonlethal levels of 2,3,7,8-TCDD by ingestion, other effects reported in animals include weight loss (NTP 1982), biochemical and degenerative changes in the liver (NTP 1982, Kociba et al. 1978), and a decline in blood cells (Kociba et al 1978). Dermal effects in animals (e.g., hair loss, chloracne) have also been reported by ingestion exposure (Mc Connell et al. 1978). In many species, the immune system and fetal development are particularly susceptible to 2,3,7,8-TCDD exposure. Offspring of animals receiving oral exposure to 2,3,7,8-TCDD developed birth defects such as skeletal deformities and kidney defects, weakened immune responses, impaired reproductive system development, and learning and behavior impairments (Giavini et al. 1983, Gray and Ostby 1995, Tryphonas 1995, Schantz and Bowman 1989, Schantz et al. 1992). Reproductive effects in the form of miscarriages were reported in rats, rabbits, and monkeys exposed orally to 2,3,7,8-TCDD during pregnancy (McNulty 1984). Rats of both sexes were observed to have endocrine changes in the form of alterations in sex hormone levels with dietary exposure. Other reproductive effects include a decline in sperm production in male rats, and carcinogenic effects of cancer of the liver, thyroid, and other sites in rats and mice exposed orally to 2,3,7,8-TCDD (NTP 1982, Kociba et al. 1978). Research evidence is also increasing, supporting the neurotoxic effect for mammals and birds from ingestion exposure to dioxin-like compounds, including certain PCBs and CDFs. Changes in thyroid hormones and neurotransmitters, singly or together, at critical periods in the development of the fetus are considered responsible for the neurological changes (Brouwer et al. 1995; De Vito et al. 1995; Henshel et al. 1995b; Henshel and Martin 1995a; Vo et al. 1993).

3.3 Human Health Studies

3.3.1 Exposure Studies: Fish species residing in waters contaminated with lipophilic pollutants (i.e., fat-soluble pollutants as PCBs) bioaccumulate these contaminants and become a further source of contamination for larger, predator fish (e.g., sport caught trout and salmon) (Humphrey 1988). This process results in a biomagnification or increase in the levels of contaminants in the predator fish which may subsequently be consumed by humans. Fish consumption has been shown to be a major pathway of human exposure to persistent toxic substances such as PCBs (Birmingham et al. 1989; Fitzgerald et al. 1996; Humphrey 1983; Newhook 1988), exceeding exposures from land, air, or water sources (Humphrey 1988). Humphrey (1988) reported that PCBs were the dominant contaminants detected in Lake Michigan trout (3,012 parts per billion or ppb) and chinook and coho salmon (2,285 ppb) surpassing other contaminants such as DDT (1,505 ppb, 1,208 ppb), hexachlorobenzene (5 ppb, 5 ppb), oxychlordane (25 ppb, none shown), trans-nonachlor (195 ppb, 162 ppb) and dieldrin (75 ppb, 53 ppb) respectively in trout and salmon. Fish specimens collected from the dinner plate of study participants were used to determine these median PCB concentrations. Recently, total PCB levels have decreased in most Lake Michigan fish species and appear to remain below the FDA action level of 2 mg/kg (parts per million or ppm) but the concentrations in chinook and coho salmon have risen slightly since the late 1980s (Stow et al. 1995).

Early investigations of Lake Michigan fish consumption have broadened our knowledge about transmission of contaminants from fish to humans, including fetus and infant exposure from maternal consumption. Investigating a cohort of Lake Michigan fisheaters, Humphrey (1988) discovered that sport anglers who regularly consumed Great Lakes salmon and trout (consumption rate of $\geq$24 pounds/year [or $\geq$11 kg/year]) had median serum PCB levels approximately 4 times higher (56 ppb) than those who consumed no or very small amounts of Lake Michigan fish (15 ppb) (consumption rate of 0-6 pounds/year [or 0-2.7 kg/year]). Halogenated contaminants (e.g., PCBs) have also been detected in adipose tissue, breast milk, and cord blood, associated with consumption of contaminated fish (ATSDR 1998). Other studies have also supported these findings. For example, Schwartz et al. (1983) demonstrated that consumption of Lake Michigan fish was positively associated with the PCB concentration in maternal serum and breast milk. Maternal serum PCB concentrations were also positively associated with the PCB levels in the umbilical cord serum of the infant (Jacobson et al. 1983).

Body burden levels of PCBs are still elevated in fish consumers. Hovinga et al (1992) reported a mean serum PCB concentration of 20.5 ppb in 1982 for persons consuming >24 pounds of Lake Michigan sport fish per year, and 19 ppb in 1989 demonstrating little decline within the 7 year interval. For those ingesting <6 pounds of Lake Michigan sport fish per year, the mean serum PCB concentrations were 6.6 ppb in 1982, and 6.8 ppb in 1989. The mean serum PCB concentrations for those consuming <6 pounds of Lake Michigan fish per year are comparable to the mean serum PCB levels of 4 to 8 ppb found in the general population who do not have occupational PCB exposure (Kreiss 1985).

Research has shown that vulnerable communities for exposure to contaminants from fish consumption include Native Americans, minorities, sport anglers, elderly, pregnant women, and fetuses and infants of mothers consuming contaminated Great Lakes fish (Dellinger et al. 1996, Fitzgerald et al. 1996; Lonky et al. 1996; Schantz et al. 1996). These communities may consume more fish than the general population or may have physiologic attributes such as physical and genetic susceptibilities that may cause them to be at greater risk. Higher body burdens of mean serum PCBs and DDE were found in an elderly cohort of Lake Michigan sport fisheaters (i.e., ≥50 years of age) who were compared to nonfisheaters (Schantz et al. 1996). Fisheaters had mean serum PCB levels of 16 ppb while the nonfisheaters had mean levels of 6 ppb. For DDE, fisheaters had mean serum levels of 16 ppb and the nonfisheaters had a mean level of 7 ppb.

In addition, women have been shown to consume Great Lakes sport fish during their reproductive years (Courval et al. 1996, Lonky et al. 1996, Waller et al. 1996). There are also gender differences in fish consumption patterns. A Lake Michigan sport anglers study, with subjects between the ages of 18-34 years, also demonstrated gender differences with males tending to consume more fish than female subjects (Courval et al. 1996). Research has subsequently shown that consumption of contaminated fish by these at-risk populations is associated with adverse human health effects.

3.3.2 Health Effects: Developmental, reproductive, neurobehavioral or neurodevelopmental, and immunologic effects have been reported in studies conducted within the Great Lakes basin and outside the basin. Developmental effects in the form of a decrease in gestational age and low birth weight have been observed in a Lake Michigan Cohort exposed prenatally to PCBs (Fein et al. 1984). These findings have also been observed in offspring of women exposed to PCBs occupationally in the manufacture of capacitors in New York (Taylor et al. 1989).

Reproductive effects have also been reported. Courval and coworkers (1997, 1999) examined couples and found a modest association in males between sport-caught fish consumption with the risk of conception failure after trying for at least 12 months. Studies of New York state anglers have not shown a risk of spontaneous fetal death due to consumption of fish contaminated with PCBs (Mendola et al. 1995) nor an effect on time-to-pregnancy among women in this cohort (Buck et al. 1997).

Neurobehavioral or neurodevelopmental effects have been documented from exposure to persistent toxic substances in newborns, infants, and children of mothers consuming Great Lakes sport fish. Early investigations of the Lake Michigan Maternal Infant Cohort revealed that newborn infants of mothers consuming >6.5 kg/year of Lake Michigan fish had neurobehavioral deficits of depressed reflexes and responsiveness, when compared to non-exposed controls (Jacobson et al. 1984). The fisheating mothers consumed an average of 6.7 kg of Lake Michigan contaminated fish per year, equal to 0.6 kg or 2 to 3 salmon or lake trout meals/month. Prior to study admission, exposed mothers were required to have fish consumption that totaled more than 11.8 kg over a 6-year period. Subsequent studies of the Michigan Cohort have revealed neurodevelopmental deficits in short-term memory at 7 months (Jacobson et al. 1985) and at 4 years of age (Jacobson et al. 1990b), and also growth deficits at 4 years of age associated with prenatal exposure to PCBs (Jacobson et al. 1990a). A more recent investigation of Jacobson's Michigan Cohort has revealed that children most highly exposed prenatally to PCBs showed IQ deficits in late childhood at 11 years of age (Jacobson and Jacobson 1996). Highly exposed children received prenatal PCB exposure equal to at least 1.25 ug/gram (ppm) in maternal milk, 4.7 ng/milliliter (ppb) in cord serum, or 9.7 ng/milliliter (ppb) in maternal serum.

The early findings in newborns by Jacobson have been supported by a more recent study by Lonky and coworkers (1996) of newborns. In this study, neurobehavioral effects (e.g., abnormal reflexes) were observed in an examination of newborns (12-24 and 25-48 hours after birth), whose mothers had consumed Lake Ontario fish. Newborns, whose mothers had consumed >40 PCB-equivalent pounds of fish in their lifetime, were placed in the high exposure group and were found to manifest a greater number of immature responses and less attention to stimuli. The PCB-equivalent pounds were calculated based upon how the fish was prepared (e.g., extent fat removed) as well as other factors, such as fish species and amount/years of consumption.

In addition to neurotoxic effects observed in newborns, infants, and children, Mergler and coworkers (1997) reported early nervous dysfunction in adults who consumed St. Lawrence River fish. The deficits were found with higher fish consumption. Initial testing for neurotoxic effects were not observed by Schantz and coworkers (1999) in an elderly adult population (i.e., ≥50 years) of Lake Michigan sport fisheaters with exposure to PCB and DDE. This study is ongoing.

Immunologic effects have also been reported. Smith's study (1984) demonstrated that maternal serum PCB levels during pregnancy were positively associated with the type of infectious diseases that infants developed during the four months after birth. In addition, incidence of infections has been shown to be associated with the highest fish consumption rate of mothers (i.e., at least three times per month for three years) (Swain 1991, Tryphonas 1995).

Other health effects have been documented with PCB exposure. Elevated serum PCB levels were associated with self-reported diabetes and liver disease in cohorts of Red Cliff and Ojibwa Native Americans (Dellinger et al. 1997, Tarvis et al. 1997). Fischbein and coworkers (1979) found that workers exposed to a variety of PCB Aroclors reported joint pain.

Health effects studies conducted outside the Great Lakes basin have been supportive of the reports from the Great Lakes basin. A summary of these health effects studies can be found in the recent paper published by Johnson and coworkers (1998).

4.0 Societal Responses: Health Advisories for Fish Consumption

The purpose of fish consumption advisories is to protect public health by alerting the residents of potential health risks from consuming contaminated fish (EPA 1995). Advisories can also include information to educate the public about the healthy benefits of fish consumption and to minimize exposure to contaminants in fish by proper preparation and cooking (Tilden et al. 1997). Within the Great Lakes, PCB contamination of Great Lakes fish is generally responsible for health advisories, while mercury contamination is responsible for advisories covering inland bodies of water, such as rivers and lakes (Kamrin and Fischer 1999).

The Great Lakes Sport Fish Advisory Task Force, consisting of environmental and health professionals from the eight Great Lakes states, developed a Health Protective Value (HPV) as a guideline for determining risk from consuming contaminated Great Lakes sport fish (Anderson et al. 1993; Kamrin and Fischer 1999). The HPV is the highest acceptable daily intake of a contaminant (e.g., PCBs) in fish that would not result in a health risk, particularly reproductive and developmental effects, and applies to both sensitive and less sensitive groups (Kamrin and Fischer 1999). For PCBs, the HPV is 0.05 ug PCBs/kg/day. Species of fish are assigned a consumption category that would result in a PCB intake level below the HPV. This value is derived from animal and human study findings, and is similar to the USEPA's reference dose for computing non-cancer risk. There are five consumption categories including *unlimited consumption*, *one meal a week*, *one meal a month*, *one meal every two months*, and *do not eat*. Five of the Great Lakes states have adopted this guideline and two use a version of the HPV. The five include Illinois, Minnesota, Ohio, Pennsylvania, and Wisconsin. Illinois utilizes the HPV for Lake Michigan but also uses the USFDA standard for fish of 2ppm for inland waters. Michigan uses the HPV and the USFDA standard. Indiana also employs the HPV but includes a safety factor for sensitive populations. New York considers acceptable levels (or action levels) of all contaminants in fish and, based on these levels, assigns consumption categories. For example, sensitive populations are permitted to consume only one fish meal a week from water bodies containing fish with PCB levels below the 2 ppm.

Tilden and coworkers (1997) conducted a population-based survey of fish consumption within the eight Great Lakes states. The study results demonstrated that almost 50% of the Great

Lakes fish consumers had an awareness of the health advisories. Of the 50%, approximately 60 % of the males and less than 40% of the females were aware of the advisories. These findings emphasize the importance of targeting health advisories to sensitive groups such as women of reproductive age. The sensitive groups include women of childbearing age and their fetuses and infants, the elderly, sports anglers, and minorities. More information about sensitive groups may be found under the “Weight of Evidence” discussion (3.0).

Studies have shown that having an awareness of health advisories can be successful in changing fishing and fish consumption habits (Fiore et al. 1989; Velicer and Knuth 1994). The communication programs in the Great Lakes generally target white, licensed anglers (Tilden et al. 1997). Written information (i.e., regulation booklets and advisory brochures) is circulated by the government and the fishing industry to licensed anglers, and these sources of information appear to be effective in reducing consumption of contaminated fish. For example, Fitzgerald and coworkers (1999) found that 97% of the men in their study were aware of fish advisories and two-thirds of these men had reduced their fish consumption. This reduction in fish consumption was due to public health intervention strategies such as risk communication along with the use of fish advisories. More recent efforts have been directed toward groups with less awareness of health advisories such as women of childbearing age, minorities, and other frequent fish consumers (Knuth 1995, Tilden et al. 1997)). One of these projects is the ATSDR-funded Consortium of Great Lakes states headed by Dr. Henry Anderson. Anderson and his group have developed outreach materials for women of childbearing age and minority groups which are being utilized by seven of the eight Great Lakes states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin). These outreach materials such as posters and recipe cards are being adapted by each of the states for their specific needs, and are being distributed at women and childrens’ clinics, health fairs, state fairs, and fishing shows to increase health advisory awareness.

Although all of the Great Lakes states have health advisories for contaminants in fish, particularly for PCBs, recent studies demonstrate that sensitive groups may not receive the advisory information (Tilden et al. 1997; Velicer and Knuth 1994). The evaluation of health advisories is an integral part of determining the effectiveness of a program. The USEPA’s

Guidance document for fish advisories (EPA 1995) makes recommendations for evaluating the risk communication efforts for fish advisories and provides a step-by-step approach for conducting an evaluation of an existing program. Program evaluation is necessary to determine 1) if the health advisory is reaching the target population, 2) if it is being implemented properly, 3) if it is effective, 4) the cost, and 5) the cost relative to effectiveness (Windsor et al. 1994).

5.0 ATSDR’s Program: a Model for the Great Lakes Water Quality Agreement

The ATSDR’s Great Lakes Human Health Effects Research Program (GLHHRP) serves as a model by which the requirements of the human health component of the Great Lakes Water Quality Agreement are being met. The goals of the GLHHRP are to 1) identify the populations at risk who may be exposed to chemical contaminants from the Great Lakes, and 2) prevent the potential adverse human health effects that research has demonstrated is associated with exposure. These goals represent the program’s public health focus intended to protect the health of populations consuming contaminated Great Lakes fish. ATSDR has established an applied research strategy to achieve these goals based upon the traditional model of disease prevention (De Rosa and Johnson 1990; Johnson et al. 1998). These strategies are key requirements of the human health component of the Great Lakes Water Quality Agreement.

The GLWQA calls for the LaMPs “. . . to include a definition [description] of the threat to human health . . . posed by Critical Pollutants, singly or in synergistic or additive combinations . . . .” (IJC 1994). The GLWQA also calls for the establishment of a surveillance and monitoring system, one of whose purposes it to identify emerging problems. For ATSDR, identification has involved identifying vulnerable populations and cohorts of populations who consume contaminated fish and have a potential for developing adverse human health effects (Anderson et al. 1996; Courval et al. 1996, 1999; Daly et al. 1996; Fitzgerald et al. 1996, 1999; Schantz et al. 1996; Stewart et al. 1999; Vena et al. 1996; Waller et al. 1996). The ATSDR cohort populations are part of a surveillance and monitoring system to identify emerging problems of long-term health effects associated with consumption of contaminants in fish.

Evaluation is another ATSDR strategy element used to determine causal linkages or conclusions regarding biologic plausibility. Early reports from the ATSDR's GLHHRP have demonstrated exposure associations between consumption of contaminants in Great Lakes fish and body burdens particularly for those with high fish consumption. The program has entered into a second evaluation phase in which associations are being established between body burdens of contaminants (e.g., in serum) and health effects observed in humans and animals.

As with the GLWQA, implementation is an integral part of ATSDR's strategy. Having helped to establish the pathway of exposure for at-risk populations, ATSDR's prevention strategy involves risk communication and health education to minimize the public's exposure to contaminants in fish (Tilden et al. 1997). Health advisories for fish consumption are important means of communicating to the public the potential toxic effect from contaminants in Great Lakes fish. An ATSDR-funded research group has helped to develop uniform health advisory guidelines for fish consumption that is being utilized by the Great Lakes states. In addition to the funded research, ATSDR is presently preparing a report assessing health advisories for fish consumption within the Great Lakes states. This report will include an examination of some of the outreach approaches (e.g., pamphlets, posters, Internet) used by the Great Lakes states to disseminate health advisory information. As a further component of the prevention strategy, ATSDR has an ongoing program dealing with the effect of mixtures of chemicals found in the Great Lakes and other sites to determine synergistic or additive effects of these chemical mixtures (Hansen et al. 1998). Within the next year, a toxicological profile will be published by ATSDR describing the state-of-the-science for chemical mixtures found in the Great Lakes and other hazardous waste sites.

As part of the impact assessment, ATSDR has established a process by which the GLHHRP projects are reviewed. Results of these research projects are customarily published to expand the public's awareness of potential adverse human health effects from consuming contaminated fish. ATSDR has also been participating in the Lakes Erie, Michigan, and Superior LaMP work groups, and has utilized this opportunity to 1) develop a human health section document that can be utilized as a prototype for all LaMPs, 2) inform the governmental and non-governmental agencies and the public about recent findings from the ATSDR funded research, and 3) develop an awareness about the current health-related issues in the Great Lakes basin that can assist in the direction of the GLHHRP.

This strategy and its component elements have represented major strides in helping to fulfill the requirements of the Great Lakes Water Quality Agreement by delineating the potential human health threat from contaminants in Great Lakes fish and by implementing actions that will protect human health. Having achieved these major steps, ATSDR is now making an effort to advance the science in relatively pristine areas such as health effects from multiple chemicals found in the Great Lakes and other sites (Hansen et al. 1998), and the development of biomarkers of exposure. This step-by-step process will also be instrumental in building a data base of knowledge that can be utilized in dealing with other health and environmental related issues both nationally and internationally.

6.0 Conclusions and Recommendations

Much has been accomplished. Much still needs to be done. Within the ecosystem, there are encouraging signs and successes. For example, contaminant declines have been observed at most Great Lakes sites as evidenced in the eggs of herring gulls (Environment Canada and EPA 1999). In southern Lake Michigan during 1998, yellow perch seemed to be spawning successfully and lake sturgeons have been reported to reproduce successfully in three tributaries of Lake Michigan’s Green Bay.

In the human health sector, research has identified fish consumption as the major pathway of exposure to some contaminants from Lake Michigan and other Great Lakes. Body burdens from consumption of contaminated fish have been noted in vulnerable communities. Human health effects have subsequently been observed. Despite these compelling findings, issues related to environmental exposures and human health still remain. Health research needs to continue, but a shift in priorities is now needed to prevention, intervention, and collaborative activities. In addition, work still needs to be done in these areas. Recommendations are being made for:

- biologic markers of exposure, effect, and susceptibility
- health effects of chemical mixtures

- endocrine disruptors
- PCB congeners and their health effects
- health advisories and outreach approaches
- surveillance and monitoring programs

6.1 Biologic Markers of Exposure Effect and Susceptibility

Research has demonstrated that regular high levels of fish consumption can result in high body burdens of lipophilic contaminants such as PCBs and that the body burdens of these contaminants remains relatively constant in the body even after exposure cessation. For the goal of prevention, improved markers are needed to indicate biologic changes that predict health impairment or disease (NRC 1989) and the preclinical signs of disease (De Rosa and Johnson 1996). The three categories of biologic markers include markers of exposure, effect, and susceptibility (NRC 1989). A biologic marker of exposure may be the body burden, indicative of recent or past exposure. A marker of effect may include health impairment (e.g., altered function of the luteinizing hormone for ovarian function) or overt disease (e.g., fertility problems). A pre-existing condition affecting the dose of a substance to the target tissue is an example of a biologic marker of susceptibility. The ATSDR-funded research and other research projects are examining body burdens of contaminants in serum, reproductive problems related to conception, and other health-related problems, that will be instrumental in identifying early warning signs requiring intervention. However, the biologic markers of exposure and effect often lack the precision to identify those who have an exposure, impairment, or disease, and those who do not. For this reason, additional research is needed to develop biologic markers that clearly identify the concentration of contaminants and the point in the human physiological process beyond which lasting adverse health effects will be observed.

6.2 Health Effect of Chemical Mixtures

Within our present state-of-knowledge, the human research demonstrating health effects from consumption of contaminated fish can be said to be relatively sound. Although these studies, in most cases, have made associations between a single contaminant detected in fish and body burden or health effects, detections of multiple chemicals have been found in Great Lakes fish (Humphrey 1988; Dellinger et al. 1996). Our present state-of-knowledge is vastly limited in identifying the subtle effect of multiple chemicals detected, even at low levels, in contaminated fish. For this reason, research is needed to clearly delineate whether a synergistic or additive health effect occurs with multiple chemicals, and with a combination of chemicals having similar properties.

6.3 Endocrine Disruptors

Research has demonstrated that many of the contaminants found in fish from Lake Michigan and other Great Lakes have been shown to adversely affect the endocrine system of animals and humans. An environmental endocrine disruptor is ". . . an exogenous agent that interferes with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development, and/or behavior" (EPA 1997a). Some of the known endocrine disrupting chemicals include atrazine, chlordanes, DDT and metabolites, dieldrin, dioxins and furans, PCBs, and toxaphene (EPA 1997b). These are contaminants that have been detected in Lake Michigan and other Great Lakes. Other substances, detected in the Great Lakes, are considered probable endocrine disruptors. These include cadmium, hexachlorobenzene, lead, mercury, and mirex. Although research continues on reproductive (Buck et al. 1999, Courval et al. 1999) and other effects that may be associated with exposure to endocrine disrupting chemicals, our knowledge about these substances in humans remains limited. Epidemiologic research needs to quantify the magnitude of exposures and effects of substances considered to be endocrine disruptors (EPA 1997a). Since endocrine disrupting chemicals, such as PCBs and DDT, have been detected simultaneously in fish, their effect as chemical mixtures also requires investigation.

6.4 PCB Congeners and Their Health Effects

Further human research is needed to identify the specific PCB congeners associated with adverse human health effects. The use of the capillary column gas chromatography, starting in the late 1980s and early 1990s, has enabled laboratories to identify the 209 PCB congeners (Communication with Virlyn Burse 1/25/00). Stewart and coworkers (1999) found that the most heavily chlorinated PCB homologues (i.e., 7 or 8 chorines per PCB biphenyl ring) were significantly higher in the fetal cord blood of infants whose mothers had consumed Lake Ontario fish. These highly chlorinated and persistent PCB homologues were also detected in fish from Lake Ontario. Animal studies have supported this observation that highly chlorinated PCBs are responsible for adverse health effects. Congener-specific studies will help to identify those congeners that are most likely to adversely influence human health and require public health intervention.

6.5 Health Advisories and Outreach Approaches

ATSDR-funded research has examined health advisories for fish consumption within the Great Lakes (Tilden et al 1997). The study findings demonstrated that approximately 50% of survey respondents were aware of health advisories with awareness being lowest in women. Studies have shown that sport fish consumption advisories and outreach information can minimize exposures to contaminants from sport fish consumption. Information about fish advisories has been successfully disseminated to licensed anglers through the recreational fishing industry and governmental offices, but has not been effective for non-licensed anglers and women who are among the at-risk populations. Added effort needs to be directed towards informing and educating at-risk populations, and should include the selection of outreach material shown to be effective in modifying behavior (e.g., proper fish preparation). In addition, a single uniform fish advisory guideline is needed that can easily be adapted to specific state needs. The work of the Great Lakes Sport Fish Advisory Task Force can be used as a template for developing comprehensive guidelines, that will fulfill the needs of all states, not just the Great Lakes states. Factors to be considered include the size of an average fish meal, reduction in contaminant levels due to proper preparation and cooking, and other contaminants (aside from PCBs) in fish (Kamrin and Fischer 1999). ATSDR and ATSDR-funded research are continuing to examine this important area.

6.6 Surveillance and Monitoring Programs

Surveillance and monitoring programs have been successful in identifying subtle health effects associated with body burdens of contaminants associated with consumption of Great Lakes fish. ATSDR has participated in the Lake Michigan Tributary Monitoring Project, providing information about surveillance and monitoring of cohorts in the ATSDR-funded research. Input on health surveillance and monitoring should continue to be an integral part of the Lake Michigan Monitoring Project and other monitoring projects concerned with environmental issues and health.

Although progress has been made in defining the health threat from Great Lakes pollutants, important issues remain requiring our diligent effort. The Great Lakes Water Quality Agreement, under the Research and Development annex, calls for ". . . develop[ing] approaches to population-based studies to determine the long-term, low-level effects of toxic substances on human health" (IJC 1994), For the public health arena, there are a number of issues that will help to identify these long-term, low-level health effects, as discussed in the previous paragraphs. Research in these areas will provide a more comprehensive view of the threat to human health from critical pollutants, and enable ATSDR and other public health agencies to utilize this knowledge to protect the public health more effectively. In addition, a shift in priorities is now needed to prevention, intervention, and collaborative activities. These steps will also be critical to environmental agencies setting guidelines and standards to protect the Great Lakes populations and our entire nation.

Internet Information Resources and Further Reading Lake Michigan Human Health Issues

A. General Internet Resources and Readings

US Environmental Protection Home Page
http://www.epa.gov/

USEPA Great Lakes National Program Office
http://www.epa.gov/glnpo

USEPA Region 5
http://www.epa.gov/

U.S. Centers for Disease Control and Prevention
http://www.cdc.gov/

U.S. Agency for Toxic Substances Disease Registry
http://www.atsdr.cdc.gov/

U.S. ATSDR Great Lakes Health Effects Program
http://www.atsdr.cdc.goc/grlakes.html

States

Illinois Department of Health

Indiana Department of Health

Michigan Department of Community Health
http://www.mdch.state.mi.us/

Wisconsin Department of Health
http://www.dhfs.state.wi.us/

Readings

ATSDR (Agency for Toxic Substances and Disease Registry). 1993. Aldrin/Dieldrin Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1995. Chlordane Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1999. Chlorinated Dibenzo-p-Dioxins Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1995. DDT, DDE, and DDD Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Hexachlorobenzene Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1999. Mercury Fact Sheet. Atlanta, Georgia U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Polychlorinated Biphenyls Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1998. Polychlorinated Biphenyls Toxicological Profile (updated draft). Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Toxaphene Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

International Joint Commission. Revised Great Lakes Water Quality Agreement of 1978 as Amended by Protocol Signed November 18, 1987. Reprint February, 1994.

U.S. EPA and Government of Canada, 1995. The Great Lakes: An Environmental Atlas and Resource Book.

Johnson, B.L., H.E. Hicks, D.E. Jones, W. Cibulas, A. Wargo and C. T. De Rosa. 1998. Public Health Implications on Persistent Toxic Substances in the Great Lakes and St. Lawrence Basins. Journal of Great Lakes Research. 24(2): 698-722.

B. Internet Resources and Further Readings for Air:

EPA Office of Air and Radiation
http://www.epa.gov/oar/oarhome.html

U.S. EPA Health Effects Notebook for Hazardous Air Pollutants
http://www.epa.gov/ttn/uatw/hapindex.html

OSHA Indoor Air page:
http://www.osha-slc.gov/SLTC/indoorairquality/index.html

C. Internet Resources and Further Readings for Drinking Water:

U.S. EPA Office of Ground Water and Drinking Water Home Page
http://www.epa.gov/safewater/about.html
http://www.epa.gov/OGWDW/wot/appa.html
http://www.epa.gov/ogwdwooo/hfacts.html

U.S. EPA, How Safe is my Drinking Water? Office of Ground Water and Drinking Water
http://www.epa.gov/OGWDW/wot/howsafe.html

U.S. EPA, Current Drinking Water Standards - National Primary and Secondary Drinking Water Regulations. Office of Groundwater and Drinking Water web site at
http://www.epa.gov/OGWDW/wot/appa.html

U.S. EPA, Consumer Confidence Reports. Fact Sheet. At web site
http://www.epa.gov/safewater/ccr/ccrfact.html

USFDA Food borne Pathogenic Microorganisms and Natural Toxins Handbook Web Page
http://vm.cfsan.fda.gov/~mow/chap24.html

US Center for Disease Control. Cryptosporidiosis Fact Sheet.
http://www.cdc.gov/ncidod/diseases/crypto/cryptos.htm

Readings

Wisconsin Department of Natural Resources, 1998. “Cryptosporidium: A Risk to our Drinking Water.” Fact Sheet. Available on WDNR web site at
http://www.dnr.state.wi.us/org/water/dwg/Crypto.htm#what steps Revised June 1, 1998.

D. Internet Resources and Further Readings for Recreational Water

U.S. EPA, Office of Water, EPA’s BEACH Watch Program, 1999 Update
http://www.epa.gov/OST/beaches/update.html

U.S. EPA’s BEACH Watch Program Homepage
http://www.epa.gov/OST/beaches/

U.S. EPA Office of Water, BEACH Watch Program Homepage.
http://www.epa.gov/OST/beaches/

U.S. EPA Office of Water, BEACH Watch Program. Local Beach Health Information.
http://www.epa.gov/OST/beaches/local/

Natural Resources Defense Council (NRDC). Testing the Waters - 1999 - A Guide to Water Quality at Vacation Beaches
http://www.igc.org/nrdc/nrdcpro/ttw/titinx.html

U.S. EPA's BEACH Watch Program Homepage at http://www.epa.gov/OST/beaches/
Natural Resources Defense Council (NRDC). Testing the Waters - 1999 - A Guide to Water Quality at Vacation Beaches. at http://www.igc.org/nrdc/nrdcpro/ttw/titinx.html

Corbett, S.J., Rubin, G.L., Curry, G.K., Kleinbaum, D.G. & the Sydney Beach Users Study Advisory Group 1993, 'The health effects of swimming at Sydney beaches', American Journal of Public Health, vol.83, no.12, pp.1701-06 .
URL: http://www.epa.nsw.gov.au/soe/95/14_2s2.htm

E. Internet Resources and Further Readings for Fish/Food Consumption

U.S. EPA Fish Consumption Advisory Information
http://www.epa.gov/OST/fish/

States

Illinois Department of Natural Resources.
Indiana Department of Natural Resources. Indiana Fish Advisory

Michigan Department of Community Health. Michigan Fish Advisory
http://www.mdch.state.mi.us/pha/fish/index.htm

Wisconsin Department of Natural Resources. Wisconsin Fish Advisory
http://www.dnr.state.wi.us/org/water/fhp/fish/advisories/

Illinois Fish Advisory

F. Internet Resources and Further Readings for Health Effects Information

ATSDR's Toxicological Profiles
http://www.atsdr.cdc.gov/toxpro2.html

ATSDR HAZDAT Database: Hazardous Materials and their Human Health Effects
http://atsdr1.atsdr.cdc.gov:8080/hazdat.html

ATSDR, Public Health Implications of Exposure to Polychlorinated Biphenyls (PCBs)
http://www.atsdr.cdc.gov/DT/pcb007.html

U.S. EPA Mercury Study Report to Congress
http://www.epa.gov/ttn/oarpg/t3/reports/volume5.pdf

APPENDIX D

MAJOR STAKEHOLDERS AND PARTNERS RESPONSIBLE FOR MANAGEMENT OF THE LAKE MICHIGAN BASIN ECOSYSTEM

CONTENTS

APPENDIX D

MAJOR STAKEHOLDERS AND PARTNERS RESPONSIBLE FOR MANAGEMENT OF THE LAKE MICHIGAN BASIN ECOSYSTEM

TABLE D-1

FEDERAL ORGANIZATION STAKEHOLDERS

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
U.S. Environmental Protection Agency (EPA)	Administers educational and regulatory programs including the Clean Water Act; the Comprehensive Emergency Response, Compensation and Liability Act; the Clean Air Act; the Resource Conservation and Recovery Act; the Federal Insecticide Fungicide and Rodenticide Act; and the Toxic Substances Control Act. These statutory programs are designed to protect the environment (prevent and control pollution). In addition, EPA provides environmental assessments, water quality monitoring, regulations and regulatory oversight, education, planning, technical assistance, grants, and loans for pollution control. EPA in conjunction with state, federal, regional, and local agencies is responsible for maintaining, furthering, and enforcing regulatory programs. Voluntary programs designed to protect the environment are sometimes substituted when the regulatory approach is infeasible. These programs include the Binational Virtual Elimination Strategy, the 33/50 Program, and the Pesticide Environmental Stewardship Program.	Staff, information, and data, laboratory and research facilities; grants and loans for pollution control; educational materials; and monitoring equipment. Offices located in 10 regional centers and Washington, DC. www.epa.gov
U.S. Department of Commerce - National Oceanic and Atmospheric Administration (NOAA)	NOAA administers programs in cooperation with states to provide information, research, and management services for the nation's ocean, coastal, and estuarine resources. NOAA funds and performs basic research and assessments relating to coastal eutrophication. In addition, NOAA maintains databases for agricultural pesticides and nutrient loadings. One of NOAA's missions is to restore and maintain coastal ecosystems critical to the current and future state of our nation. NOAA's National Marine Fisheries Service is responsible for protecting and managing the nation's living marine resources. Other NOAA offices are the National Ocean Service, the National Weather Service, and the Oceanic and Atmospheric Research office.	Funds to state coastal programs Staff for technical assistance Data, reports, and educational materials Occasional funds for special demonstration projects www.noaa.gov

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
NOAA - Coastal Zone Management Act Programs (CZMA)	NOAA administers a quasi-regulatory coastal protection program (in cooperation with EPA) that sets performance-based management measures for control and prevention of nonpoint source pollution in coastal areas for all land use activities.	Staff for technical assistance Funds for plan development www.nos.noaa.gov/OCRM/CZM/welcome.html
NOAA - National Sea Grant Program	The National Sea Grant Program is a university-based program designed to support greater knowledge and wise use of aquatic resources, including the Great Lakes.	Staff network of advisory agents, researchers, and educators Funds for research and workshops www.nsgo.seagrant.org/NationalSeaGrant.html
U.S. Department of the Interior (DOI)	DOI is responsible for the oversight, management, or monitoring of national natural resources, including land, water, and wildlife.	Staff, maps, reports, demonstration sites, educational materials, and monitoring equipment www.doi.gov
DOI Bureau of Indian Affairs (BIA)	BIA provides technical assistance to tribes on tribal lands, mainly for social services. It also provides some assistance for conservation work and educational programs. BIA maintains natural resource inventories and monitoring of groundwater and surface water.	Maps, natural resource inventories of Indian and tribal lands Funds for special projects Staff for technical assistance to tribes www.doi.gov/bureau-indian-affairs.html

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
DOI Fish and Wildlife Service (FWS)	FWS is responsible for oversight and regulation of the nation's wildlife resources and management of units of the National Wildlife Refuge System, including National Fish and Wildlife Refuges, enforcement of federal game and fish laws, and cooperative administration of national wetlands program with the Corps of Engineers and EPA. FWS funds cooperative projects to enhance wildlife habitat, especially fisheries investigations. The Environmental Contaminants program directs efforts to identify and assess contaminant effects on fish and wildlife in order to prevent, reduce, and eliminate contamination problems. FWS is engaged in three efforts designed to conserve coastal resources: (1) The Coastal Program (2) Awarding Coastal Wetlands Conservation Grants to coastal states for acquisition, restoration, or enhancement of coastal wetlands and tidelands (3) Legislation that limits federal subsidies for development within the Coastal Barriers Resources System FWS is also responsible for listing endangered species, declaring critical habitats, and establishing wildlife refuges and wilderness areas.	Staff for enforcement of Endangered Species Act and other laws on public and private land, research reports and data on habitat, populations and management of wildlife, funds for cooperative projects, educational materials, teacher training, curricula, and maps www.fws.gov
DOI National Park Service	The National Park Service administers and manages national parks for preservation of natural resources. The Water Resources Division is responsible for providing water resource management, policy, planning, and operational support to National Park Service managers servicewide. The Air Resources Division has the same responsibilities concerning air quality.	Staff for oversight and administration Funds for special studies and occasional cooperative projects on land adjoining park boundaries www.nps.gov
DOI U.S. Geological Survey (USGS)	USGS conducts long-term baseline monitoring of water resources (quantity, flow, and quality); hydrologic and geologic investigations and data; and special intensive short-term studies. Water quality data is accumulated through the National Water Quality Assessment Program. In addition, the Toxic Substances Hydrology Program is designed to provide information on the behavior of toxic substances in the nation's hydrologic environments.	Maps, data, and information on hydrology and water quality status and trends Staff for technical assistance in designing a monitoring plan. www.usgs.gov
Department of Transportation - U.S. Coast Guard	In accord with the Oil Pollution Act of 1990, the Coast Guard has an expanded role in response to hazardous substance spills.	www.uscg.mil

AGENCY AND PROGRAM	**PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES**	**RESOURCES AVAILABLE AND POSSIBLE ROLES**
U.S. Department of Agriculture (USDA), Conservation Reserve Program (CRP)	The CRP conserves and protects highly erodible or other environmentally sensitive land from production by putting it in permanent vegetative cover through easements and annual rental payments.	In most cases responsibilities within these programs are divided between various USDA departments: Natural Resources Conservation Service (NACS) - Technical assistance in planning, design, and implementation of Best Management Practices (BMPs) www.nrcs.usda.gov Farmers Services Agency (FSA) - Administrative oversight of program and cost-share funding disbursement www.fsa.usda.gov Cooperative Extension Service (CES) - Education and information about the variety of conservation and economic choices available Cooperative State Research, Education, and Extension Service (CSREES) - Research, data, and the results of new technologies www.reeusda.gov
Wetlands Reserve Program (WRP)	The WRP is available through states and is intended to return drained wetlands to wetland status and to protect existing wetlands. The WRP uses the same easement-payment method as CRP.	Technical and financial support to help landowners protect, restore, and enhance wetlands www.wl.fb-net.org
Sustainable Agricultural Research and Education Program (SARE)	SARE is a practical research, education, and grant program to promote lower input methods of farming.	Offers competitive grants to increase knowledge about and help farmers and ranchers adopt sustainable agriculture practices www.sare.org

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
U. S. Department of Defense (DOD) Army Corps of Engineers (COE)	COE oversees construction and operation of large flood-control and public water-supply reservoirs and conducts water-quality monitoring on lakes within its jurisdiction. The agency regulates in-lake activities and shoreline development. COE is responsible for granting or rejecting Clean Water Act Section 404 permits for dredging or filling wetlands. In assessing the merits of the permit application, the Corps is supposed to consider the extent and duration of the permit's adverse effects, possible alternatives, impact on fish and wildlife, water quality, flooding, recreation, historical and cultural values, and other factors. The agency can enforce permit requirements for wetland BMPs or other mitigation measures. Section 1135 of the Water Resources Development Act of 1986 authorizes structural or operational modifications to existing COE projects for purposes of improving the environment. Also, Section 204 of the Water Resources Act of 1994 allows the Corps to use dredged material beneficially to restore or create wetlands, provided the environmental, economic, and social benefits of the project justify the costs.	Maps, special studies, and water-quality monitoring data. Staff and funds for improvement of existing projects. Staff for review and oversight of Section 404 (wetlands) permits. Field offices located in various districts throughout states. Washington DC office. Water Resources Development Acts (WRDA) authorize environmental restoration at certain Great Lakes sites. www.usace.army.mil
U.S. Department of Agriculture (USDA) - Forest Service	The Forest Service is responsible for the control of the timber harvest in national forests and for reforestation of the harvested areas. The agency maintains that it employs an ecosystem management plan towards national forest areas taking into account biodiversity and long-term sustainability.	www.fs.fed.us
U.S. Department of Energy (DOE)	DOE is responsible for the cleanup of radioactive wastes that have accumulated over the last 50 years throughout the region. DOE is also responsible for providing clean, affordable, and dependable supplies of energy including renewable resources. DOE has been involved in the deregulation of the energy industry, which could increase pollution in the region from coal-fired energy facilities. The utility industry is the biggest source of pollution in the Great Lakes basin.	www.doe.gov
Federal Energy Regulatory Commission (FERC)	FERC is responsible for approving licenses for hydroelectric facilities and the dams that have been and are responsible for significant damage to Great Lakes fisheries. FERC inspects hydroelectric projects at all levels and has the power to regulate the safety precautions that hydroelectric facilities take to avoid damage to the ecosystem. FERC regulates the transmission and sale for resale of natural gas in interstate commerce, the transmission of oil by pipeline in interstate commerce, and the transmission and wholesale sales of electricity in interstate commerce.	www.ferc.fed.us

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
U.S. Department of Health and Human Services (USDHHS)	USDHHS is the U.S. government's principle agency for protecting the health of all Americans and providing essential human services.	www.os.dhhs.gov
Centers for Disease Control (CDC)	The CDC strives to promote health and quality of life by preventing and controlling disease, injury, and disability. CDC could potentially become involved in Lake Michigan issues if there is a serious contamination of the water leading to civilian illness. The nearest CDC office to Lake Michigan is in Cincinnati, Ohio.	www.cdc.gov

TABLE D-2

STATE ORGANIZATION STAKEHOLDERS

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Illinois Environmental Protection Agency (IEPA)	IEPA administers many programs (similar to EPA's) for protection of water quality in groundwater and surface waters, including the National Pollutant Discharge Elimination System (NPDES) permit program, water quality standards regulations, the nonpoint source program, and ambient statewide monitoring programs.	Staff for technical assistance to local governments and individuals implementing BMPs. Water quality monitoring, data, and reports. Illinois Environmental Protection Agency 2200 Churchill Road, P.O. Box 19276 Springfield, IL 62794-9276 Phone: (217) 782-3397 24-hour emergency number: Phone: (217) 782-3637 www.epa.state.il.us
Illinois Department of Natural Resources	The Illinois Department of Natural Resources promotes appreciation of the state's natural resources and works with the people of Illinois to protect and manage those resources to ensure a high quality of life for present and future generations.	dnr.state.il.us
Illinois Department of Agriculture	The Illinois Department of Agriculture's Bureau of Land and Water Resources distributes funds to 98 soil and water conservation districts for programs aimed at reducing soil loss and protecting water quality.	www.agr.state.il.us

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Indiana Department of Environmental Management (IDEM)	IDEM administers many programs (similar to EPA's) for protection of water quality in groundwater and surface waters, including the NPDES permit program, water quality standards regulations, the nonpoint source program, and ambient statewide monitoring programs.	Staff for technical assistance to local governments and individuals implementing BMPs. Water quality monitoring, data, and reports. Indiana Department of Environmental Management 100 N. Senate P.O. Box 6015 Indianapolis, IN 46206-6015 Phone: (800) 451-6027 24-hour emergency number: Phone: (317) 233-7745 www.state.in.us/idem/
Indiana Department of Agriculture	The Indiana Natural Resources Director in the Office of the Commissioner of Agriculture works to ensure that the needs of Indiana constituents are met with regards to natural resources. The Natural Resources Director works closely with the 92 Soil and Water Conservation Districts, the USDA, the Purdue University Cooperative Extension Service, and the Indiana Department of Natural Resources. The director cooperates and partners with individuals and organizations in the public and private sector to help conserve and protect our nation's natural resources.	www.ai.org/oca
Michigan Department of Environmental Quality (DEQ)	Michigan administers many programs (similar to EPA's) for protection of water quality in groundwater and surface waters, including the NPDES permit program, water quality standards regulations, the nonpoint source program, and ambient statewide monitoring programs. Michigan DEQ focuses on environmental regulatory, permitting, and related enforcement functions.	Staff for technical assistance to local governments and individuals implementing BMPs. Water quality monitoring, data, and reports. Michigan DEQ Box 30473 Lansing, MI 48909 Environmental Assistance Center Phone: (800) 662-9278 24-hr emergency number: (Michigan only) Phone: (800) 292-4706 www.deq.state.mi.us/

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Michigan Department of Natural Resources (DNR)	The Department of Natural Resources (DNR) is responsible for the stewardship of Michigan's natural resources and for the provision of outdoor recreational opportunities, a role it has relished since creation of the original Conservation Department in 1921. The DNR focuses on promoting diverse outdoor recreational opportunities, wildlife and fisheries management, forest management, state lands and minerals, State Parks and Recreation Areas, conservation, and law-enforcement.	www.dnr.state.mi.us/
Michigan Department of Agriculture	The Michigan Department of Agriculture sponsors programs for aerosol container recycling, groundwater stewardship, and pollution prevention in farming.	www.mda.state.mi.us/
Wisconsin Department of Natural Resources (DNR)	Wisconsin administers many programs (similar to EPA's) for protection of water quality in groundwater and surface waters, including the NPDES permit program, water quality standards regulations, the nonpoint source program, and ambient statewide monitoring programs. The Wisconsin DNR administers both natural resources programs and environmental law enforcement.	Staff for technical assistance to local governments and individuals implementing BMPs. Water quality monitoring, data, and reports. Wisconsin Department of Natural Resources P.O. Box 7921 Madison, WI 53707 Phone: (608) 266-2621 www.dnr.state.wi.us/
Wisconsin Department of Agriculture	The Wisconsin Department of Agriculture administers programs in land and water resource management, atrazine prohibition, conservation engineering, drainage districts, groundwater protection, shoreland management, and soil conservation.	datcp.state.wi.us/

TABLE D-3

TRIBAL AUTHORITY STAKEHOLDERS

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Little River Band of Ottawa Indians Natural Resources Commission	The Natural Resources Commission promotes environmental protection for tribal communities in an evolving partnership. EPA has a trustee responsibility for direct program implementation and provides grant funds for project and program development. Certain federal statutes provide for tribes to assume program responsibilities under treatment as state provisions.	Little River Band of Ottawa Indians P.O. Box 314 Manistee, MI 49660 Phone: (616) 723-8288 Fax: (616) 782-6882
Little Traverse Band of Ottawa Indians Planning Department		Little Traverse Band of Ottawa Indians 1345 U.S. 31 North P.O. Box 246 Petosky, MI 49770 Phone: (616) 348-3410 Fax: (616) 348-2589
Hannahville Indian Community		Hannahville Indian Community N14911 Hannahville B1 Rd. Wilson, MI 49896-9728 Phone: (906) 466-2959 Fax: (906) 466-2933
Grand Traverse Band of Ottawa and Chippewa Indian Natural Resources Division	The Natural Resources Division is responsible for Great Lakes fisheries, inland hunting and fishing, environmental planning and compliance, and conservation enforcement. Staff from the division participate on the Lake Michigan forum and Technical Coordinating Committee.	Grand Traverse Band of Ottawa and Chippewa 2605 N. West Bayshore Dr. Suttons Bay, MI 49682 Phone: (616) 271-3474 Fax: (616) 271-4230
Saginaw Chippewa Tribal Council		Saginaw Chippewa Tribal Council 7070 East Broadway Rd. Mt. Pleasant, MI 48858 Phone: (517) 772-5700 Fax: (517) 772-3508
Pokaogon Band of Potawatomi		Pokaogon Band of Potawatomi 714 N. Front St. Dowagiac, MI 49047 Phone: (616) 782-8998 Fax: (616) 723-8761

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Oneida Tribe of Wisconsin Environmental Department		Oneida Tribe of Wisconsin P.O. Box 365 Oneida, WI 54155 Phone: (414) 869-4521 Fax: (414) 869-2194
Sokaogon Chippewa Community Environmental Department		Sokaogon Chippewa Community Route 1, P.O. Box 625 Crandon, WI 54520 Phone (715) 478-2604 Fax: (715)478-5275
Menominee Indian Tribe Environmental Services - Menominee Forestry Center		Menominee Indian Tribe P.O. Box 670 Keshena, WI 54135 Phone: (715) 799-3095 Fax: (715) 799-4525
Stockbridge-Munsee Band of Mohicans Environmental Department		Stockbridge-Munsee Band of Mohicans Route 1 Bowler, WI 54416 Phone: (715) 793-4942 Fax: (715) 793-1307
Forest County Potawatomi Community		Forest County Potawatomi Community P.O. Box 346 Crandon, WI 54520 Phone: (715) 478-7209

TABLE D-4

INTERNATIONAL AND INTERSTATE STAKEHOLDERS

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
International Joint Commission (IJC)	The IJC is an independent organization set up under the 1909 Boundary Waters Treaty between the United States and Canada. The IJC monitors and assesses progress made pursuant to the Great Lake Water Quality Agreement.	www.ijc.org
Great Lakes Commission (GLC)	The GLC is an interstate commission of gubernatorial-appointed and legislatively mandated representatives of eight Great Lakes States in the United States. It has a statutory mandate to represent its views on development, use, and conservation of Great Lakes basin aquatic resources. The GLC promotes orderly, integrated, and comprehensive development, use, and conservation of the basin's water resources. The GLC plans the welfare and development of water resources in the basin as a whole and in areas that have special problems. The GLC also makes it possible for states and citizens in the basin to derive maximum benefit from the use of public works, in the form of navigation aids or otherwise, that already exist or are being constructed. In addition, the GLC advises in securing and maintaining proper balance among industrial, commercial, agricultural, water supply, residential, recreational, and other legitimate uses of basin water resources. Finally, the GLC establishes and maintains an intergovernmental agency to accomplish the purposes of the compact more effectively.	www.glc.org

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Great Lakes Fishery Commission (GLFC)	The GLFC was established by the Convention of Great Lakes Fisheries between Canada and the United States in October 1955. The GLFC was formed for the following purposes: To formulate a research program designed to determine the need for measures to make possible the maximum sustained productivity of any stock of fish that is of concern to both countries. To coordinate and undertake such research. To recommend appropriate measures on the basis of findings of the research. To formulate and implement a comprehensive program for the eradication or minimization of sea lamprey populations. To publish information obtained under its activities.	www.glfc.org/
Council of Great Lakes Governors	The Council of Great Lakes Governors is a private, nonprofit corporation formed in 1982 to work cooperatively on public policy issues common to the eight Great Lakes states. The Council emphasizes the benefits of a regional approach to addressing the economic needs and the environmental challenges it faces.	www.cglg.org
Great Lakes Protection Fund	The Great Lakes Protection Fund was created in 1989 as a multistate environmental endowment. It seeks to become a global model of political and economic cooperation in the management of a shared natural resource. The Fund is a permanent $100 million endowment. It solicits grant proposals for projects, in participating states, that demonstrate or promote regional action to enhance the Great Lakes ecosystem.	www.glpf.org

TABLE D-5

PUBLIC ORGANIZATION STAKEHOLDERS

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Local Government	Local municipalities within the Lake Michigan watershed have the ability to plan land development and implement zoning programs to protect coastal zones from erosion, storm runoff, and waste contamination. Public participation can be instrumental in identifying problem areas and possible solutions for improving the health of the Great Lakes ecosystem. The EPA, FWS, the Forest Service, NOAA, and the National Park Service all solicit participation in ecosystem approaches to the Great Lakes basin.	
Lake Michigan Forum	The Lake Michigan Forum provides EPA with public input on the Lake Michigan Lakewide Management Plan (LaMP). Forum participants are stakeholders in the Lake Michigan basin and include industry, environmental groups, sport fishing groups, academia, agriculture, and Native Americans. As the nongovernmental component of the LaMP process, the forum has established a work plan in an effort to identify and stimulate nongovernmental activities that are consistent with or implement the goals set through in the LaMP process. The forum work plan covers a variety of issues ranging from specific activities (such as developing pollution prevention and watershed initiatives) to broader ideas like pressing for commitment to the LaMP process and improving education and outreach efforts.	www.lkmichganforum.org/
Illinois Conservation Foundation	The mission of the Illinois Conservation Foundation is to enhance, through external funding, the goals and programs of the Illinois Department of Natural Resources.	Phone: (312) 814-7237
Lake Michigan Federation	The Lake Michigan Federation is made up of volunteers and professionals working to restore Lake Michigan, the waters that feed into it, and its shoreline. Since 1970, the federation has empowered people with the knowledge and skills necessary to promote positive change in their communities. It is the only organization dedicated to the protection of the largest lake within the United States.	www.lakemichigan.org/

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Great Lakes United	Great Lakes United is an international coalition dedicated to preserving and restoring the Great Lakes-St. Lawrence River ecosystem. Great Lakes United is made up of member organizations representing environmentalists, conservationists, hunters and anglers, labor unions, community groups, and citizens of the United States, Canada, and First Nations and Tribes. Great Lakes United develops and promotes effective policy initiatives, carries out education programs, and promotes citizen action and grassroots leadership to ensure the following: • Clean water and clean air for all citizens • Better safeguards to protect the health of people and wildlife • A conservation ethic that will leave a healthy Great Lakes	www.glu.org
Council of Great Lakes Industries	Council of Great Lakes Industries is a nonprofit organization that represents the common interests of United States and Canadian industrial organizations from the manufacturing, utilities, transportation, communications, financial services, and trade sectors that have investments in the Great Lakes Basin. The Council works to ensure that industry is a substantive partner in the Great Lakes regional public policy development process. The Council is a partner organization with the World Business Council for Sustainable Development, Geneva, Switzerland.	www.cgli.org

AGENCY AND PROGRAM	**PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES**	**RESOURCES AVAILABLE AND POSSIBLE ROLES**
Great Lakes Sport Fishing Council	The Great Lakes Sport Fishing Council is a nonprofit confederation of organizations and individuals who have banded together in the Great Lakes region. It is an advocacy organization whose members are concerned about the present and future of sport fishing and its economic benefits in the Great Lakes and adjoining waters and in protecting and enhancing the regional sport fishery and its wetlands, habitat, and environment. In addition to general council business, area reports are presented by delegates from member-clubs in various states. The council also supports reports by representatives such as biologists, limnologists, DNR, and federal agencies and organizations. These council briefings cover a wide range of topics such as exotics; state and federal fish stocking programs; new or revised fishing regulations; outlooks for the forage base and sport fishery; environmental problems and initiatives; illegal trafficking in gamefish; scientific research and what it mean to anglers; commercial or sport fishing abuses; proposed legislation; economic impacts; tourism enhancement; and other pertinent subject matters that affect or interest them.	www.great-lakes.org/

AGENCY AND PROGRAM	PROGRAM DESCRIPTIONS AND AGENCY RESPONSIBILITIES	RESOURCES AVAILABLE AND POSSIBLE ROLES
Michigan Association of Conservation Districts (MACD)	The MACD, a nonprofit 501(c)3 organization was established to represent and provide services to Michigan's 82 conservation districts. Each Conservation District is recognized as a local unit of state government with specified responsibilities and limitations according to state law (Act 297 of 1937 as amended). Michigan's Conservation Districts are organized by local people to address soil and water conservation concerns. Districts provide site-specific, technical assistance and information to landowners, local decision-makers, educators, and the general public in resource management. The primary focus of the districts is controlling nonpoint source pollution to prevent off-site damage, especially to surface water and groundwater quality. Districts also provide assistance to communities in forest management, wildlife habitat management, pollution prevention, and other state and local resource concerns. For example, the Muskegon Conservation District serves as the local Remedial Action Plan Coordinator for the Muskegon Lake and White Lake Areas of Concern.	Gateway to information, maps, and special studies on local resource concerns Staff for technical assistance on water quality, agricultural, and wildlife habitat projects Grant-writing and acquisition to assist Public Advisory Councils, local governments and individuals implementing Remedial Action Plans, Watershed Management Plans, and other environmental planning and implementation projects Facilitators and catalysts for partnerships on a variety of planning, educational, and implementation projects for natural resource and ecosystem stewardship activities www.macd.org
Annis Water Resources Institute (AWRI), Grand Valley State University	AWRI is a university-based organization dedicated to practical research and education for decision-makers and the general public. Its Lake Michigan Center on the shoreline of Muskegon Lake, Michigan, serves as a catalyst for lake and watershed activities. The AWRI Information Services Center provides geographic information system capability and expertise in watershed projects. Its environmental analytical laboratory works on Areas of Concern. The AWRI Outreach and Education Program has worked closely with the Lake Michigan Forum for the Making Lake Michigan Great Tour of the W. G. Jackson vessel and for the Lake Michigan: State of the Lake Conference.	740 Shoreline Drive Muskegon MI 49441 Phone: (616) 895-3749 www.4.gvsu.edu/wri/

APPENDIX E

LAKE MICHIGAN TMDL STRATEGY PLANNING DOCUMENT

Lake Michigan TMDL Strategy Planning Document

1.0 Introduction

This strategy planning document identifies the goals, objectives, processes, and key issues related to the development and use of Total Maximum Daily Loads (TMDL) for the open waters of Lake Michigan. The procedures outlined in this document are consistent with those stipulated under the Water Quality Guidance for the Great Lakes System (40 CFR Part 132, Appendix F) and other U.S. Environmental Protection Agency regulations, policy, and guidance promulgated or published under the authority of Section 303 of the Clean Water Act (CWA).

TMDLs for tributaries to Lake Michigan are being addressed by the states. Nonetheless, TMDL activities related to those tributaries are included in this document because of their importance to the quality of the open waters of the lake.

This document is intended to generate discussion and will guide the development of the final TMDL Strategy for Lake Michigan. The strategy will map out a plan to coordinate the work of EPA, the states, and other interested stakeholders involved in the TMDL process. The strategy will not discuss TMDL implementation; that will be part of any TMDL that is ultimately developed. Furthermore, since a TMDL is only one of many tools discussed below for managing the Great Lakes, other protection and restoration efforts will not wait for the development of a TMDL and may eventually make a TMDL for the open waters of the lake unnecessary. As a result, this document is only the first step in a lengthy process.

This strategy planning document is organized in six sections and one appendix. Following this introduction, Section 2.0 provides background on the status of Lake Michigan and 303(d) listed water segments within the Lake Michigan watershed. Section 3.0 describes the TMDL process and compares it with the Lakewide Management Plan (LaMP) program goals defined under the Great Lakes Water Quality Agreement (GLWQA). Section 4.0 describes the key issues to be resolved to develop a Lake Michigan TMDL Strategy. Section 5.0 presents a framework for a TMDL strategy to serve as a “strawman” for generating discussion and comment. Section 6.0 briefly describes the next steps in the TMDL strategy development process. Finally, Appendix A lays out the key steps in the TMDL process.

General Relationship Among a TMDL Strategy and Other Management Programs and Tools

The TMDL Strategy will address one of many tools that can be used to manage Great Lakes ecosystem quality. The following discussion generally outlines the statutory basis for water quality management and the variety of tools for addressing water quality impairment in the lakes. The Lake Michigan LaMP describes those programs and activities in greater detail. This introductory discussion is intended to place the TMDL program within the larger context of Great Lakes management.

Statutory Authorities: Setting Goals

The CWA provides the overall goals (fishable, swimmable, and drinkable) and authority for regulating certain activities that affect clean water in this country. In addition, the GLWQA between the United States and Canada defines more specific and common goals for the Great Lakes basin. The states and tribes use the provisions of the CWA for designating water body uses and the necessary standards to be met to support those uses. Any request for a National Pollutant Discharge Elimination System (NPDES) permit to discharge into a water body is judged against the designated use for the receiving water body and the adopted state standards. Within the Great Lakes Basin, those water quality standards must meet the common Great Lakes Water Quality Guidance objectives, including: 1) being no less restrictive than the limits on pollutants that protect human health, aquatic life, and wildlife; 2) encompassing anti-degradation policies; and 3) incorporating implementation procedures.

Tools: Regulatory, Non-regulatory, and Voluntary Approaches to Pollution Control

Under the statutory authorities governing lake water quality management, a variety of regulatory and non-regulatory programs are implemented at the federal, state, and local levels. In addition, the public and private sectors implement voluntary pollution reduction programs and strategies to reduce pollutant load to the lakes. Several of those programs are described below.

Water Discharge Permitting. The CWA prohibits discharges of "pollutants" through a "point source" into a "water of the United States" unless the discharge is authorized under a NPDES permit. The permit specifies limits on effluent concentrations and loads, monitoring and reporting requirements, and other provisions to ensure that the discharge does not impair water quality or human health. In essence, the permit translates general CWA requirements into specific provisions tailored to the operations of each entity discharging pollutants. Illinois, Indiana, Michigan, and Wisconsin all have been delegated their NPDES permit programs and are authorized to issue permits.

TMDL - Achieving Water Quality Standards. For those waters not meeting quality standards after application of wastewater treatment technology mandated through an NPDES permit, states are required to calculate a TMDL. TMDL calculations are usually complex and may address a variety of pollutant sources. Although the states have primary responsibility for performing TMDLs, EPA will provide resources for technical assistance to assist in developing TMDLs, including TMDLs for interstate waters like the Great Lakes.

Technical and Economic Assistance. Reductions of pollutant load to the Great Lakes are also supported through technical and economic assistance provided by the basin governments. For example, Section 319 of the CWA authorizes EPA to provide funds to the states for nonpoint source control project grants. Similarly, the U.S. Department of Agriculture provides economic assistance through the Environmental Quality Incentives Program to aid in controlling agricultural runoff. Overall, scores of federal, state, local, and private assistance programs are available to help reduce pollutants and control pollutant load to the lakes.

Pollution Prevention Partnerships. Partnerships among governments, the private sector, and other interested stakeholders help achieve voluntary pollution reductions. For example, through Partners for the Environment, EPA collaborates with more than 7,000 organizations that use voluntary goals and commitments to achieve measurable environmental results in a timely and cost-effective way. Partners include small and large businesses, citizens groups, state and local governments, universities, and trade associations.

The results of voluntary actions taken through more than 20 distinct partnership programs are impressive. Focusing on pollution prevention, organizations set and reach environmental goals such as conserving water and energy or reducing greenhouse gases, toxic emissions, solid wastes, indoor air pollution, and pesticide risk.

Tools: Assessing Watershed Conditions

In addition to placing controls on pollutant load to the lake, new programs are in place to improve the long-term assessment of water quality conditions in the basin. The 1998 Clean Water Action Plan (CWAP) began the process of developing *unified watershed assessments* based on the consolidation of information for a whole *watershed* from federal, state, tribal and intergovernmental groups assessment tools. These assessments build upon the data collection, assessment, and reporting activities mandated under Sections 305(b), 303(d), and 304(l) of the CWA. The plan identifies unified watershed Categories I through IV. The categories are: I) not meeting clean water and other natural resources goals, II) prevention action is needed to sustain water quality and aquatic resources, III) outstanding resource waters that deserve the highest protection and IV) watersheds with insufficient data.

Tools: Restoring Degraded Portions of the Lake Michigan Ecosystem

Finally, restoration activities administered by the federal government and the States are also an integral part of Great Lakes management. In particular, CERCLA has provided authority and funding to support sediment and other remediation in the Areas of Concern and other degraded areas within the basin. The CWAP calls for states and tribes, working with all appropriate agencies, organizations, and the public, to identify the Category I watersheds most in need of restoration, beginning in the 1999-2000 period. A schedule will be developed and coordinated with the list of waters that do not meet State Water Quality Standards under section 303(d) of the CWA.

Coordinating Lake Management Activities through Planning

The CWAP and the Lake Michigan Lakewide Management Plan both call for working with numerous federal agencies, states, tribes, and other organizations to address the impairments. For the portions of Lake Michigan that require a TMDL, the LaMP Technical Coordinating Committee will function as the convening and coordinating committee to address Lake Michigan issues. Data from the Lake Michigan Mass Balance Study and Enhanced Tributary Monitoring Project will be added to the 1999 unified assessments to identify any outstanding data gaps. The time frame for filling the data gaps and the resources available will help determine the TMDL strategy and schedule for Lake Michigan. The following discussion provides a starting point for the TMDL Strategy development process.

2.0 Background - Status of Lake Michigan and State TMDL Programs

Lake Michigan supports many beneficial uses, including recreation, drinking water supply, ecological habitat, and certain industrial and commercial uses. Nonetheless, despite overall reductions in conventional and toxic pollutant loads to Lake Michigan over the past 20 years, data indicate that pollutants still exert negative impacts on the chemical, physical, and biological components of the Lake Michigan ecosystem. The remaining problems in Lake Michigan are significantly related to legacy contamination. Specifically, the lake ecosystem contains contaminants at levels that result in fish consumption advisories, impairments to aquatic organisms and wildlife, seasonal beach closures, and contamination of drinking water sources.

Fish consumption advisories for Lake Michigan are generally the result of elevated levels of PCB and mercury in fish. Fish consumption advisories for these chemicals also are used for the tributaries of Lake Michigan. In addition to PCBs and mercury, chlordane, dioxins, dieldrin, DDT and metabolites, and furans are considered level 1 critical pollutants in Lake Michigan. However, only those pollutants that are listed on one or more States' 303(d) lists for the open waters of the lake will be included in a TMDL completed for the lake.

Other pollutants cause or contribute to use impairment on a local or regional scale in Lake Michigan. In addition, some pollutant loadings are of concern in Lake Michigan, but do not necessarily exceed water quality standards. Those pollutants of concern include: hexachlorobenzene, toxaphene, cadmium, copper, arsenic, PAHs, chromium, zinc, and cyanide. Atrazine, PCB substitute compounds, and selenium are toxic substances that have characteristics indicating a potential to impact the physical or biological integrity of Lake Michigan. Those three compounds are considered emerging pollutants. Finally, pathogens, such as *E. coli* and *Cryptosporidium*, have caused beach closings and tainted drinking water along the coast of Lake Michigan, and nutrient loading remains a problem in certain near-shore areas and embayments, rivers, and lakes.

303(d) Listed Water Segments

Lake Michigan and many of its tributaries are impaired and do not meet water quality standards for PCBs, mercury, and other constituents. Waters that do not meet water quality standards require a state-developed TMDL for each water body and pollutant. Table 1 lists the impaired water segments, both Lake Michigan segments and tributaries discharging directly into Lake Michigan; the parameters of concern resulting in the state's identification of the impaired or threatened water body under Section 303(d) of the CWA; and the schedule for completing the TMDL for the water body. Table 1 includes those listed water bodies that discharge into Lake Michigan.

Table 1. Lake Michigan State 303(d) List Summaries

State	Water Body	Schedule	Parameters of Concern								
			WQS-PCBs	WQS-Mercury	FCA-PCBs	FCA-Mercury	E. Coli	Lead	Pesticides	D.O.	Other
WI	Fox River	2 years			✓					✓	Turbidity, aquatic toxicity
	Black River			✓						✓	
	Green Bay	2 years			✓					✓	Bacteria
	Kewaunee River				✓						
	Kewaunee Harbor										Aquatic toxicity, FCA
	Kewaunee Marsh										Aquatic toxicity, wildlife
	Lake Michigan										Multiple
	Little Menominee										Aquatic toxicity
	Manitowoc River	2 years (South Branch)			✓						
	Menominee AOC										FCA-arsenic, habitat loss
	Milwaukee Estuary				✓						Toxicity, habitat loss
	Oak Creek										Aquatic toxicity
	Oconto River					✓					
	Peshtigo River					✓					
	Pike River										Fish kills, toxicity
	Racine Harbor										Aquatic toxicity, FCA
	Root River				✓					✓	
	Sheboygan River	2 years			✓	✓					
	Sturgeon Bay										Aquatic toxicity
	Two Rivers Harbor										Aquatic toxicity, FCA

Table 1. Lake Michigan State 303(d) List Summaries (Continued)

State	Water Body	Schedule	Parameters of Concern								
			WQS-PCBs	WQS-Mercury	FCA-PCBs	FCA-Mercury	E. Coli	Lead	Pesticides	D.O.	Other
MI	Grand River	2003, 2008	✓		✓					✓	CSO, pathogens, untreated sewage, macroinvertebrate rated poor
	Kalamazoo River	2006	✓	✓	✓						
	Lake Michigan										FCA
	Manistee Lake	2006									CSO, pathogens, untreated sewage
	Manistique River	1999, 2011	✓	✓	✓	✓					CSO, pathogens, untreated sewage
	Menominee River	2009, 2010	✓	✓	✓	✓					CSO, pathogens, untreated sewage, FCA-TCDD
	Black River	1999			✓						chlordane
	Galien River	2009			✓						
	Mona Lake	2009			✓						
	Muskegon Lake	2008, 2010	✓	✓							
	Pere Marquette River	2008, 2010	✓	✓							
	Sawyer Creek	2003									macroinvertebrate rated poor
	St. Joseph River	2003, 2007, 2009	✓	✓	✓						CSO, pathogens, untreated sewage, poor macroinvertebrate
	White Lake	2009			✓						FCA-chlordane
IN	Grand Calumet River	1998-2000			✓	✓		✓	✓	✓	Cyanide, oil and grease, copper, impaired biotic, ammonia, chlorides

Table 1. Lake Michigan State 303(d) List Summaries (Continued)

State	Water Body	Schedule	Parameters of Concern								
			WQS-PCBs	WQS-Mercury	FCA-PCBs	FCA-Mercury	E. Coli	Lead	Pesticides	D.O.	Other
	Lake Michigan	2000-2004			✓	✓	✓				
	Indiana Harbor	1998-2000			✓	✓		✓	✓	✓	
	Little Calumet River	2000-2004					✓		✓	✓	Cyanide
IL	Lake Michigan										
	Waukegan River - South Branch										Priority organics, metals, habitat alterations

Notes: CSO = Combined Sewer Overflow
FCA = Fish Consumption Advisory

Water Quality Standards Applicable to Lake Michigan

Under the Water Quality Guidance for the Great Lakes System, the Great Lakes states and tribes are to adopt numeric water quality criteria and water quality programs that are consistent with the stipulations of 40 CFR Part 132. As a result, once approved by EPA water quality standards (WQS) for constituents identified under 40 CFR 132.3 promulgated by the states and tribes for waters in the Lake Michigan system will be consistent with the minimum requirements of 40 CFR Part 132. Water quality standards currently promulgated by the states are found at the following:

Illinois

The State of Illinois sets WQSs and methods for calculating standards and criteria for Illinois waters in the Lake Michigan Basin and Lake Michigan under 35 Illinois Administrative Code (IAC) Subpart E. The waters of the Lake Michigan Basin that must meet these WQSs include: the open waters of Lake Michigan within the jurisdiction of Illinois lakeward from a line drawn across the mouth of tributaries to Lake Michigan, but not including waters enclosed by breakwaters; Lake Michigan harbors and waters within the jurisdiction of Illinois; and waters tributary to Lake Michigan. The Chicago River, the North Shore Channel, and the Calumet River of are not included in the Lake Michigan Basin.

Indiana

The State of Indiana sets WQSs and methods for calculating standards and criteria for all Indiana waters within the Great Lakes system under 327 Indiana Administrative Code 2-1.5. The standards address all Indiana waters within the Lake Michigan Basin. The goal of the state is to restore and maintain the chemical, physical, and biological integrity of those waters.

Michigan

The State of Michigan sets WQSs and methods for calculating standards and criteria for the Great Lakes, connecting waters, and all other surface waters of the state under Part 4 of the Natural Resources and Environmental Protection Act, Act 451 of 1994.

Wisconsin

The State of Wisconsin sets WQSs and methods for calculating standards and criteria for Wisconsin surface waters under the Wisconsin Administrative Code (WAC) Chapter Natural Resources (NR) 102. WAC Chapter NR 104 sets uses and designated standards for intrastate and interstate waters, and WAC Chapter NR 105 sets surface water quality criteria and secondary values for toxic substances. All surface waters within the drainage basin of the Great Lakes are to be protected from the impacts of persistent, bioaccumulating toxic substances by avoiding or limiting to the maximum extent practicable increases in those substances.

3.0 The Relationship Between TMDL and the LaMP Processes

This section first describes the key elements that a Lake Michigan TMDL strategy must address. The section then provides an overview of the twelve key components or steps in TMDL development. The section concludes with a comparison of the TMDL and LaMP processes.

Key Elements of a TMDL Strategy

Any TMDL strategy developed for Lake Michigan should focus on five key elements: 1) Goals and Objectives, 2) Scope and Scale, 3) Monitoring and Data, 4) Coordinated Planning Efforts, and 5) Partnerships.

GOALS AND OBJECTIVES: If the TMDL process is to be successful, sound and achievable goals and objectives must be identified. Several statutory and planning processes have established goals and objectives, along with specific substances identified as critical pollutants that need to be controlled or eliminated. Strategically, it will be important to evaluate all of the associated goals and objectives under the various planning processes to ensure that there are no conflicts. It is also important to evaluate all of the substances identified as pollutants to determine which ones can or should be readily controlled through a TMDL process, and which ones will need to be managed though some other process. As part of a strategic planning process, it will be important to narrow down the goals and objectives, as well as the substances identified as critical pollutants, into a clear and concise suite that fits under the guidelines for waterbodies or waterbody segments needing TMDLs. The TMDL process is just one of many tools used to address specific goals and objectives and certain identified critical pollutants that are currently causing an impairment to meeting the designated uses of the Great Lakes and their basins. The development of TMDCs does not preclude the use of other mechanisms that will be used to attain of the other goals and objectives that have been set forth for the Great Lakes and their basins by the various planning and statutory processes.

Those statutory and planning processes that have identified goals and objectives, along with identified critical pollutants, include:

1) The designated uses of the waterbody or waterbody segment as established by the states along with the applicable water quality standards and criteria associated with the identified designated uses (which are to be consistent with the Water Quality Guidance for the Great Lakes System, 40 CFR Part 132).

2) The Great Lakes Initiative, which established final water quality guidance for the Great Lakes Systems for criteria limits or methodologies for the control of bioaccumulative chemicals of concern (BCC), EPA, March 1995.

3) The GLWQA, which identifies both the 14 beneficial uses for the Great Lakes and the requirement for no increase in toxic loads, 1972, and the amendments of 1978 and 1987.

4) The International Joint Commission (IJC), 1987, which identified substances as critical pollutants.

5) The Great Lakes Binational Toxics Strategy, which focuses on the virtual elimination of persistent toxic substances in the Great Lakes.

6) The Area of Concerns and their corresponding Remedial Action Plans (RAPs) which have identified goals and objectives.

7) The goals and objectives identified in the LaMPs along with the substances designated as lakewide critical pollutants.

8) The goals and objectives of the Source Water Protection Planning process.

9) The goals and objectives set forth in the CWAP, which has defined key actions and milestones.

SCOPE AND SCALE: Because of the large geographic size of the Great Lakes and their basins, and the complexity of the impairments and sources of those impairments, it is necessary to clearly identify both the scope and scale that can be managed by the TMDL process. It is also important to understand that the TMDL process functions through the use of a mathematical model that at best can only predict possible results, but not necessarily actual results.

First, the scope of the overall TMDL process within the lake and its basin should be defined. Beyond defining the impairments, it is important that both the causes and sources of the impairments be identified. Therefore, the initial scope should focus on three main categories as possible sources of impairment: tributaries, air deposition, and in-place or legacy pollutants. Under each one of those categories, additional sources can be further defined, such as point and nonpoint sources for tributaries, local and distant point and nonpoint sources for air deposition, and sites at which in-place pollutants are present, such as AOCs or Superfund sites. Each of those issues could then be addressed by the TMDL process within an identified scale.

MONITORING AND DATA: Because the Great Lakes are a very complex system, the need for sound, scientifically credible data is critical to the ability to produce TMDLs that result in reasonable load allocations that fall within an acceptable confidence range. It is also important that the data used in the modeling component of a TMDL be scientifically sound and credible. That consideration is especially important because the loads that are to be allocated for control are in some cases regulatory. It is also very important that the data be of high quality, since the implementation plans associated with the load allocations should reasonably result in water quality improvement and meet WQS.

COORDINATED PLANNING EFFORTS: Because of the many issues associated with maintaining and protecting the water quality of the Great Lakes and their associated basins, numerous planning efforts are currently ongoing. Some of those planning efforts were defined under the goals and objectives section of this document. Other planning efforts will include the TMDL implementation plans and any program activities that may or may not be incorporated into the TMDL implementation plans.

Effectively implementing this process will require committed leadership and the ability to develop and maintain good partnerships.

PARTNERSHIPS: To develop Great Lake TMDLs and ensure effective implementation of the TMDL implementation plans, effective partnerships must be developed. To establish effective partnerships for both the development and the implementation of TMDLs within the Great Lakes and their associated basins, the following strategic approach is presented.

1) Identify the lead agency or agencies that will be responsible for developing and maintaining the needed partnerships for developing and implementing the TMDL process.

2) Identify the partners needed and define their roles and responsibilities ensuring the effective development and implementation of the TMDLs and the TMDL implementation plans.

3) Identify the partners in two major categories: those that would function in a statutory or regulatory mode and those that would function in a voluntary mode.

4) Evaluate the partners' resource capability in being able to carry out their defined roles and responsibilities. When there is a lack of resources, determine the options that might be available to assist or reinforce resource capabilities for partners.

5) Develop and define a forum through which partners can be brought together to exchange information and work effectively to develop and implement TMDLs.

Components of a TMDL

Section 303(d) of the CWA, EPA's implementing regulations at 40 CFR Part 130, and the Water Quality Guidance for the Great Lakes System (40 CFR Part 132) describe the statutory and regulatory requirements for approvable TMDLs. The minimum components of a TMDL are outlined in Appendix A of this document and include the following:

1) Description of Waterbody, Impairment or Standard Violation, Pollutant of Concern, Pollutant Sources, and Priority Ranking
2) Description of TMDL Endpoints -- Applicable Water Quality Standards and Numeric Quality Targets
3) Loading Capacity - Linking Water Quality and Pollutant Sources
4) Load Allocations (LA)
5) Wasteload Allocations (WLA)
6) Margin of Safety (MOS)
7) Seasonal Variation
8) Monitoring Plan for TMDLs Developed Under the Phased Approach
9) Implementation Plans (recommended under current policy)
10) Reasonable Assurances of Implementation
11) Public Participation
12) Submittal Letter

In addition, 40 CFR Part 132 establishes specific requirements related to TMDL development in the Great Lakes Basin..

Revisions of the TMDL process are expected in the year 2000. New regulations have been proposed that will change requirements under the Section 303(d) lists and for TMDLs. Under the proposed regulations, the states are responsible for developing the list of impaired or threatened waters every two years (this requirement may change). Impairment is defined as those waters that do not meet the standards for their designated use or the appropriate WQS.

The LaMP process is outlined under the GLWQA of 1978. Under the GLWQA, as amended by the Protocols of 1983 and 1987, the United States and Canada (the Parties) agreed ". . . to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." To achieve that purpose, the Parties agreed to develop and implement, in consultation with state governments, provincial governments, and tribes, LaMPs for open lake waters.

In the case of Lake Michigan, the only Great Lake wholly within the borders of the United States, the LaMP development effort has been led by the United States, as called for in Section II of the CWA. As specified in Annex 2 of the GLWQA, the LaMP for Lake Michigan is designed to reduce loadings of critical pollutants to restore 14 designated beneficial uses and prevent increases in pollutant loadings in areas in which the specific objectives of the agreement are not exceeded. Moreover, the Specific Objectives Supplement to Annex I of the GLWQA requires the development of ecosystem objectives for Lake Michigan. Pursuant to that charge, the Lake Michigan LaMP embodies a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses by seeking a balance between critical pollutant reduction and ecosystem sustainability in open lake waters and the watersheds that comprise the lake basin.

Comparison of the TMDL and the LaMP Processes

The TMDL and the LaMP processes are fundamentally similar, but there are several key distinctions between them:

1) Both processes are intended to achieve clearly defined endpoints -- a water quality standard or numeric water quality target in the case of a TMDL, and a set of ecosystem objectives under the LaMP. However, the TMDL endpoints focus solely on water quality standards, while the LaMP considers other ecosystem objectives in addition to numeric water quality targets. For example, the LaMP calls for the removal of restrictions on consumption of fish and wildlife, prevention of deformities or reproductive problems, and protection of the benthos. As a result, the LaMP process has identified more than 20 critical pollutants to serve as the focus for management activities, while a TMDL for the open waters of the lake will focus on only those pollutants that are linked to exceedances of WQSs.

2) Both processes require a documented status of the ecosystem.

3) Management planning to achieve ecosystem objectives is a key component of the LaMP. Implementation planning is recommended under the TMDL process and may be a required part of an approvable TMDL under the proposed regulations. However, planning is currently not the central focus of a TMDL.

4) Developing a direct link between pollutant load and achievement of the endpoint, often through water quality modeling, is a critical component of a TMDL. In contrast, the LaMP describes the relationship between loading and achievement of an ecosystem objective as a partnership effort involving the governments, tribes, and non-governmental sectors of the basin.

5) Both processes require an integrated monitoring plan for the lake. In 1999, the Lake Michigan Monitoring Coordinating Council was established to provide coordination and support for monitoring across agency and jurisdictional boundaries.

6) Both processes require data, but the data are to be measured against different objectives. The Lake Michigan Mass Balance Study provides actual water column, sediment, and biota concentration data, and the models scheduled to be run in 2000 will provide mass budgets, time concentrations, and load response.

In sum, the TMDL and LaMP processes are intended to achieve the common objective of restoring the Lake Michigan ecosystem. However, a TMDL defines ecosystem protection more narrowly through the application of WQSs and places great emphasis on understanding the relationship between pollutant load and achievement of the standard. In contrast, the LaMP defines ecosystem protection and restoration more broadly and places greater emphasis on pollution control planning and developing implementation targets.

4.0 Issues to Be Resolved

The Lake Michigan LaMP Technical Coordinating Committee has identified a number of key issues to be resolved to better coordinate LaMP and TMDL activities (options for addressing each of these issues will be developed under the TMDL Strategy).

Issue 1:	Identifying roles and responsibilities for each of the listed waters: tributaries, nearshore waters, open waters of the lake.
Issue 2:	Should the lake be partitioned into segments that would be easier and more efficient to address with TMDLs?
Issue 3:	Encourage consistency in 303(d) listing procedures among the States.
Issue 4:	Maintain consistency in endpoint determinations (water quality standards) among the States.
Issue 5:	Review the use of mass balance studies (e.g., the Green Bay and Lake Michigan Mass Balance Studies) and review their applicability to support a TMDL.
Issue 6:	Integrate with other Programs (e.g., Source Water Protection Program).
Issue 7:	Clarify the relationship between LaMP restoration and protection goals and TMDL endpoints (water quality standards). - 20 LaMP critical pollutants vs. water quality standards exceedances
Issue 8:	Investigate options for addressing air deposition of TMDL pollutants.
Issue 9:	Develop approaches for determining margin of safety when addressing fish consumption advisories.
Issue 10:	Maintain consistency among the five Great Lakes.
Issue 11:	Define the role of the Tribes in the TMDL process.

5.0 Strawman Framework for a Lake Michigan TMDL Strategy

As a means of generating discussion about the likely components of a Lake Michigan TMDL strategy, the following "strawman" framework is offered. Throughout this process, opportunities for public participation must be provided when identifying impaired water bodies, setting TMDL endpoints, and allocating loads. Public involvement in eventual development of implementation plans is also critical (see Appendix A).

Process

The process of developing the TMDLs for the Great Lakes will include the following steps:

1) Identify the impairments.

2) If at all possible, identify impaired segments.

3) Approve the listing of the segment under Section 303(d).

4) Generate the TMDL.

A) Determination of sources: While air deposition of mercury and PCBs may pose the largest portion of the load of those two pollutants to the lakes, other sources must be identified. In addition, other portions of the lakes were identified on the 1998 lists for impairments other than fish consumption advisories.

B) Determination of loads from the sources:

Significant amounts of data regarding the Great Lakes already exist, much generated during the LaMP process. Additional information about air deposition of mercury is being gathered through the Devil's Lake Pilot Project. Data from that project, as well as other air deposition mercury projects, will be incorporated, as generated, into the development of any appropriate TMDL.

Numerous TMDLs are scheduled for tributaries to the various Great Lakes. Those efforts will certainly result in the generation of addition data on loading of pollutants to the Great Lakes, as well as bringing about lower loadings as the TMDLs are implemented.

Although a large quantity of data is available, significant data gaps have been identified. The data gaps include:

1) Relevant information about TMDLs or mass balance activities for interstate or other waters that may contribute insight into TMDLs for Great Lakes listed waters

2) Discussion of impairments listed in LaMPs and the TMDL lists, and the relationship to state standards

3) Air deposition data for mercury and PCBs in the Great Lakes Basin

As the process moves forward, numerous data gaps will certainly be noted. As they are noted, it will be important to determine whether the data exist elsewhere, and if not, who should be working to gather the data (federal or state authorities, a contractor, or another entity)

C) Determination of the maximum load that will not cause a violation of WQSs

D) Allocation the load to the various sources

E) Development of an implementation plan to ensure the TMDL is carried out

Time Frame -

A 15-year time frame is available to complete a TMDL. Is that timeframe consistent with state expectations?

Roles and Responsibilities -

Some states have indicated in their 303(d) lists that EPA is responsible for developing the Great Lakes TMDLs for air deposition pollutants, while other states have made a more qualified statement.

Federal role: The federal role in the Great Lakes TMDL process is, at a minimum: 1) approve or disapprove 303(d) lists and 2) approve or disapprove the TMDLs. If the lists or TMDLs are disapproved, and EPA has the responsibility to issue appropriate lists or TMDLs. However, the Federal role will be much larger than that stated above. The EPA will take the lead on “open water” TMDLs, facilitate the generation of the TMDLs, provide funding through various mechanisms, assist in data gathering (especially for air deposition pollutants), provide technical support, coordinate efforts among the states, serve as an information repository, and provide legal analysis and support.

State role: List impaired waters, take the lead on tributary water TMDLs, and provide support and data for “open water” TMDLs.

6.0 Next Steps in the TMDL Development Process

This document is only the first step in the process to develop a TMDL strategy for Lake Superior. EPA envisions the following next steps in the process:

1) Gather comments on this strategy planning document and the issues identified in Section 4.0 of this document.

2) Convene regulators in the Fall of 2000 to begin discussions on the following:

    a) The outstanding issues identified in Section 4.0 of this document,
    b) Plans for a Winter 2001 information meeting
    c) Plans for future stakeholder meetings
    d) Clarification resource needs and availability
    e) Investigation of the formation of work groups

3) Convene an information meeting in the Winter of 2001 to review information collected about pollutant load to the lake, including the preliminary results of the Devil's Lake Mercury Pilot Study. Review changes in the TMDL regulations and guidance.

4) Convene a series of stakeholder meetings or workshops to inform the development of a draft Lake Superior TMDL Strategy.

EPA has not yet developed a final schedule for the next steps. EPA welcomes comments on the proposed next steps, a schedule of activities, and any issues raised in this strategy planning document.

APPENDIX A

REVIEW ELEMENTS OF TMDLs

Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency's Code of Federal Regulations Part 130, and the Water Quality Guidance for the Great Lakes System (40 CFR Part 132) describe the statutory and regulatory requirements for approvable Total Maximum Daily Loads (TMDL). EPA generally requires the following information to determine whether a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations; the information should be included in the submittal package. Use of the verb "must" below denotes information that is required because it is related to elements of the TMDL required under the CWA and by regulation.

1. Description of Waterbody, Pollutant of Concern, Pollutant Sources and Priority Ranking

The TMDL analytical document must identify the waterbody as it appears on the state's or tribe's 303(d) list, the pollutant of concern, and the priority ranking of the waterbody. The TMDL submittal must include a description of the point and nonpoint sources of the pollutant of concern, including the magnitude and location of the sources. When it is possible to separate natural background from nonpoint sources, a description of the natural background must be provided, including the magnitude and location of the source(s). Such information is necessary for EPA's review of the load and wasteload allocations that are required by regulation. The TMDL submittal should also contain a description of any important assumptions made in developing the TMDL, such as: (1) the assumed distribution of land use in the watershed; (2) population characteristics, wildlife resources, and other relevant information that affects the characterization of the pollutant of concern and its allocation to sources; (3) present and future growth trends, if taken into consideration in preparing the TMDL; and (4) explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments or chlorophyl a and phosphorus loadings for excess algae.

2. Description of the Applicable Water Quality Standards and Numeric Water Quality Target

The TMDL submittal must include a description of the applicable state's or tribe's water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the antidegradation policy. Such information is necessary for EPA's review of the load and wasteload allocations that are required by regulation. A numeric water quality target for the TMDL (a quantitative value used to measure whether the applicable water quality standard is attained) must be identified. If the TMDL is based on a target other than a numeric water quality criterion, a numeric expression, usually site specific, must be developed from a narrative criterion, and a description of the process used to derive the target must be included in the submittal.

3. Loading Capacity - Linking Water Quality and Pollutant Sources

As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water can receive without violating water quality standards (40 CFR § 130.2(f)). It is required that the loadings be expressed as either mass-per-time, toxicity, or other appropriate measure (40 CFR § 130.2(I)). The TMDL submittal must identify the waterbody's loading capacity for the applicable pollutant and describe the rationale for the method used to establish the cause-and-effect relationship between the numeric target and the identified pollutant sources. In most instances, the method will be a water quality model. Supporting documentation for the TMDL analysis must also be contained in the submittal, including the basis for assumptions, strengths and weaknesses in the analytical process, results of water quality modeling, and more. Such information is necessary for EPA's review of the load and wasteload allocations that are required by regulation.

In many circumstances, a critical condition must be described and related to physical conditions in the waterbody as part of the analysis of loading capacity (40 CFR § 130.7(c)(1)). The critical condition can be thought of as the "worst-case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. *Critical condition*s are the combination of environmental factors (for example, flow temperature and others) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence. *Critical conditions* are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may be necessary to meet water quality standards. Stream design guidelines for Great Lakes tributaries are specified under 40 CFR Part 132, Appendix F.

4. Load Allocations

EPA regulations require that a TMDL include load allocations (LAs), which identify the portion of the loading capacity allocated to existing and future nonpoint sources and to natural background (40 CFR. § 130.2(g) and 40 CFR 132, Appendix F). Load nonpoint sources, load allocations should be described separately for background allocations may range from reasonably accurate estimates to gross allotments (40 CFR § 130.2(g)). When it is possible to separate natural background from and for nonpoint sources.

If the TMDL concludes that there are no nonpoint sources and/or natural background, or the TMDL recommends a zero load allocation, the LA must be expressed as zero. If the TMDL recommends a zero LA after considering all pollutant sources, the TMDL must include a discussion of the reasoning behind that decision, since a zero LA implies that an allocation only to point sources will result in attainment of the applicable water quality standard and that all nonpoint and background sources will be removed.

5. Wasteload Allocations (WLAs)

EPA regulations require that a TMDL include wasteload allocations (WLA), which identify the portion of the loading capacity allocated to existing and future point sources (40 CFR § 130.2(h) and 40 CFR 132, Appendix F). If no point sources are present, or if the TMDL recommends a zero WLA for point sources, the WLA must be expressed as zero. If the TMDL recommends a zero WLA after considering all pollutant sources, the TMDL must include a discussion of the reasoning behind this decision, since a zero WLA implies that an allocation only to nonpoint sources and background will result in attainment of the applicable water quality standard and that all point sources will be removed.

In preparing the wasteload allocations, it is not necessary that each individual point source be assigned a portion of the allocation of pollutant loading capacity. When the source is a minor discharger of the pollutant of concern, or if the source is included in an aggregated general permit, an aggregated WLA can be assigned to the group of facilities. But it is necessary to allocate the loading capacity among individual point sources as necessary to meet the water quality standard.

The TMDL submittal should also discuss whether a point source is given a less stringent wasteload allocation on the basis of an assumption that nonpoint source load reductions will occur. In such cases, the state or tribe will be required to demonstrate reasonable assurance that the nonpoint source reductions will occur within a reasonable time.

6. Margin of Safety

The statute and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge about the relationship between load and WLAs and water quality (CWA § 303(d)(1)(C), 40 CFR §130.7(c)(1), and 40 CFR 132, Appendix F). EPA guidance explains that the MOS may be implicit, that is, incorporated into the TMDL through conservative assumptions in the analysis, or explicit, that is, expressed in the TMDL as loadings set aside for the MOS. If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS must be described. If the MOS is explicit, the loading set aside for the MOS must be identified.

7. Seasonal Variation

The statute and regulations require that a TMDL be established with consideration of seasonal variations. The method chosen for including seasonal variations in the TMDL must be described (CWA § 303(d)(1)(C), 40 CFR § 130.7(c)(1)).

8. Monitoring Plan for TMDLs Developed Under the Phased Approach

EPA's 1991 document *Guidance for Water Quality-Based Decisions:* The TMDL Process (EPA 440/4-91-001) recommends a monitoring plan when a TMDL is developed under the phased approach. The guidance recommends that a TMDL developed under the phased approach also should provide assurances that nonpoint source controls will achieve expected load reductions. The phased approach is appropriate when a TMDL involves both point and nonpoint sources and the point source is given a less stringent wasteload allocation on the basis of an assumption that nonpoint source load reductions will occur. EPA's guidance provides that a TMDL developed under the phased approach should include a monitoring plan that describes the additional data to be collected to determine whether the load reductions required by the TMDL will lead to attainment of water quality standards.

9. Implementation Plans

On August 8, 1997, Bob Perciasepe (EPA Assistant Administrator for the Office of Water) issued a memorandum, "New Policies for Establishing and Implementing Total Maximum Daily Loads (TMDLs)," that directs the regions to work in partnership with states and tribes to achieve nonpoint source load allocations established for 303(d)-listed waters impaired solely or primarily by nonpoint sources. To that end, the memorandum asks that Regions assist States/Tribes in developing implementation plans that include reasonable assurances that the nonpoint source load allocations established in TMDLs for waters impaired solely or primarily by nonpoint sources will in fact be achieved. The memorandum also includes a discussion of renewed focus on the public participation process and recognition of other relevant watershed management processes used in the TMDL process. Although implementation plans are not approved by EPA, they help establish the basis for EPA's approval of TMDLs.

10. Reasonable Assurances

EPA guidance calls for reasonable assurances when TMDLs are developed for waters impaired by both point and nonpoint sources. In a water impaired by both point and nonpoint sources, when a point source is given a less stringent wasteload allocation on the basis of an assumption that nonpoint source load reductions will occur, reasonable assurance that the nonpoint source reductions will take place must be explained if the TMDL is to be approvable. The information is necessary for EPA to determine that the load and wasteload allocations will achieve water quality standards.

In a water impaired solely by nonpoint sources, reasonable assurances that load reductions will be achieved are not required for a TMDL to be approvable. However, for such nonpoint source-only waters, states and tribes are strongly encouraged to provide reasonable assurances about achievement of load allocations in the implementation plans described in section 9 above. As described in the August 8, 1997 Perciasepe memorandum, such reasonable assurances should be included in state's or tribe's implementation plans and "may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs."

11. Public Participation

EPA policy is that there must be full and meaningful public participation in the TMDL development process. Each state or tribe must, therefore, provide for public participation consistent with its own continuing planning process and public participation requirements (40 CFR § 130.7(c)(1)(ii)). In guidance, EPA has explained that final TMDLs submitted to EPA for review and approval must describe the state's or tribe's public participation process, including a summary of significant comments and the state's or tribe's responses to those comments. When EPA establishes a TMDL, EPA regulations require that EPA publish a notice seeking public comment (40 CFR § 130.7(d)(2)).

Inadequate public participation could be a basis for disapproving a TMDL; however, when EPA determines that a State/Tribe has not provided adequate public participation, EPA may defer its approval action until adequate public participation has been provided for, either by the state or tribe or by EPA.

12. Submittal Letter

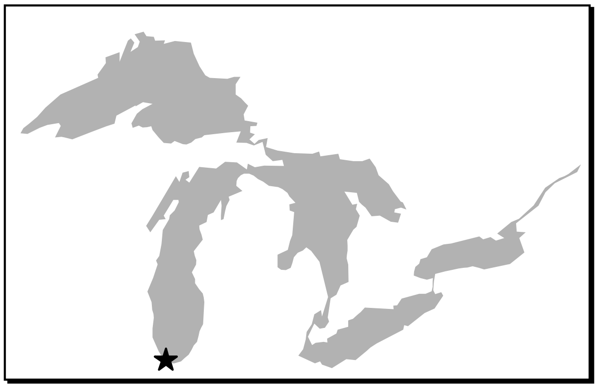
A submittal letter should be included with the TMDL analytical document; the letter should specify whether the TMDL is being submitted for a technical review or is a final submittal. Each final TMDL submitted to EPA must be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the CWA for review and approval. The procedure clearly establishes the state's or tribe's intent to submit, and EPA's duty to review, the TMDL under the statute.

The submittal letter, whether for technical review or final submittal, should contain such information as the name and location of the waterbody, the pollutant(s) of concern, and the priority ranking of the waterbody.

APPENDIX F

LAKE MICHIGAN AREAS OF CONCERN

Grand Calumet River
Area of Concern



Background

The Grand Calumet River, originating in the east end of Gary, Indiana, flows 13 miles (21 kilometers [km]) through the heavily industrialized cities of Gary, East Chicago, and Hammond. The majority of the river's flow drains into Lake Michigan via the Indiana Harbor and Ship Canal, sending about one billion gallons of water into the lake each day. The Area of Concern (AOC) begins 15 miles (24 km) south of downtown Chicago and includes the east branch of the river, a small segment of the west branch, and the Indiana Harbor and Ship Canal. Today, 90 percent of the river's flow originates as municipal and industrial effluent, cooling and process water, and stormwater overflows. Although discharges have been reduced, a number of contaminants continue to impair the AOC.

Beneficial Use Impairments

Problems in the AOC include contamination from polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH) and heavy metals, such as mercury, cadmium, chromium, and lead. Additional problems include high levels of fecal coliform bacteria, biochemical oxygen demand (BOD), and suspended solids, oil, and grease. These contaminants originate from both point and nonpoint sources. Nonpoint sources include:

Beneficial Use Impairments

✔ Restrictions on fish and wildlife consumption.
✔ Tainting of fish and wildlife flavor.
✔ Degradation of fish and wildlife populations.
✔ Fish tumors or other deformities.
✔ Bird or animal deformities or reproductive problems.
✔ Degradation of benthos.
✔ Restrictions on dredging activities.
✔ Eutrophication or undesirable algae.
✔ Restrictions on drinking water consumption, or taste and odor.
✔ Beach closings.
✔ Degradation of aesthetics.
✔ Degradation of phytoplankton and zooplankton populations.
✔ Added cost to agriculture and industry.
✔ Loss of fish and wildlife habitat.

! **Contaminated Sediment.** The Grand Calumet River and Indiana Harbor and Canal contain 5 to 10 million cubic yards (3.9 to 7.7 million cubic meters) of contaminated sediment up to 20 feet (6 m) deep. Contaminants include toxic compounds (for example, PAHs, PCBs, and heavy metals) and conventional pollutants (for example, phosphorus, nitrogen, iron, magnesium, volatile solids, oil, and grease).

! **Industrial Waste Site Runoff.** Stormwater runoff and leachate from 11 of 38 waste disposal and storage sites in the AOC, located within .2 mi (.3 km) of the river, are degrading water quality on the AOC. Contaminants include oil, heavy metals, arsenic, PCBs, PAHs, and lead.

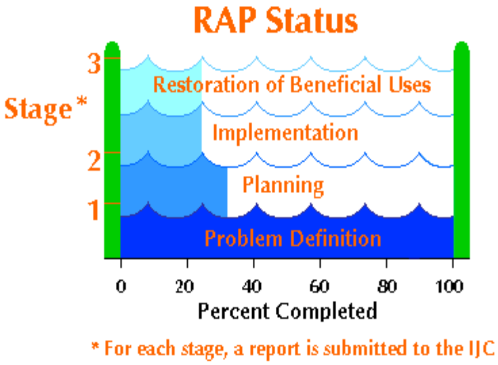
! **CERCLA Sites.** There are 52 sites in the AOC that are listed in the federal Comprehensive Environmental Response Compensation and Liability Act Information System (CERCLIS). Five of those sites are Superfund sites on the National Priorities List (NPL).

! **Hazardous Waste Sites under RCRA.** There are 423 hazardous waste sites in the AOC that are regulated under the Resource Conservation and Recovery Act (RCRA), such as landfills or surface impoundments where hazardous waste is disposed of. Of those sites, 22 are treatment, storage, and disposal facilities.

- **Underground Storage Tanks (UST)**. There are more than 460 underground storage tanks in the AOC. More than 150 leaking tank reports have been filed for the Lake County section of the AOC since mid-1987.
- **Atmospheric Deposition.** Atmospheric deposition of toxic substances from fossil fuel burning, waste incineration, and evaporation enter the AOC through direct contact with water, surface water runoff, and leaching of accumulated materials deposited on land. Toxins from this source include dioxins, PCBs, insecticides, and heavy metals.
- **Urban Runoff.** Rain water passing over paved urban areas washes grease, oil, and such toxic organics as PCBs and PAHs into surface waters of the AOC.
- **Contaminated Groundwater.** Groundwater contaminated with organic compounds, heavy metals, and petroleum products contaminates AOC surface waters. The U.S. Environmental Protection Agency (EPA) estimates that at least 16.8 million gallons (63.6 million liters) of oil float on top of groundwater beneath the AOC.

Point sources of contaminants include

- **Industrial and Municipal Wastewater Discharges.** Three steel manufacturers contribute 90 percent of industrial point source discharges to the AOC. One chemical manufacturer discharges into the AOC. Permitted discharges include those of arsenic, cadmium, cyanide, copper, chromium, lead, and mercury. Three municipal treatment works (Gary, Hammond, and East Chicago sanitary districts) discharge treated domestic and industrial wastewater into the AOC.
- **Combined Sewer Overflows (CSO).** Fifteen CSOs contribute untreated municipal waste, including conventional and toxic pollutants, to the AOC. Annually, CSO outfalls discharge an estimated 11 billion gallons (41.6 billion liters) of raw wastewater into the harbor and river. Approximately 57 percent of the annual volume of CSO is discharged within eight miles (12.9 km) of Lake Michigan, resulting in near shore contamination with fecal coliform.



Historically, the Grand Calumet River supported highly diverse, globally unique fish and wildlife communities. Today, remnants of that diversity near the AOC are found in the Gibson Woods and Pine nature preserves. Those areas contain tracts of dune and swale topography and associated rare plant and animals species, such as Franklin's ground squirrel, Blanding's turtle, the glass lizard, and the black crowned night heron, among others. The problems described above, however, have impaired many desired uses of the AOC, including

RAP Status

The Remedial Action Plan (RAP) process produced a Stage One document in January 1991. The state submitted a Stage 2 document to the International Joint Commission in December 1997. Stage 2 links physical, biological, and chemical stressors to each impairment of use. Stage 2.5 extends the Stage 2 ecosystem approach and reviews how each regulatory, voluntary, and enforcement activity in the AOC helps restore beneficial uses. The document begins to link those activities to environmental stressors. With the CARE committee’s assistance, the state expects to finish the Stage 2.5 effort. By tracking the myriad activities that help restore beneficial uses, the CARE committee and state have begun to track Stage 3 progress, implementation.

RAP Milestones

The Stage 2.5 effort will be completed in Autumn 2000. The CARE committee will propose a suite of short-term and long-term environmental indicators and endpoints to delist each beneficial use. The CARE committee expects to have a list by the end of 2000.

Priorities

The Stage 2.5 will be complete by autumn 2000. The CARE committee will propose a suite of short-term and long-term environmental indicators and endpoints to delist each beneficial use. The CARE committee expects to have a list by the end of 2000.

☑ Remediation

- Complete design of the proposed confined disposal facility that will hold dredged sediments from the Canal's Federal Navigation Channel
- Continue planning USX project to dredge five miles of Grand Calumet River

☑ Habitat/Resource Management

- Continue the Natural Resources Damages Assessment

☑ P2/Nonpoint Source

- Complete year 2 of the 3-year Total Maximum Daily Load for the River and Canal

☐ Human Health

☐ Stewardship Sustainability

☐ Education and Outreach

☐ Research Projects/Data Gaps

Contacts

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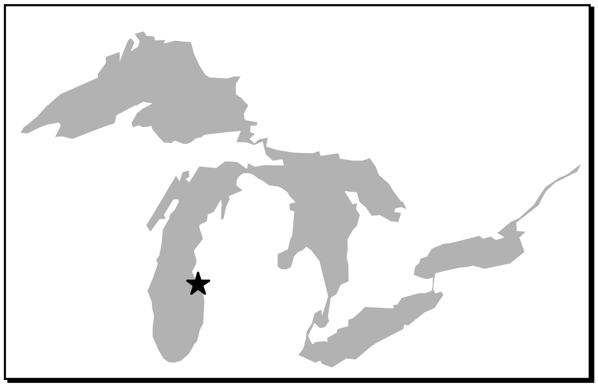
Muskegon Lake
Area of Concern



Background

Muskegon Lake is a 4,149-acre inland coastal lake located in Muskegon County, Michigan, along the east shore of Lake Michigan. The Area of Concern (AOC) includes the entire lake and the immediate drainage area, with the lake separated from Lake Michigan by sand dunes. The Muskegon River flows through the lake before emptying into Lake Michigan. Additional tributaries include Mosquito Creek, Ryerson Creek, Ruddiman Creek, Green Creek, and Four Mile Creek. The immediate inland area is primarily residential and industrial, with chemical and petrochemical companies, foundries, a pulp and paper mill, and other industries located on the lake or within its immediate watershed.

Beneficial Use Impairments

Muskegon Lake was originally identified as an AOC because, before 1973, it received direct discharges of industrial wastewater, municipal wastewater treatment plant effluent, combined sewer overflows, and urban runoff. The discharges degraded water and habitat quality in Muskegon Lake and its tributaries. Through the Remedial Action Planning (RAP) process, the Muskegon Lake Public Advisory Council (PAC) and the Michigan Department of Environmental Quality (MDEQ) RAP Team have identified several beneficial uses as impaired.

Beneficial Use Impairments

- ✔ Restrictions on fish and wildlife consumption.
- Tainting of fish and wildlife flavor.
- ✔ Degradation of fish and wildlife populations.
- Fish tumors or other deformities.
- Bird or animal deformities or reproductive problems.
- ✔ Degradation of benthos.
- ✔ Restrictions on dredging activities.
- ✔ Eutrophication or undesirable algae.
- ✔ Restrictions on drinking water consumption, or taste and odor.
- Beach closings.
- ✔ Degradation of aesthetics.
- Degradation of phytoplankton and zooplankton populations.
- Added cost to agriculture and industry.
- ✔ Loss of fish and wildlife habitat.

AOC Status

The initial Muskegon Lake RAP was completed in 1987 with limited public involvement. A Muskegon Lake PAC was officially established in October 1993 to obtain broad-based stakeholder input into the development and implementation of the RAP. The PAC includes representatives of various interests groups in the area. An update of the Muskegon Lake RAP was completed in October 1994. That document focused on five objectives: affording and insuring participation opportunities in the process by a PAC, as well as a team of specialists from various divisions of MDEQ (Surface Water Quality, Environmental Response, Waste Management, Fisheries, Air Quality, Land and Water Management, and Wildlife); documenting water quality data collected and analyzed since the 1987 RAP was published; analyzing the current status of use impairments; and making recommendations that, when carried out, will lay the foundation for the next phase of the RAP process (that is, implementing specific measures to remediate water quality problems and use impairments) and identification of data gaps. Studies addressing contaminated sediments, habitat, and water quality have been completed to fulfill recommendations of the 1994 RAP. A repository of that information is located at the offices of the Muskegon Conservation District.

RAP Milestones

- ✔ 1987: Muskegon Lake Remedial Action Plan completed
- ✔ 1993: Muskegon Lake PAC established
- ✔ 1994: Muskegon Lake Remedial Action Plan Update completed
- ✔ 1995: Muskegon & White Lake “Watershed” Study
- ✔ 1995: Wildlife Habitat Assessment
- ✔ 1995: Aquatic Plant Assessment
- ✔ 1997: Muskegon River Watershed Assessment
- ✔ 1998: Muskegon County - Land Use Trends Report
- ✔ 1998: Lower Muskegon River Streambanks Erosion Survey
- ✔ 1999: Ruddiman Creek Phase I Assessment
- ✔ 1999/2000: Sediment Toxicity Contamination Study
- ✔ 1999/2000: Muskegon River Mouth Wetland Buffer Zone Study
- ✔ 1999/2000: Lake Michigan Tributary Monitoring Project in Muskegon Lake AOC/Muskegon River Watershed

Priorities

The Muskegon Lake PAC is dedicated to actively participating in the continuing improvement of the quality of Muskegon Lake. RAP Team and PAC coordination is being pursued through scheduling regular monthly meetings, developing common objectives, and developing timetables and budgets for recommended actions.

☑ Remediation

- Contaminated sediment remediation on Muskegon Lake’s south side.
  - Division St. Stormwater Outfall in Muskegon Lake between Heritage Landing & the YFCA;
  - Former Grand Trunk Railroad/Sweetwater brownfield/State-City Public Launch Ramp site at Lakeshore Dr. and McCracken St.;
  - Ruddiman Creek and mouth at Muskegon Lake including the Amoco Tank Farm brownfield site;
  - Ryerson Creek and mouth at Muskegon Lake including the Teledyne brownfield site;
  - Westran Corporation Lake Fill and Harshorn Marina site on Muskegon Lake’s south side;
  - Muskegon River mouth wetland buffer zone including the Zephyr site and the Causeway/City Dump site;
  - Coal gasification “tar ball” site offshore from Morris St. on Muskegon Lake’s south side.

- Brownfield remediation on Muskegon Lake’s south shore.
  Numerous brownfield sites are adjacent to the contaminated sediments sites listed above. Three priority sites for a coordinated soil and sediment cleanup approach are:
  - Amoco site at Ruddiman Creek mouth;
  - Teledyne site at Ryerson Creek mouth;
  - Former Grand Trunk Railroad/Sweetwater/Public Launch site.

☑ Habitat/Resource Management

- Remove and prevent sediment load at mouth of river in Muskegon Lake's northeast end to restore critical fish and wildlife habitat
- Restoration of native habitat landscapes on brownfield/foundry fill areas along Muskegon Lake's south and east shoreline
- Permanent easement/conservancy of identified sensitive wildlife habitat and critical fish habitat areas (based on existing natural features inventory; pre-settlement vegetation maps; 1995 Muskegon Lake Habitat and Aquatic Plant Assessments; MDNR Fisheries Division information).

☑ P2/Nonpoint Source

- Phase II Voluntary Stormwater ordinance and technical assistance program to incorporate Best Management Practices (BMP) into shoreline and watershed brownfield redevelopments.
- Implement BMPs on sites identified in the Muskegon River Streambank Erosion Inventory.

☑ Human Health

- Identify and correct sanitary sewer integrity and cross connection problems to prevent direct sewage discharge and health advisories for Muskegon Lake and immediate tributaries.
- Determine impact of contaminated groundwater on the ecosystem in the Bear Creek, Bear Lake and Zephyr Oil sediment/wetland areas.
- Drinking water protection assessments (correlate Lake Michigan Mass Balance information with Lake Michigan and Muskegon Lake current and discharge information).

☑ Stewardship Sustainability

- Develop a coordinated volunteer water quality monitoring program in Muskegon Lake, tributary creeks and Muskegon River watershed tributaries (based on results of the lake Michigan Tributary Monitoring project).
- Sustainability Training Program to institutionalize "Adopt-A-Watershed" activities throughout the Muskegon Lake AOC/River watershed (initiating sustainable volunteer and school programs to monitor ecosystems, restore habitat, clean up waterways, stencil storm drains, provide teacher training on ecosystems and watersheds).
- Single contact/gateway program established for public access to technical information, public involvement opportunities and long term training for public stakeholders capacity, leadership and empowerment for natural resources stewardship.

☑ Education and Outreach

- Increase youth/adult public knowledge on ecosystem principles, remediation of contaminated sites, needs, management via programming in schools, conservation districts, university extensions and community colleges.

☑ Research Projects/Data Gaps

- Identify health of benthic/ecosystem of nearshore sediments adjacent to brownfield (high potential redevelopment/dredge areas).
- Map/Identify groundwater quality from contaminated sites discharging/leaching into the lake and rivermouth area.
- Identify atrazine “tributary source” and Mass Balance pollutant “soil source” hot spot areas in the Muskegon River watershed for best management practice, education and remediation potential.
- Muskegon Lake nutrient budget (TMDLs, sediment loads, etc).
- Identify point source water quality discharged from regulated sources to lake/tributaries/storm drains.
- Sediment characterization in Bear Lake at Bear Creek mouth.

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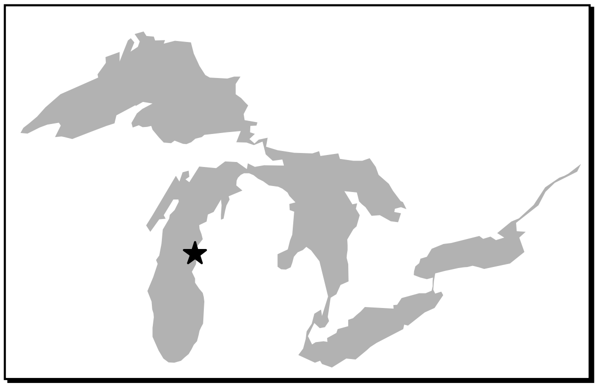
White Lake
Area of Concern



Background

White Lake is a 2,570-acre coastal, drowned river mouth lake located in Muskegon County, along the east shore of Lake Michigan in the vicinity of the communities of Montague and Whitehall. The Area of Concern (AOC) includes White Lake and a one-quarter-mile wide zone around the lake. Most of the land around the AOC is wooded or grassy, with some sand dunes located along Lake Michigan. Land use in the AOC is primarily recreational and agricultural, and to a lesser extent residential and industrial.

Beneficial Use Impairments

The Remedial Action Plan (RAP) process identified eight of the Great Lakes Water Quality Agreement's 14 beneficial uses as impaired. Beneficial use impairments in the AOC include restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, degradation of benthos, restrictions on dredging activities, restrictions on drinking water consumption, or taste and odor problems, and degradation of aesthetics.

Beneficial Use Impairments

- ✔ Restrictions on fish and wildlife consumption.
- Tainting of fish and wildlife flavor.
- ✔ Degradation of fish and wildlife populations.
- Fish tumors or other deformities.
- Bird or animal deformities or reproductive problems.
- ✔ Degradation of benthos.
- ✔ Restrictions on dredging activities.
- ✔ Eutrophication or undesirable algae.
- ✔ Restrictions on drinking water consumption, or taste and odor.
- Beach closings.
- ✔ Degradation of aesthetics.
- Degradation of phytoplankton and zooplankton populations.
- Added cost to agriculture and industry.
- ✔ Loss of fish and wildlife habitat.

White Lake was originally listed as an AOC primarily because contaminated groundwater was migrating to the lake from the Occidental Chemical Site (formerly Hooker Chemical Company). There are eight other contaminated sites that have the potential to affect the lake, some of them in various states of remediation.

AOC Status

White Lake was originally listed as an AOC because of venting of a groundwater plume contaminated with an organic solvent from the Occidental Chemical Company site. Analysis of recent well monitoring data indicates that the plume of contaminated groundwater moving from the site is being intercepted by the lake-front purge well network and effectively treated before it is discharged to White Lake. Other potential sources of groundwater contamination to White Lake and its tributaries have been identified, and remediation efforts are under way.

There was substantial improvement in the water quality of White Lake before 1987, simply because of the diversion of industrial and municipal discharges away from the lake by the mid-1970s. Similarly, results of analysis of water samples collected in 1992 from the navigational channel between White Lake and Lake Michigan indicate that water quality has improved since the previous samples were taken in 1983. All parameters measured in 1992 met Michigan's water quality standards, established to protect human and aquatic life. Concentrations of heavy metals are lower than those observed in earlier sampling, chloride concentrations are the lowest recorded since testing of that parameter began in 1963, and phosphorous and nitrogen levels have remained relatively stable since the diversion of wastewater from White Lake in 1974. While a 28-day caged fish study conducted in the channel in 1992 showed that chlordane, DDE, and dieldrin are present, the levels accumulated in the fish do not suggest a substantial problem.

RAP Milestones

- ✔ 1987: MDNR completed a RAP and submitted it to the International Joint Commission for review.
- ✔ October 1993: The White Lake PAC was officially established.
- ✔ 1995: An update of the RAP was prepared by MDEQ and the White Lake PAC.
- ✔ 1995: Muskegon & White Lake "Watershed" Study
- ✔ 1995: Wildlife Habitat Assessment
- ✔ 1995: Aquatic Plant Assessment
- ✔ 1998: Sediment Toxicity Contamination Study
- ✔ 1998: White Lake County - Land Use Trends Report
- ✔ 1998: White Lake Boat Usage Study
- ✔ 1999/2000: Lake Michigan Tributary Monitoring Project in White Lake AOC/White Lake Watershed

Priorities

The White Lake PAC is dedicated to actively participating in the continuing improvement of the quality RAP Team and PAC coordination is being pursued through regular meetings, development of common objectives, and developing timetables and budgets for recommended actions.

The Lake Michigan Federation and the White Lake PAC have completed a study of habitat and wetlands around White Lake. The study was undertaken in response to the 1995 White Lake RAP Update, which noted loss of fish and wildlife populations and recommended that a habitat assessment be conducted.

The study was designed to establish a baseline of information to assist in making future decisions regarding development around the lake. Conducted by a wildlife biologist, the study noted that sixty percent of the quarter-mile study area was already developed. It also found four high-quality marsh areas worth preserving and nearly continuous forest cover along most of the shoreline that provides valuable habitat for birds and other animal species.

Remediation of contaminated sediments in Tannery Bay is scheduled for as early as summer 1999.

☑ Remediation

- The Hooker Chemical/Occidental Chemical Company is currently sampling and evaluating sediment contamination. Remediation of specific lakebottom sites is likely and would benefit from a match of federal funds.
- Further study of the extent of contamination from the Whitehall Leather Company is needed, in addition to possible remediation funds.
- Assessment is needed of sediments at discharge points for other contaminated sites, including Muskegon Chemical/Koch Chemical, the White Lake landfill, an old Whitehall city wastewater treatment facility, and a former landfill on the marsh upstream of the lake.

☑ Habitat/Resource Management

- Acquisition of two large, undeveloped shoreline tracts owned by Dupont and Hooker Chemical/Occidental Chemical.
- Funds for outreach and implementation of habitat study recommendations.
- Native fish species (white bass, Great Lakes spotted muskellunge) restoration.

☑ P2/Nonpoint Source

- Assessment and remediation of shoreline sewage gaps.

☐ Human Health

☑ Stewardship Sustainability

- Public education programs on ecosystems for schools and adult populations.

☑ Education and Outreach

- School curriculums, tying environmental issues to state tests, such as the MEAP.
- Habitat education programs for shoreline property associations and schools, including fact sheets that can be tailored to specific ARCs.

☑ Research Projects/Data Gaps

- Quantitative information on the extent and impact to sediments of historical pollution from contaminated sites around the lake.
- Regular assessment of the health of benthic populations.
- Specific fish and wildlife contaminant monitoring data based upon knowledge of contaminated sites and sediments to direct sampling.

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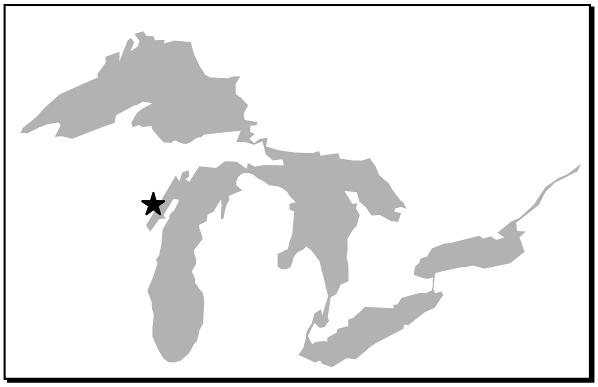
Menominee River Area of Concern



Background

The Menominee River forms the boundary between the northeast corner of Wisconsin and the southern tip of the Upper Peninsula of Michigan. The river's headwaters are found in both states. The main stem of the river flows between the cities of Menominee, Michigan, and Marinette, Wisconsin before emptying into Green Bay.

The Menominee River Area of Concern (AOC) includes the lower 4.8 km of the river from the Upper Scott Paper Company (Wisconsin) Dam to the river's mouth, and approximately 5 km north and south of the mouth, along the adjacent shoreline of Green Bay. The AOC also includes the cities of Marinette and Menominee, as well as the adjacent near shore area of Green Bay, Wisconsin, extending three miles north and south of the river mouth. Land use in the AOC is primarily industrial and residential. A chemical company, two paper mills, two municipal wastewater treatment plants, a ship-building company, and a foundry are located along the river.

Beneficial Use Impairments

- ✔ Restrictions on fish and wildlife consumption.
- Tainting of fish and wildlife flavor.
- ✔ Degradation of fish and wildlife populations.
- Fish tumors or other deformities.
- Bird or animal deformities or reproductive problems.
- ✔ Degradation of benthos.
- ✔ Restrictions on dredging activities.
- Eutrophication or undesirable algae.
- Restrictions on drinking water consumption, or taste and odor.
- ✔ Beach closings.
- Degradation of aesthetics.
- Degradation of phytoplankton and zooplankton populations.
- Added cost to agriculture and industry.
- ✔ Loss of fish and wildlife habitat.

Beneficial Use Impairments

Of the 14 beneficial use impairments, 6 were identified through the Remedial Action Plan (RAP) process. A primary cause of the use impairments identified is arsenic contamination in the turning basin and in sediments along the right bank of the river, below the Ansul Fire Protection Company in Marinette, Wisconsin. This problem resulted from improper arsenic storage and disposal practices by Ansul. Other pollutants, such as mercury, polychlorinated biphenyls (PCBs), and oil and grease, have also contributed to use impairments.

AOC Status

The Wisconsin Department of Natural Resources (WDNR) is working in cooperation with the Michigan Department of Environmental Quality (MDEQ) to develop and implement the RAP. The multi-stakeholder Citizens' Advisory Committee (CAC) and a Technical Advisory Committee (TAC) have been instrumental in the development of the RAP by mobilizing public support, increasing awareness, and conducting data and problem analysis. A vision statement for the desired future state of the Lower Menominee River was developed by the CAC and used as guidance in the preparation of RAP goals and objectives that were developed jointly by the CAC and TAC. The Stage 1 Report for the Lower Menominee River RAP was completed and submitted to EPA and the International Joint Committee (IJC) in 1991. Annual progress reports have been prepared to track and celebrate achievements. The WDNR is working with Ansul Fire Protection Company under the RCRA Corrective Action Program to address arsenic contamination in the AOC.

RAP Milestones

✔ 1996: RAP update published by the WDNR
✔ 1995: Paint sludge removal operations along Green Bay resulted in the excavation of more than 10 million pounds of hazardous waste from the bay. An additional 20 million pounds of contaminated sediments were removed during this effort, which was part of an enforcement order issued to the Lloyd Flanders furniture company in Menominee.
✔ 1991: The Stage 1 RAP Report was completed and submitted it to the IJC for review.
✔ ?: The Menominee River CAC was officially established.
✔ ?: The Menominee River TAC was officially established.

Priorities

☑ **Remediation**

- Local brownfields restoration projects.

☑ **Habitat/Resource Management**

- Fish population and habitat restoration.
- Local waterfront redevelopment projects.

☑ **P2/Nonpoint Source**

- Pollution prevention education and projects.

☐ **Human Health**

☐ **Stewardship Sustainability**

☑ **Education and Outreach**

- Support for Citizens Advisory Committee.

☐ **Research Projects/Data Gaps**

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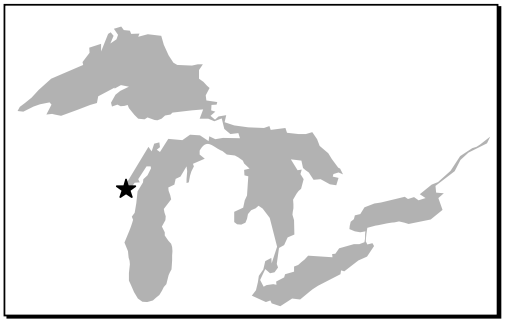
Lower Green Bay and Fox River Area of Concern



Background

The Lower Green Bay and Fox River Area of Concern (AOC) consists of the lower 11.2 km of the Fox River below DePere Dam and a 55 km^2 area of southern Green Bay reaching to Point au Sable and Long Tail Point. The drainage area encompasses portions of 18 counties in Wisconsin and 40 watersheds of the Upper Fox River, Wolf River, and the Fox River basins, including the largest inland lake in Wisconsin, Lake Winnebago and its pool lakes. While water quality problems and restrictions on public use are most severe in the AOC, water resources of the entire basin are affected by runoff pollution from urban and rural areas, municipal and industrial wastewater discharges, and degraded habitats. Eleven use impairments have been documented, and two are suspected of being impaired (see impairment graphic).

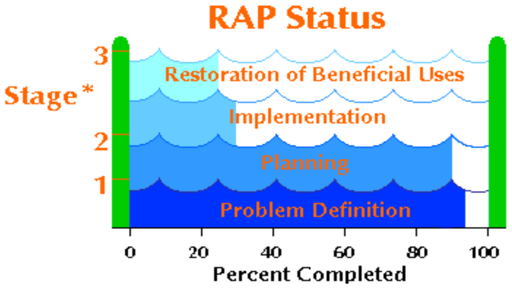
Beneficial Use Impairments

Of the 14 beneficial use impairments, 10 were identified for the Lower Green Bay and Fox River AOC, through the Remedial Action Plan (RAP) process. The two primary impaired desired uses of the AOC are shore and water use. Fishing, boating, swimming, hunting, and passive recreation have been restricted. Reproduction is impaired among both fish and fish-eating birds. Consumption advisories warn against eating mallard ducks and fish of 12 species. Shipping and navigation in the harbor and channel have been impaired because of the high cost of dredging and deposing of contaminated sediment. The harbor must be dredged to a depth of 24 feet to allow deep-draft navigation.

Beneficial Use Impairments

- ✔ Restrictions on fish and wildlife consumption.
- Tainting of fish and wildlife flavor.
- ✔ Degradation of fish and wildlife populations.
- Fish tumors or other deformities.
- ✔ Bird or animal deformities or reproductive problems.
- ✔ Degradation of benthos.
- ✔ Restrictions on dredging activities.
- ✔ Eutrophication or undesirable algae.
- ✔ Restrictions on drinking water consumption, or taste and odor.
- ✔ Beach closings.
- ✔ Degradation of aesthetics.
- ✔ Degradation of phytoplankton and zooplankton populations.
- Added cost to agriculture and industry.
- Loss of fish and wildlife habitat.

RAP Status



* For each stage, a report is submitted to the IJC

The Lower Green Bay RAP was developed by the Wisconsin Department of Natural Resources (WDNR) under a multi-stakeholder partnership with other agencies, local governments, scientists, citizens, industries, and environmental groups. More than 75 people participated for two years on four technical advisory committees (TAC) and a citizen's advisory committee (CAC) for development of the community-based plan. The TAC developed reports identifying the problems and goals, and objectives for management and technical solutions designed to restore the bay and river. The CAC identified the 10 most pressing problems that should be addressed in the RAP, defined a "desired future state" for lower Green Bay and the Fox River, and advised on recommended remedial actions. The RAP was completed in 1987 and adopted as part of Wisconsin's Water Quality Management Plan in 1988. Almost two-thirds of the RAP's 120 recommended actions have been initiated. The RAP is viewed as a "living" document and will be updated regularly. Implementation and updating of the RAP is facilitated by WDNR through a Green Bay RAP Public Advisory Committee, a Science and Technical Advisory Committee and a Public Education and Participation Advisory Committee. In addition, two nonprofit organizations have been established by community leaders to promote implementation of nonpoint source pollution controls (Great Lakes Nonpoint Abatement Coalition) and to determine the most cost-effective actions to meet the goals of the RAP (Northeast Wisconsin Waters for Tomorrow, Inc.)

RAP Milestones

- ✔ The RAP was completed in 1987 and adopted as part of Wisconsin's Water Quality Management Plan in 1988.
- ✔ Since 1988, 38 of the 120 recommended remedial actions have been implemented.

Priorities

Substantial progress has been made in developing the RAP and implementing recommended actions. However, despite incremental improvements implemented to prevent water pollution, restore habitats, improve public access, and further define the causes of impaired uses, none of the problems in the AOC has been completely solved. Recommendations are being implemented sequentially–the easiest have been started, the more difficult have yet to be implemented. Full RAP implementation will be well beyond the year 2000.

☑ **Remediation**

- Contaminated (PCB) sediment remediation in 39 miles of the Lower Fox River

☑ **Habitat/Resource Management**

- Restore an eroded chain of barrier islands and associated aquatic habitats (Cat Island archipelago)
- Restore littoral habitats
- Protect remaining wetlands
- Exotic Species Prevention

☑ **P2/Nonpoint Source**

- Comprehensive watershed projects to abate runoff pollution
- TMDL for phosphorus and suspended solids in the Fox-Wolf Basin
- Riparian buffers throughout the Fox-Wolf Basin

☐ **Human Health**

☑ **Stewardship Sustainability**

- Sustainable Green Bay Initiative
- Enhance public access

☐ **Education and Outreach**

☑ Research Projects/Data Gaps

- State of the Bay Report

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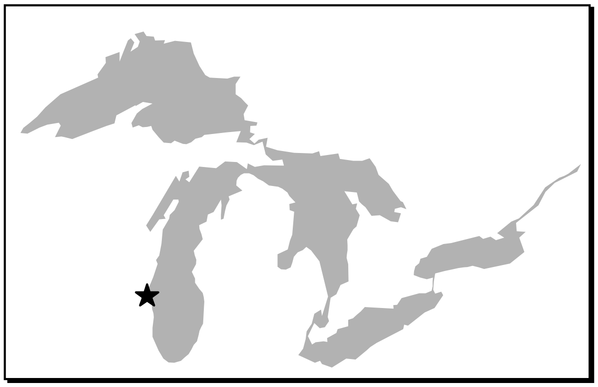
Milwaukee Estuary Area of Concern



Background

The Milwaukee Estuary Area of Concern (AOC) includes: the lower 5 km of the Milwaukee River downstream of North Avenue Dam; the lower 4.8 km of the Menominee River downstream of 35th Street; the lower 4 km of the Kinnickinnic River downstream of Chase Avenue; the inner and outer harbors and the near shore waters of Lake Michigan, bounded by a line extending north from Sheridan Park to the city of Milwaukee's Linnwood water intake. The immediate area draining to the AOC encompasses 57.5 km2 or 2.6 percent of the entire basin, including lands that drain directly to the AOC via storm sewers and combined sewer systems. This relatively small drainage area contributes disproportionately large amounts of pollutants associated with urban runoff. The AOC acts as both a source of pollution to Lake Michigan and a sink for pollutants generated throughout the watershed. Consequently, water quality is affected by pollution sources associated with land use from the entire Milwaukee River drainage basin. Current use impairments are identified in the impairment graphic.

Beneficial Use Impairments

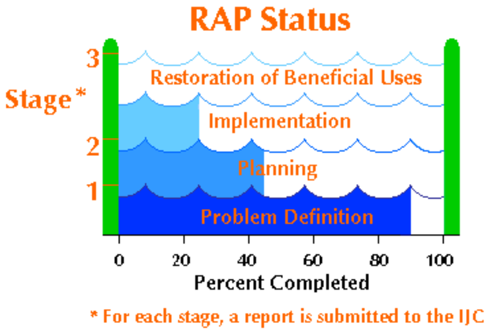
- ✔ Restrictions on fish and wildlife consumption.
- Tainting of fish and wildlife flavor.
- ✔ Degradation of fish and wildlife populations.
- ✔ Fish tumors or other deformities.
- ✔ Bird or animal deformities or reproductive problems.
- ✔ Degradation of benthos.
- ✔ Restrictions on dredging activities.
- ✔ Eutrophication or undesirable algae.
- Restrictions on drinking water consumption, or taste and odor.
- ✔ Beach closings.
- ✔ Degradation of aesthetics.
- ✔ Degradation of phytoplankton and zooplankton populations.
- Added cost to agriculture and industry.
- ✔ Loss of fish and wildlife habitat.

Beneficial Use Impairments

Of the 14 use impairments, 11 were identified for the Milwaukee AOC through the RAP process. Problems in the AOC have impaired many uses, including: fish and wildlife consumption, recreational boating, swimming, degraded fish, navigation, and aesthetics.

RAP Status

Stage One of the Milwaukee Estuary Remedial Action Plan (RAP) was initiated in 1988. The Wisconsin Department of Natural Resources (WDNR) has primary responsibility for development of the RAP. A Technical Advisory Committee, a Citizen's Advisory Committee (CAC) and a Citizen's Education and Participation Subcommittee have advised WDNR during development of the RAP. The CAC has been instrumental in building consensus from divergent views, striving for community wide unity and enthusiasm for the RAP. Much public awareness has been generated.



The development of a Stage Two RAP began in 1991, with technical work groups developing recommendations. The RAP fosters the philosophy of continuous improvement. The 1993 Milwaukee Estuary RAP documents progress made on work under the RAP and outlines a five-year work plan for implementation of the RAP. The Stage Two RAP is at least 80 percent complete.

RAP Milestones

✔ July 1994: Thus far, RAP progress report completed, including 32 Stage Two recommendations
✔ March 1991: Stage One RAP document completed

Priorities

The restoration of the Milwaukee Estuary AOC will require a long-term commitment, spanning 25 or more years. Thus far, approximately 70 recommendations have been developed by the RAP workgroups. Of those recommendations, 31 are targeted for implementation during the next few years (that is, 12 recommendations that pertain to assessment and monitoring to support informed, cost- and resource-effective decisions; 6 recommendations that pertain to demonstration projects, such as controlling runoff from storage piles, creating buffer strips, restoring streambanks, and increasing public access; 12 recommendations that pertain to community information and education; and 1 recommendation that pertains to supporting and advancing federal stormwater regulations). As those projects are completed and programs are put in place, a better understanding of what must be done to restore and maintain the Milwaukee Estuary AOC will be attained. Subsequent recommendations will be developed to address the needs identified.

☑ **Remediation**

- The highest priority in the AOC continues to be addressing contaminated sediments. Funding is needed to continue moving forward with the RAP sediment management strategy.

☐ **Habitat/Resource Management**

☑ **P2/Nonpoint Source**

- Continue various demonstration projects being conducted throughout the basin.

☐ **Human Health**

☐ **Stewardship Sustainability**

☐ **Education and Outreach**

☐ **Research Projects/Data Gaps**

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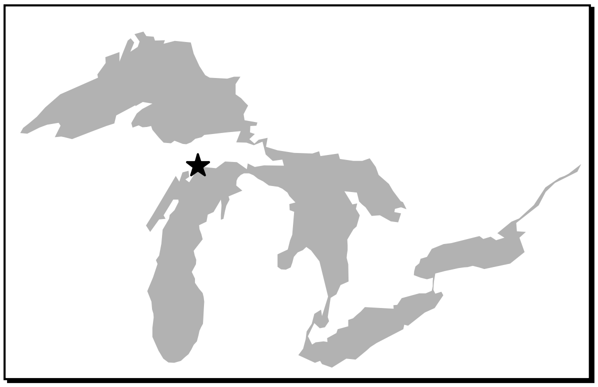
Manistique River Area of Concern



Background

The Manistique River flows southwest through Schoolcraft County in Michigan's central Upper Peninsula, discharging into Lake Michigan at Manistique. The Area of Concern (AOC) is the last 1.7 miles of the river, from the dam to the mouth of the harbor at Lake Michigan. The physical characteristics of this portion of the river have been significantly altered over the past century, with construction of artificial islands in the river for use as boat docks during the lumbering era in the late 1800s, the building of harbor breakwaters in 1913, and the completion of the dam and flume in the 1920s.

Historical uses of Manistique River waters in the AOC include receiving wastes from sawmills, a papermill, small industries, and the municipal wastewater treatment plant, as well as navigation for shipping, ferrying, recreational boating, and commercial fishing. Current uses include receiving the wastewater discharges from Manistique Papers, Inc. and the City of Manistique Wastewater Treatment Plant. Recreational uses are primarily boating, sightseeing, and fishing.

Beneficial Use Impairments

Beneficial use impairments resulted from poly-chlorinated biphenyls (PCBs), oils, and heavy metals identified as contaminants in the 1970s. In addition, large quantities of undecomposed sawdust remain in harbor and river sediments from the white pine lumbering era of more than 100 years ago, along with the relatively sterile sandy sediment that eroded from river banks as a result of log drives on the river.

Beneficial Use Impairments

- ✔ Restrictions on fish and wildlife consumption.
- Tainting of fish and wildlife flavor.
- Degradation of fish and wildlife populations.
- Fish tumors or other deformities.
- Bird or animal deformities or reproductive problems.
- ✔ Degradation of benthos.
- ✔ Restrictions on dredging activities.
- Eutrophication or undesirable algae.
- Restrictions on drinking water consumption, or taste and odor.
- ✔ Beach closings.
- Degradation of aesthetics.
- Degradation of phytoplankton and zooplankton populations.
- Added cost to agriculture and industry.
- ✔ Loss of fish and wildlife habitat.

AOC Status

The significant progress that has been made in improving water quality in the AOC over the past 18 years has resulted from increased treatment of the wastewater discharged into the river. However, some beneficial uses in the AOC continue to be impaired because of historical pollution. PCB contamination of sediment in the AOC has continued to be the factor prompting the greatest concern in the Manistique River AOC. In 1996, the U.S. Environmental Protection Agency (EPA) proposed that it had developed innovative dredging and treatment technologies that could be used in an environmentally sound dredging project that could remove PCB contamination from the AOC. There was mutual support for the effort among the community, the potentially responsible parties (PRP) and EPA. Under the agreement, the

PRPs will provide funding for the dredging project equal to what it would cost to cap the harbor and maintain it for 30 years (estimated to be $6 million). EPA will provide additional funding to supplement the PRPs' contribution, if needed, to complete the cleanup. The PRPs also are providing in-kind services to support implementation of the remedy. To date, over 111,000 cubic yards of contaminated sediments have been removed for treatment and disposal.

In 1997, a RAP Update was developed by the local community to address other impaired beneficial uses in the AOC.

RAP Milestones

- ✓ 1997: Local community developed an update to the RAP.
- ✓ 1995: U.S. EPA began annual dredging based on a remedial action recommendation.
- ✓ 1993: The Manistique River Public Advisory Council (PAC) was officially established.
- ✓ 1987: MDNR submitted the initial RAP to the IJC.

Priorities

EPA anticipates that all the dredging activities will be completed by winter 2001: Most of the BUI's should be restored; and the process for delisting the AOC may begin.

☑ **Remediation**

- Completion of the EPA Superfund dredging of contaminated sediments in the harbor.

☐ **Habitat/Resource Management**

☑ **P2/Nonpoint Source**

- Streambank erosion control (with nonpoint source pollution best management practices) is needed in the upper watershed to restore fish habitat and prevent sedimentation in the harbor.

☐ **Human Health**

☐ **Stewardship Sustainability**

☑ **Education and Outreach**

- Several local educational projects have been accomplished but additional efforts by and support for the PAC are needed.

☐ **Research Projects/Data Gaps**

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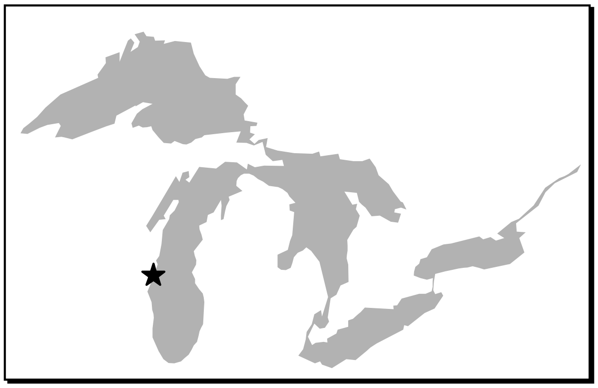
Sheboygan River Area of Concern



Background

The Sheboygan River Area of Concern (AOC) encompasses the lower Sheboygan River, downstream of the Sheboygan Falls Dam, including the entire harbor and near shore waters of Lake Michigan. The AOC serves as a sink for pollutants carried from three watersheds: the Sheboygan River, the Mullet River, and the Onion River. Pollutants of concern, both conventional and toxic, have been identified as: suspended solids, fecal coliform bacteria, phosphorus, nitrogen, PCBs, PAHs, and heavy metals. Today, industrial, agricultural, and residential areas line the rivers of the Sheboygan River Basin. Agriculture is the dominant land use in the area, occupying a total 67 percent of the land area. A number of past and present pollution sources and practices have contributed to the use impairments identified in the impairment graphic.

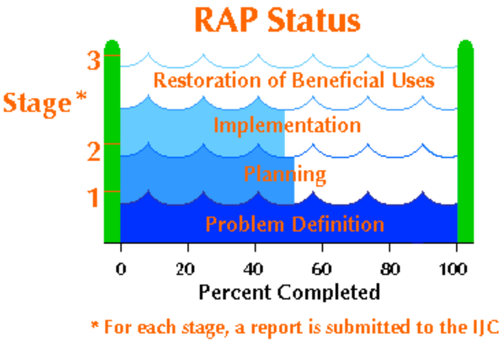
Beneficial Use Impairments

Of the 14 beneficial use impairments, 8 have been identified for the Sheboygan AOC through the Remedial Action Plan (RAP) process.

Beneficial Use Impairments

✔ Restrictions on fish and wildlife consumption.
Tainting of fish and wildlife flavor.
✔ Degradation of fish and wildlife populations.
✔ Fish tumors or other deformities.
✔ Bird or animal deformities or reproductive problems.
✔ Degradation of benthos.
✔ Restrictions on dredging activities.
✔ Eutrophication or undesirable algae.
Restrictions on drinking water consumption, or taste and odor.
Beach closings.
Degradation of aesthetics.
✔ Degradation of phytoplankton and zooplankton populations.
Added cost to agriculture and industry.
Loss of fish and wildlife habitat.

RAP Status



A two-year cooperative effort of the Wisconsin Department of Natural Resources (WDNR), other agencies, researchers, and the citizens of the Sheboygan area resulted in the completion of a Sheboygan River and Harbor Stage One RAP in 1989. All the groups worked together to identify management goals for the river and harbor for the year 2000 and to identify specific management strategies and for controlling existing sources of pollution, abate environmental contamination and restore beneficial uses. The goals and objectives of the RAP describe the "desired future state" of the Sheboygan River ecosystem. The Sheboygan County Water Quality Task Force served as the Citizens Advisory Committee (CAC) for Stage One development. The CAC included representatives of industry, government, fishing and conservation groups, and others and was instrumental in facilitating information exchange between environmental agencies and the public. An intergovernmental Technical Advisory Committee provided necessary reviews. In 1994, a revised RAP was prepared by WDNR and other stakeholders; it outlined activities targeted for implementation and progress toward development of a comprehensive strategy for restoring water quality, fisheries, recreational uses, and other benefits of the Sheboygan River Basin. The 1994 RAP was published in October 1995 and was distributed for review at 51 libraries statewide, including the Mead Public Library in Sheboygan and the Memorial Library in Sheboygan Falls. Three work groups (Water Quality, Biota, and Information and Education) were formed to recommend remedial actions for the development of the Stage Two RAP.

The Sheboygan River Superfund project is awaiting a record of decision from EPA. That phase will usher in the long-awaited sediment remediation of the Sheboygan River. WDNR Land and Water staffs from the region and bureau are working with their fellow trustees, the U.S. Fish and Wildlife Service, and the National Oceanic and Atmospheric Administration, to determine the Natural Resource Damage Assessment (NRDA) for the restoration phase for the Sheboygan River Superfund Site.

RAP Milestones

Fisheries and Water Resources staff completed 45 stream assessments throughout SER as part of baseline monitoring. Fish surveys, macroinvertibrate collections, and habitat assessments were conducted at each site. The data will be used for the State of the Basin reports, dam removal assessments, and stream classifications to provide information for water regulation and zoning projects.

Sheboygan Basin staff also have been working on the Franklin Dam removal project on the Sheboygan River. An environmental assessment was completed, and a public meeting was held.

Priorities

Improving the quality of the Sheboygan River Basin ecosystem and achieving the "desired future state" will require a long-term commitment from all levels of government, as well as local interest groups and citizens. RAP implementation must promote such involvement at a feasible pace, allowing results to materialize one step at a time. This step-by-step implementation will be based on the recommendations of the RAP. Those recommendations, which are implementable in two-to five-year periods, will be important steps in restoration of the basin. Those steps are not the first; many projects and programs are underway. Recommendations will continue to be developed as understanding deepens about the most efficient and lasting ways to restore the Sheboygan River and Harbor.

Monetary support alone, although important, does not ensure the success of the RAP. Successful implementation of the RAP requires the cooperation of all stakeholders and the willingness of the basin's citizens to voluntarily change the way we lead our lives.

☑ **Remediation**

- Superfund Record of Decision finalized and sediment remediation initiated.

☑ **Habitat/Resource Management**

  - Completion of the Natural Resource Damage Assessment

☐ **P2/Nonpoint Source**

☐ **Human Health**

☑ **Stewardship Sustainability**

- Completion of the Franklin Dam project

☑ **Education and Outreach**

- Web site to manage volunteer water quality monitoring data using the Pigeon River watershed pilot project as an example.

☑ **Research Projects/Data Gaps**

- Compile data from the stream assessments for the State of the Basin report.

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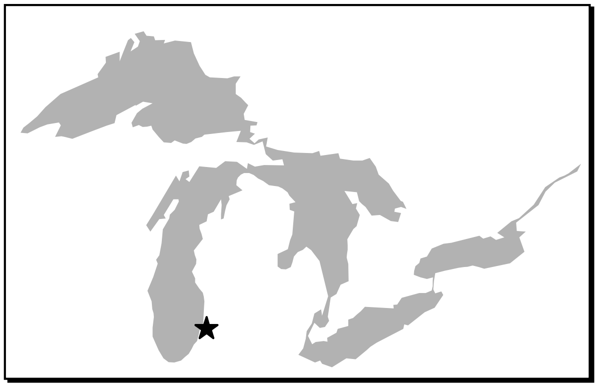
Kalamazoo River Area of Concern



Background

The Kalamazoo River is located in the southwest portion of the lower peninsula of Michigan. The river flows in a westerly direction and discharges into Lake Michigan near the town of Saugatuck. The upstream boundary of the Area of Concern (AOC) is Morrow Dam, which forms Morrow Pond and extends downstream to Lake Michigan, a distance of approximately eighty miles. The Kalamazoo River has been identified as a site of environmental contamination pursuant to the Michigan Natural Resources and Environmental Protection Act 451 and is included on the Superfund National Priorities List.

Beneficial Use Impairments

The Kalamazoo River has been identified as a Great Lakes AOC because of historical releases of poly-chlorinated biphenyls (PCBs) from de-inking operations at local paper mills. The Remedial Action Planning (RAP) process identified eight of the Great Lakes Water Quality Agreement's 14 beneficial uses as impaired. Beneficial use impairments in the AOC include restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, bird or animal deformities or reproductive problems, degradation of benthos, restrictions on dredging activities, beach closings, degradation of aesthetics, and loss of fish and wildlife habitat.

Beneficial Use Impairments

✔ Restrictions on fish and wildlife consumption.

Tainting of fish and wildlife flavor.

✔ Degradation of fish and wildlife populations.

Fish tumors or other deformities.

✔ Bird or animal deformities or reproductive problems.

✔ Degradation of benthos.

✔ Restrictions on dredging activities.

Eutrophication or undesirable algae.

Restrictions on drinking water consumption, or taste and odor.

✔ Beach closings.

✔ Degradation of aesthetics.

Degradation of phytoplankton and zooplankton populations.

Added cost to agriculture and industry.

✔ Loss of fish and wildlife habitat.

AOC Status

Since the PCB contamination was identified as a problem in 1971, several actions have been taken to improve conditions within the AOC. The discharge of PCBs has been substantially reduced because of the ban on PCB production and other regulatory point source controls, such as the National Pollutant Discharge Elimination System (NPDES) permit program. PCB-laden sediments eroding from Portage Creek banks at Bryant Mill Pond have been removed. PCB-contaminated soils at landfills have been encapsulated. A remediation plan for PCB-contaminated sediments in the Kalamazoo River is being developed.

RAP Milestones

✔ 1999: PAC establishes itself as the Kalamazoo Watershed Council with 501(c)(3) status.
✔ 1998: MDEQ published the Kalamazoo River RAP
✔ 1993: Kalamazoo PAC was established.
✔ 1987: MDEQ completed the draft Stage One Kalamazoo River RAP.

Priorities

The Kalamazoo River Watershed Council (KAWC) believes that the clean-up level used for PCB contaminated sediments should be the most stringent ones applicable and protective of life in and along the river. The KRWC has published the Position Statement on the Clean-up and Protection of the Kalamazoo River, and is actively seeking endorsements. To date, a number of organizations, county and local governments, and state and federal elected representatives have endorsed this position statement.

The KRWC has developed and distributed educational materials about their organization, the river, and actions that people can take to protect water quality and public health throughout the watershed. Watershed management projects in several sub-basins are working to reduce pollutant inputs and develop preventative land use measures. Stormwater management plans and projects are underway in both Kalamazoo and Battle Creek. A phosphorous total maximum daily load for Lake Allegan has been established and reduction implementation is underway.

☑ **Remediation**

- Superfund Records of Decision finalized and recommendations implemented.

☑ **Habitat/Resource Management**

- Habitat restoration at sites identified by local organizations and district staff.

☑ **P2/Nonpoint Source**

- Nonpoint source pollution control projects completed at sites identified by local organizations and district staff.

☐ **Human Health**

☑ **Stewardship Sustainability**

- Local land use planning educational efforts for elected and appointed local officials. GIS data is available for this application.

☑ **Education and Outreach**

- Public education on health issues and pollution prevention.
- Support for the Kalamazoo River Watershed Council.

☐ **Research Projects/Data Gaps**

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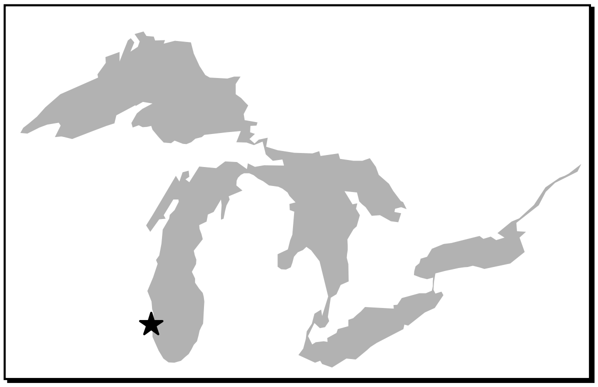
Waukegan Harbor Area of Concern



Background

The Waukegan Area of Concern (AOC) is located in Lake County, Illinois, on the west shore of Lake Michigan. There is also an expanded study area (ESA), bounded by Dead River on the north; a bluff line that parallels Sheridan Road on the west, the southern boundary of the former U.S. Steel Property on the south, and the near shore waters of Lake Michigan on the east. The ESA was added to explore additional concerns of the citizens about areas beyond the AOC.

A natural inlet and portions of adjacent wetlands were filled to form the present shape of the harbor. Waukegan Harbor consists of approximately 1.2 km^2 of industrial, commercial, municipal, and open or vacant lands. The watershed of the Waukegan ESA contains the Waukegan River drainage basin, the North Ditch drainage basin, and other near shore areas that drain to Lake Michigan.

Beneficial Use Impairments

Restrictions on fish and wildlife consumption.

Tainting of fish and wildlife flavor.

Degradation of fish and wildlife populations.

Fish tumors or other deformities.

Bird or animal deformities or reproductive problems.

✔ Degradation of benthos.

✔ Restrictions on dredging activities.

Eutrophication or undesirable algae.

Restrictions on drinking water consumption, or taste and odor.

✔ Beach closings.

Degradation of aesthetics.

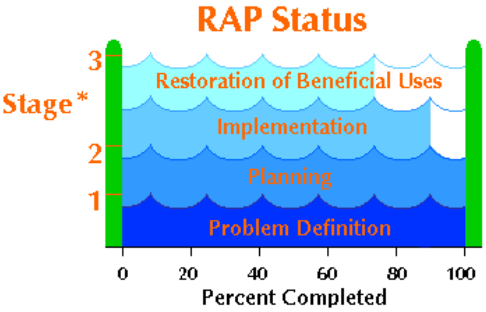
✔ Degradation of phytoplankton and zooplankton populations.

Added cost to agriculture and industry.

✔ Loss of fish and wildlife habitat.

Beneficial Use Impairments

Of 14 beneficial use impairments, 5 have been identified for the Waukegan ESA (those checked on the impairment graphic), on the basis of listing criteria approved by the International Joint Commission (IJC) in 1991. Impairments include degradation of benthos, restrictions on dredging, beach closings, degradation of phytoplankton populations, and loss of fish and wildlife habitat. Signs warning anglers not to eat fish caught in Waukegan North Harbor were removed on February 20, 1997, as directed by the Illinois Department of Public Health. Monitoring of fish from both the harbor and Lake Michigan over the past three years has shown no appreciable difference in PCB concentrations between the North Harbor and other harbors and the open lake.



* For each stage, a report is submitted to the IJC

RAP Status

A Waukegan Harbor Citizen Advisory Group (CAG) was organized in 1990 to act as a local advisory group to the Illinois Environmental Protection Agency to address environmental concerns in the AOC. The CAG includes representatives of industry, fishing interests, and environmental interests as well as residents.

The first stage of the Waukegan Harbor Remedial Action Plan (RAP), detailing the use impairments and providing a definition of the problems, was completed in 1993, following extensive review and comment by the CAG and an Interagency Workgroup (IAWG). Stage Two focuses on specific pollutant loads to the AOC and the ESA, as well as the remedial actions planned to restore the impaired uses of the contaminated sites. Revision of the Stage Two document was based on the comments of the CAG and the IAWG. The Stage Two RAP public meeting and review by the IJC were accomplished in September 1995. The Stage Three RAP was released in 1999.

RAP Milestones

- ✔ 1993: Stage One of the RAP was completed
- ✔ 1995: Stage Two RAP public meeting and IJC review were accomplished.
- ✔ 1999: The Stage III RAP was submitted.

Priorities

Four major remedial actions have been completed that will significantly reduce the quantity of contaminants in Waukegan Harbor and the nearshore area. Approximately 453,600 kg (1 million pounds) of PCBs were removed during remediation activities at the Outboard Marine Corporation site. The other three major remedial actions include the Johns-Manville Company, Waukegan Paint and Lacquer and the Waukegan Tar Pit. At Waukegan Paint and Lacquer, approximately 15 m^3 of paints, solvents and flammable solids were removed from weathered tanks before leaking into sandy soil next to Lake Michigan. At the Johns-Manville site, asbestos covering nearly 24 ha has been remediated to prevent entry into Lake Michigan. Two remedial investigations are underway on adjacent property of Waukegan Manufactured Gas and Coke and the Greiss-Pfleger Tannery. Both of these sites are suspected of contributing to surface and groundwater contamination. These remedial investigations are being funded by private parties through coordination with state and federal regulatory agencies.

The Waukegan CAG has been instrumental in obtaining cooperation from local parties involving additional investigations. Groundwater monitoring from local parties was completed in an area south of the harbor. The CAG helped obtain access from private businesses and federal grant money to install the monitoring wells. An adjacent salvage yard ceased operation in 1993 and the CAG is working with a local bank, who holds the property title, to resolve environmental concerns about the site.

☑ **Remediation**

- Facilitate an agreed upon location for a confined disposal facility that would house sediment dredged from the shipping channel.
- Raise funds to fulfill the local share match for the U.S. Army Corps of Engineers dredging of the shipping channel.

☑ **Habitat/Resource Management**

- Fish sampling of the harbor during Spring, 2000.

☐ **P2/Nonpoint Source**

☐ **Human Health**

☐ **Stewardship Sustainability**

☑ **Education and Outreach**

- Co-sponsor the GLWQB annual meeting in May, 2000.

☐ **Research Projects/Data Gaps**

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APPENDIX G

OVERVIEW OF THE LAKE MICHIGAN BASIN

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APPENDIX G
OVERVIEW OF THE LAKE MICHIGAN BASIN

This appendix describes the general setting and characteristics of the Lake Michigan basin, including the physical and biological history of the basin, key facts and figures about the region, Areas of Concern, and Areas of Stewardship. This appendix concludes with a description of key areas and habitat types in the basin.

G.1 HISTORICAL CONTEXT

In order to assess the status of the Lake Michigan ecosystem, the ecosystem must be viewed in its historical context. This section will describe the geology, climate, pre-settlement plants and animals, and a brief history of human settlement in the Lake Michigan basin.

G.1.1 Geology

The Lake Michigan basin is part of the Great Lakes basin, which was formed during the last 10,000 years. However, the foundation for the Great Lakes basin was laid over 3 billion years ago, during the Precambrian Era. The Precambrian Era was a long period of geologic activity. Mountain systems were built of sedimentary and volcanic rocks, which were then folded and heated and eroded. During the Paleozoic Era some 230 to 600 million years ago, the area was covered by marine seas that deposited lime silts, clays, sand, and salts; these substances consolidated into limestone, shale, halite, and gypsum.

More than 1 million years ago, during the Pleistocene Epoch, the first glacier moved over the Great Lakes region. With ice more than 6,500 feet thick, it scoured the earth and leveled hills. Valleys formed prior to the glacier were deepened and enlarged to form basins that would eventually become the Great Lakes. After thousands of years, the climate warmed and the glacier retreated, allowing vegetation and wildlife to return. This was repeated several times over thousands of years.

Glacial drift (sand, silt, clay and boulders) was deposited with each successive glacier. Resulting features seen today include moraines, linear mounds of fill material, flat till plains, drumlins, and eskers, all formed of well sorted sands and gravels. These areas are significant because they are groundwater storage and transmission areas (aquifers). They are also sources of commercial sand and gravel extraction.

As the glaciers retreated, large volumes of meltwater occurred along the front of the ice, forming large lakes. After the first glaciers, these lakes were larger than our present-day Great Lakes. The beach ridges along the perimeter of Lake Michigan (flat plains and eroded bluffs) indicate former lake shorelines.

As the last glacier retreated, the land began to rise. This “uplift” caused changes in the size, depth, and drainage patterns of the glacial lakes. Today, the water from Lake Michigan flows to Lake Huron through the Straits of Mackinac. The straits are deep and wide. As a result, both lakes are at the same elevation.

About 10,000 years ago, the present Great Lakes basin appeared. The “uplift” or crustal tilting, as it is called, is still occurring in Lakes Superior and Ontario. Crustal tilting, along with long-term weather pattern changes, suggests the Great Lakes are continuing to evolve *(Great Lakes: An Environmental Atlas and Resource Book* 1995).

G.1.2 Climate

Advancing and retreating glaciers carved out Lake Michigan and the Lake Michigan basin. Water levels changed in response to melting ice. The results of the glaciers can be seen along the varied shoreline and in the abandoned former lake shoreline inland. In the Indiana Dunes National Lakeshore at the southern end of the lake, for example, a series of dune ridges marks the progression of the lake's retreating water levels. The youngest dunes are found closest to the shore, formed between 4,000 years ago and present (Hill and others 1991).

Today, warm, moist air from the Pacific Ocean and the Gulf of Mexico collides with cold, dry arctic air over the Lake Michigan basin. Due to its sheer size and volume, the lake moderates the effects of both air systems by acting as a heat or cold "sink." As a result, shoreline temperatures differ from the temperatures of inland areas (Brown and others 1974). In the summer, temperatures near the shoreline are cooler than inland. This is reversed in the fall, with relatively warmer lake waters moderating the air temperature near the lakeshore. In addition to modifying temperatures in the basin, the lake influences weather patterns, precipitation, and wind velocity and direction (Eichenlaub 1979).

Global warming resulting from human activities poses the threat of increased temperatures and changing precipitation rates. The Lake Michigan shoreline could change quickly, submerging or exposing ecosystems accustomed to harshness and variability but unable to cope with rapid, permanent changes.

G.1.3 Plants and Animals

In the last ice age the spruce and fir forests that are today in northern Canada followed the retreating ice at about 1 kilometer per year. The climate was warming at a rate of 1 or 2 °C degrees every 1,000 years (Schneider 1989). As the ice retreated, new plant and animal species colonized and interacted, mostly from the surrounding watersheds which connected to the lake through channels, rivers and wetlands (Baily and Smith 1981).

The fish species that colonized Lake Michigan began to evolve in response to opportunities or niches present in the form of varying depths, embayments, and the corresponding food supplies and habitats afforded by geography. In particular, one fish family (the *Coregonids*) became very successful at filling these niches. This family includes the lake whitefish, lake herring, chubs, and ciscoes. Expansion of this fish family into different habitats within the lake resulted in the development of separate stocks, subspecies, and species, including the deepwater ciscoe known as *C. johannae,* which was endemic to Lake Michigan (Baily and Smith 1981).

Terrestrial plant and animal species colonized the Lake Michigan basin from other areas of the continent after each glacial retreat. As a result, the basin is a mixture of unique species from the boreal forests of the north, the grasslands of the west, and the deciduous forests of the east.

Ecoregions are large landscape areas defined by climate, physical characteristics, and the plants and animals that are able to live there. Defined ecoregions help to identify the unique plant and animal species and their habitats that colonized the Lake Michigan basin after the last glacier retreated some 8,000 to 10,000 years ago.

The Southern Lower Michigan Ecoregion extends across the southern half of the lower peninsula of Michigan. Before settlement, this region was forested with oak-hickory or beech-sugar maple mixtures. Closer to the lake and dunes were forests of eastern hemlock, beech, white pine, red and white oak, and sugar maple. Extensive marshes, fens, and swamp forests were also present. Oak hickory and lakeplain areas were dependent on fire to rejuvenate native plant communities. Today, the ecoregion is comprised of rolling hills and flat lakeplains of fertile soils. The shoreline is banded with sand dunes. Sand dunes are threatened by mining; forests and lakeplain areas are being developed; and fire suppression has degraded oak-hickory forests and lakeplains.

The South Central Great Lakes Ecoregion overlaps with the Southern Lower Michigan Ecoregion. It extends from Muskegon, Michigan, through Northwest Indiana to the Calumet region on the southeast side of Chicago. Before settlement, the dune ridges closest to the lake were covered by white pine and jack pine. Further from the lake, the ridges were oak-hickory savannas, and in the lowlands, tallgrass prairies. Wetlands interspersed the dunes ridges. Near Warren Woods, Michigan, beech-maple forests blanketed the area. Today, this region is a combination of gently rolling lowlands, flat plains, and dune and swale ridges formed by receding glaciers. Industrial and urban development dominate the ecoregion; however, it is still surprisingly rich in biological diversity and protected areas.

The Southwestern Great Lakes Morainal Ecoregion and the overlapping Southeast Wisconsin Savanna Ecoregion extends from southeast Chicago to Milwaukee and inland to central Wisconsin. Before settlement, beaches and low, white pine and jack pine covered dunes, lakeplain prairies, and diverse wetlands were nearest the lake. Inland, lakeplain oak savanna and prairie communities and wetlands dominated the landscape. Today, the region is characterized by flat, undulating topography resulting from glaciation. The lakeshore is largely hardened with artificially nourished beaches and the most heavily urbanized development of the Lake Michigan basin. Small remnant natural areas are protected in a mosaic of parks and protected areas.

The Northern Lacustrine-Influenced Upper Michigan and Wisconsin Ecoregion extends north of Milwaukee and includes Door County and the areas to the Mackinac Bridge. Before settlement, the region was covered by northern hardwood forest, jack pine barrens, white and red pine forests, and hardwood and conifer swamps. Dune and swale topography characterized the nearshore with ridges of white or red pine, white spruce, balsam fir, and hardwoods. Extensive marshes were found along the shoreline, particularly in Green Bay. Fire was important in maintaining the jack pine barrens. Early post-settlement, intensive logging depleted forest resources, followed by agriculture. Today, the Lake Michigan shoreline is bedrock or cobble beach of exposed limestone and dolomite. Residential and vacation home development pressures are stressing the ecosystems along the shoreline.

The Northern Lacustrine-Influenced Lower Michigan Ecoregion extends across the upper half of Michigan’s lower peninsula. Before European settlement, jack pine, white pine, and northern pin oak dominated large areas of this region. Today, limestone bedrock is exposed along the shore. Sand deposits are thick. Much of the area has been logged. Orchards and vineyards have replaced forests. Residential and vacation home developments are replacing natural ecosystems.

G.1.4 Human Habitation

The first inhabitants of the Lake Michigan basin arrived as the last glacier was receding about 10,000 years ago. When French explorer Jean Nicolet and the French voyagers began traveling through the basin beginning in the early 1600s, while searching for a passage to the Orient, the Lake Michigan basin was inhabited by the Illinois, Potowattomi, Fox, Menominee, and other Tribes dependent on the fur bearing and game animals of the region, as well as subsistence foods such as wild rice, and trees for canoes and shelter. In 1763 the region, including Lake Michigan, came under British control. When the United States acquired the Northwest Territory in 1796, the Lake Michigan basin was included. Explorers were succeeded by missionaries and fur trappers and finally, settlers. The Native Americans were relegated to reservations or moved further west.

Significant changes to the Lake Michigan ecosystem began in the mid-1800s, when large numbers of people began to settle the region. By 1850, commercial fishing was a major industry and had resulted in a noticeable decline in fish populations by the 1870s (Wells and McLain 1973, Eshenroder and others 1995). Industrial pollution had also begun to affect fish populations as the result of the damming of rivers, deforestation, and the dumping of sawmill and other waste into the tributaries and lake itself. The waterways became major highways for trade. The fertile land yielded lumber and agricultural products.

The earliest loggers harvested white pine. Stands of virgin white pine reached 60 meters in height, and a single tree could contain 10 cubic meters (6,000 board feet) of lumber. Because it is light and strong, the pine was much in demand for shipbuilding and construction. Other hardwoods such as maple, walnut, and oak were logged to make furniture, barrels, and specialty products. The logging industry was exploitive at this time. Clear cutting and improper reforestation practices denuded the landscape throughout the basin. Soils were eroded and streams and rivers choked with sediment. The water quality of streams, rivers, and lakes was degraded.

Large-scale clearing of the land for agriculture in the 1800s rapidly changed the landscape as well. Wheat and corn were the first commodities to be packed in barrels and shipped from the region. Grist mills, one of the region’s first industries, were built on tributaries to process grains for shipment. Specialty crops such as fruits and vegetables were grown for a burgeoning urban population. Wetlands were filled to create more land for crops. Tributaries and streams were dammed and channelized, and flows were diverted to fields, leading to an imbalance in natural water level fluctuations. Soils stripped of natural vegetation for agricultural use washed away to the lake. Fish habitats and spawning areas were destroyed by surface runoff from poor agricultural practices.

The northern part of the basin was an important mining area. Dolomite and limestone, as well as marble granite and iron were mined in the Kingsford/Iron Mountain area on the Menominee River and near communities of Escanaba, Menominee, and Manistique.

By 1900 the population of the region soared. Chicago and Milwaukee were major cities and centers for Great Lakes trade and transportation of goods throughout the Midwest. Industrial development flourished. Further north, the paper production industry developed at Green Bay.

Commercial fishing greatly expanded until a significant change to the ecosystem occurred. Sea lamprey, which entered the upper Great Lakes when bypasses to Niagara Falls were constructed, were first noted in Lake Michigan in 1936. By the late 1940s, the sea lamprey had decimated the lake trout and burbot populations, the top predator fish. With the elimination of the top predators, two exotic species, the alewife and rainbow smelt, flourished. By the 1960s, the lake was dominated by the alewife and, to a lesser extent, rainbow smelt. The native fish community was severely disrupted, and important commercial and sport fisheries had collapsed. *Coregonid* populations were also affected and resulted in the extinction of several species of deepwater ciscoes, including *C. johannae*. Lake trout were extirpated and to this day are not self-sustaining in Lake Michigan (Koonce 1994).

G.2 FACTS AND FIGURES: LAKE MICHIGAN BASIN TODAY

Lake Michigan, the second largest of the Great Lakes by volume (1,180 cubic miles) and the third largest by surface area (22,300 square miles) is the only Great Lake entirely within the United States, in parts of Michigan, Indiana, Illinois, and Wisconsin. The lake is 307 miles from north to south and 118 miles at its widest from east to west. It averages 279 feet in depth, with a maximum depth of 925 feet. The water retention time is 99 years, which means it takes 99 years for water to cycle through the lake.

The length of the Lake Michigan shoreline is 1,638 miles. The total land drainage area of the watershed is 45,600 square miles. The northern part of the watershed is cooler and forested. The southern, more temperate portion of the basin is urbanized, heavily industrialized, and agriculturally productive.

G.2.1 Basin Population

More than 10,057,000 people live in the basin, primarily in the southern Lake Michigan, Chicago-Milwaukee metropolitan region. This figure includes the 2,914,250 people living in Cook County, Illinois, which is part of the original Lake Michigan basin boundary before implementation of the diversions to the Illinois River/Mississippi River drainage basin.

Within the original basin boundary, Illinois contains 3,494,115 people, or 34.7 percent of the Lake Michigan basin population with a land area of 93 square miles (0.03 percent). Post diversion this figure is reduced to 579,865 people or 8.1 percent. Although the water used within the diversion area is not discharged to the Lake Michigan basin, the water supply for that population comes directly from Lake Michigan and, for the purposes of this discussion, the population relates to the original Lake Michigan basin boundary.

Indiana has 604 square miles or 2.5 percent of the basin's land area and 10.8 percent (339,264) of the basin's population. When Indiana is combined with Illinois, only slightly more than 2.5 percent of the land area in the basin is home to nearly one of every two people or 45.5 percent of the entire basin population.

Wisconsin has 2,467,463 people (24.5 percent) in its part of the basin. Approximately 70 percent of Wisconsin's coastal population reside in four southeastern counties: Ozaukee, Milwaukee, Racine, and Kenosha. Over half of the state's coastal population resides in Milwaukee County alone. The population of the city of Milwaukee and neighboring Racine declined significantly from 1970 to 1990 (-11.3 percent and -9.9 percent, respectively). In contrast, the city of Green Bay had a stable population during the 1970s and experienced a significant 9.7 percent population increase from 1980 to 1990–a trend that has continued through the 1990s. Lake Michigan coastal populations in Wisconsin counties outside Milwaukee increased by 4.2 percent between 1980 and 1990, and by 5.3 percent between 1990 and 1995–higher than in three decades. However, trends indicate continued high rates of second-home development (40 percent to more than 80 percent in the northeast). Seasonal populations in coastal counties peak during summer months, when there is almost one visitor for every two permanent residents. In the winter months, the seasonal population is only about the state average for both periods.

Michigan has 3,007,954 people in its share of the basin, or 30 percent of the Lake Michigan basin population. Census population figures, based on the number of permanent residents in an area, do not reflect the seasonal aspects of a population. Seasonal populations–tourists and recreational visitors–can play an important role in characterizing certain areas in the Lake Michigan basin. A study of the 10-county area of the northeastern portion of the basin (northwest Michigan), for example, concluded that one person in six (about 16 percent) staying in the region in 1995 was not part of the permanent population. Forty percent of those were people staying in second homes. Data for the eastern basin indicate that second-home development is projected to slow somewhat between 1990 and 2010 compared with the previous 7 percent of the region. However, counties with smaller permanent populations that have winter ski resorts experience much higher percentage winter seasonal populations.

The most significant population trend for the Lake Michigan basin is a shift away from central cities coupled with rapid growth in the surrounding metropolitan areas. In some places, this outlying growth reflects an increase only in the number of households (a shift in population density due to declining household size), not in population; however, in other places, it is a true increase in population in the outlying areas. In any case, this population shift to the urban periphery and suburbs together with the attendant trend towards smaller household sizes and demand for low-density development consumes vast amounts of agricultural lands and open space. It also alters the character of what were once small towns, distinct from urban areas, as these small towns are consumed by the ever-expanding metropolitan areas.

In basin metropolitan areas near the shore, the implications for the nearshore area are even greater because, on the one hand, the lake geographically limits how far people can move lakeward away from the city and, on the other hand, the lake provides a natural attraction for new development. The result is that many of the people leaving the central cities are heading for the nearshore area. The city of Chicago, for example, lost population between 1980 and 1990, whereas the Chicago metropolitan area experienced continued growth in areas outside the central city to the south, away from the lake, and north along the Lake Michigan shoreline. The Milwaukee/Racine area in Wisconsin, discussed above, is another example where population has increased at the county level.

Another trend is the remarkable population decrease in the highly urbanized areas in Northwest Indiana, which includes East Chicago, Hammond, and Gary. Between 1980 and 1990, the population in these cities declined by 14.8 percent, 10.1 percent, and 23.2 percent, respectively. This has been the trend since the 1970s and is expected to continue, although it has slowed somewhat in the 1990s. This population change has been influenced by the downsizing of steel mills and other manufacturing industries in the area. As the population declines in the tri-city area, more people move to the urban and suburban areas toward the southern watershed boundaries, as well as northward into Michigan along the Lake Michigan shoreline.

G.2.2 Water Use

Consumptive water uses–uses for which a quantity of water is withdrawn and not replenished–have minor impacts on the Lake Michigan water level. Lake Michigan is the source for drinking water for the communities near the lake. Millions of gallons are withdrawn daily to supply an estimated 100 gallons per person daily in the basin. Groundwater is the reservoir for supplying water to the lake via the basin's many tributaries (Manninen 1999).

Thermoelectric power plants, industry, agriculture and public water supply are other consumptive users of Lake Michigan water. For 1992, comprehensive water-use data for Wisconsin, Illinois, and Indiana (Michigan data was not available) indicate that about 90 percent (18,455 of 20,500 million gallons per day [mgd/day]) of the total water used in those parts of the Lake Michigan basin comes from surface water–both from Lake Michigan directly and its tributaries. The remaining water comes from groundwater sources.

The largest single use of withdrawn surface water for all Lake Michigan basin states is for cooling at thermoelectric power plants (more than 48 percent for Indiana, Illinois, and Wisconsin). This water comes directly from Lake Michigan. Approximately 10 percent of the surface water use in the Illinois, Indiana, and Wisconsin portion of the basin is for industrial purposes (for example, in steel and paper production). In fact, Indiana's concentration of heavy industry, particularly in its Lake Michigan counties, has made it the nation's largest industrial water-using state. Agricultural use for irrigation and livestock represents about 4.5 percent of total water use from all sources. Only about 7 percent of surface water use (1.369 Mgal/day) in the Indiana, Illinois, and Wisconsin portion of the basin is for public water supply, and about half for navigation, sanitation, and water quality purposes.

Lake Michigan water is diverted at Chicago to the Chicago Sanitary and Ship Canal. The canal links the lake to the Mississippi River. It is used as drinking water, for sewage disposal, and for commercial navigation. This diversion is one of five in the Great Lakes and has been disputed and limited by order of the U.S. Supreme Court (Maninnen 1999).

Non-consumptive water uses–uses for which no water is consumed–include hydroelectric power, recreational boating and fishing, and shipping. The second largest water-use category in the Indiana, Illinois, and Wisconsin portion of the basin is hydroelectric power, which accounts for about 31 percent of total surface water use for the non-Michigan portion of the basin.

According to the 1991, United States national fishing and hunting survey, 34 percent of all Great Lakes anglers fished in Lake Michigan, a close second to Lake Erie's 35 percent. The number of recreational boats operated on Lake Michigan each year is estimated at 400,000, or nearly half the number for all the Great Lakes. Although boating has a strong connection to fishing, which relies on clean water and productive fish stocks, much of the boating activity is tied to marina and new nearshore residential development, which degrades nearshore habitat and water quality in localized areas. Along Indiana's Lake Michigan shoreline, for example, boat slips increased from 1,100 in 1985 to 2,700 in 1991, although many new marina developments in Indiana are occurring on previously developed sites.

Lake Michigan remains an important resource for waterborne navigation in and around every lakefront community and through many of its tributaries. The U.S. Congress has authorized a total of 51 federal navigation projects in Lake Michigan and its tributaries. The majority of commerce at Lake Michigan ports is internal in the Great Lakes–materials are transported from one Great Lake port to another. Raw materials associated with steel making (such as iron ore, limestone, and coal) dominate the overall tonnages of commercial cargo transported at Lake Michigan ports. Coal remains a common cargo at many of the smaller commercial harbors, largely for coal-fired power plants.

G.2.3 Land Use

The Lake Michigan basin land use profile varies considerably from north to south. Forested lands dominate the northern portion of the basin. Preliminary data collected in 1993 by the U.S. Forest Service indicate that each of the Lake Michigan-adjacent counties in Michigan's upper peninsula contains more than 202,500 hectares (500,000 acres) of forested land. Historically, the northern basin has also been an important mining area—primarily dolomite (limestone) with some marble, granite, and iron ore (Michigan State University 1977). The heavily forested north gradually gives way to predominately agricultural lands in both the eastern and western portions of the basin. In 1991 and 1992, 35.7 percent of the basin's land was farmland, most of which was cropland and pasture. The Door Peninsula in the western basin and the "fruit belt" along the coastal counties of the eastern basin are important areas for orchards and specialty crops. Southward, agricultural land is increasingly interspersed with urban areas. The extreme southern portion of the basin—a relatively narrow band of land adjacent to the lake–is heavily urbanized. Between 40 and 46 percent of the land in the Indiana-Illinois portion of the basin is classified as urban.

Although every Great Lakes basin has some sand dunes and beaches, the expanse of sand dunes and beaches along Lake Michigan's eastern shore is one of its most impressive features. This extent of sandy beach and dunes is accented by Sleeping Bear Dunes National Lakeshore in the north and the Indiana Dunes National Lakeshore in the south—the latter containing the third highest plant diversity of all U.S. national parks (U.S. Geological Survey 1991).

The greatest alteration of the Lake Michigan nearshore environment has been in the southern part of the basin where intensive urban and industrial development has resulted in filling and "hardening" of the shoreline and discharge of large amounts of pollutants into the air, water, and lands of that coastal region.

A ridge of sedimentary rock forms an arc in the middle of the Great Lakes basin and is the source of prominent natural features found in several of the Great Lake basins. In the Lake Michigan basin, this ridge is the source of the Door and Garden Peninsulas that separate Green Bay from Lake Michigan. Perhaps the most spectacular part of this ridge, known as the Niagara Escarpment, runs through the Lake Huron and Lake Erie basins in Ontario forming the Bruce Peninsula and Manitoulin Island in the north and extending south and to the east, where the waters of Lake Erie spill over it on their way to Lake Ontario, forming one of North America's most famous tourist attractions: Niagara Falls (Ashworth 1986).

The northern part of the Lake Michigan basin, including Green Bay and Michigan’s Upper Peninsula, is dominated by the forestry industry and recreational land uses. This former mining region is today sparsely populated, with the majority of people living in Green Bay, Escanaba, Menominee, and Manistique. The northern basin serves as one of the nation's foremost Christmas tree growing regions, and the Fox River-Green Bay area of the Lake Michigan basin is recognized as the world's largest concentration of pulp and paper mills. Pulp and paper mills historically have contributed to significant pollution problems, but improvements over the last two decades have been substantial. Mill effluents containing dioxin and other chlorinated organic compounds which posed a threat to human health and the environment. New production and treatment technologies are reducing and, for particular facilities, eliminating these pollutants. Contamination from past practices, however, remains a significant concern.

Just west of Green Bay, the Menominee Indian Reservation is a showcase for sustainable forest practices. The Wolf River watershed is forested and relatively undeveloped; however, a mine in the upper watershed has been proposed.

The largest concentration of steel production in North America is located near the southern tip of Lake Michigan. Five large integrated mills with blast furnaces, and three mini-mills dependent on iron and steel scrap, produce about 25 percent of U.S. steel. The steel industry has had a major impact on land use and the nearshore environment. Its sprawling scale, including fabricating and warehouse facilities, occupies thousands of nearshore acres and unique dune ecosystems. The industry's legacy has generated tons of pollutants, some of which are still present in contaminated sediments in nearshore waters and soil within plant boundaries. Much improvement in air emissions and water effluent has occurred in recent years. For example, water use for process purposes has been substantially reduced with the incorporation of recycling and closed-loop systems.

Orchards are common in the eastern Lake Michigan basin, which is the leading Great Lakes basin source of cherries and apples for processing. The Lake Michigan basin accounts for 45 percent of total Great Lakes basin specialty crop (fruits and vegetables) acreage. Door County, Wisconsin, in the western Lake Michigan basin, is also known for its favorable growing conditions and is an important area for cherry and apple production as well.

The Lake Michigan basin alone accounts for 40 percent of the dairy cows in the entire Great Lakes basin. A well established trend is fewer but larger dairy farms with more milk from each cow. This trend in the dairy industry reflects a larger trend in agriculture towards consolidation and large-scale farming operations. Thus, while there may be a decrease in the actual number of acres used as farmland, those acres are used more intensively than before.

Recreation and tourism are important economic factors in all of the Great Lakes basins; however, due to extensive dunes and beaches, the Lake Michigan basin offers more recreational and tourist opportunities associated with beach activities. The Door County Peninsula is a busy tourist location, with residential vacation developments putting pressure on wetlands, shorelands, and the Niagara Escarpment. Two national lakeshores, Indiana Dunes and Sleeping Bear Dunes, plus many state parks offer recreational opportunities and beach access to thousands of visitors each year.

Low-density sprawl is the predominant development trend in the Lake Michigan basin. Such development has serious implications for the ecosystem, including loss of agricultural land and open space; increased reliance on private automobiles and truck transport and its attendant increased air pollution; high ratio of road surface to development served; increased infrastructure costs; loss of unique character of the landscape; and high land consumption.

Counties in the eastern Lake Michigan basin, for example, experienced reductions in farmland acreage from 7 percent to more than 15 percent from 1982 to 1992, pushing the average for that region well above the average for the state of Michigan during that period (7.8 percent). On the basis of current trends in land value and population growth, the Michigan Society of Planning Officials projects that farms and farmlands in more than two-thirds of the counties in this eastern area are at moderate to high risk due to residential development.

The Grand Rapids area faces the greatest residential pressure in the state, yet it is located within three of the five highest producing agricultural counties (Ottawa, Kent, and Montcalm) in Michigan. Ottawa County, for example, is currently the state leader in agricultural sales. From 1990 to 1995, it also was granted more construction permits (408) under Michigan's Coastal Zone Management Program than any other county in the state. Most of these permits were issued for single family homes and additions to existing homes.

The urban exodus in the extreme southern portion of the basin is also contributing to residential development in the north along the shore. For example, Berrien County, Michigan, adjacent to Indiana, held the second highest number of construction permits on the eastern shoreline between 1990 and 1995.

In the western basin the same trend is apparent. Wisconsin coastal counties on Lake Michigan showed a gain of 41,584 new housing units from 1990 to 1995, nearly half of which were in communities bordering the shoreline. In the land within 305 meters of the Lake Michigan shore, residential land use increased by about 9 percent between 1978 and 1992. Commercial land use in the nearshore area increased by around 17 percent in the same period. Permit applications (rezoning and variance requests) in Wisconsin's coastal counties increased by more than 95 percent between 1992 and 1995. Meanwhile, agricultural and open space lands decreased in 13 out of 15 of Wisconsin's Lake Michigan coastal counties between 1978 and 1992.

Waterfront development has been a major activity in the basin in the 1980s and 1990s, particularly in the urbanized areas of the southern and western portions of the basin. Increased demand for marinas and other water-based recreation opportunities is, in part, the result of improved water quality over the last two decades. Increased environmental awareness is also a factor supporting greater demand for waterfront access and opportunities. Almost all the coastal communities in Wisconsin have had some degree of waterfront revitalization. Also, Indiana's 45 miles of industrialized shoreline is giving way to increased shoreline restoration and preservation efforts as well as marina development. Increased public access and attractively designed waterfront facilities are common to waterfront revitalization efforts. Once old, deteriorated waterfronts are becoming the focal points of communities. Waterfront revitalization is an efficient use of land because it provides new economic and recreational opportunities through the renovation of already developed areas. In contrast, waterfront development along the eastern Lake Michigan shoreline consists primarily of new residences and additions to existing residences, although some redevelopment is underway in more urbanized areas.

G.2.4 Areas of Concern

Areas of Concern (AOC) are severely degraded geographic areas where beneficial uses—activities that are dependent on the chemical, physical, and biological integrity of the water—are threatened or impaired. Restrictions on fish and wildlife consumption, loss of fish and wildlife habitat, and beach closings are examples of the 14 beneficial use impairments identified under the Water Quality Agreement.

Of the 42 AOCs in the Great Lakes basin, 10 are in the Lake Michigan basin. They are Manistique River, White Lake, Muskegon Lake, and the Kalamazoo River in Michigan; the Grand Calumet River in Indiana; Waukegan River in Illinois; and Milwaukee Estuary, Sheboygan River, Fox River-Southern Green Bay, and Menominee River in Wisconsin. All 14 beneficial uses are impaired at one or more of the AOCs. Remedial Action Plans (RAP) are being developed in each AOC. The Waukegan Harbor AOC is on the road to being delisted. PCB-contaminated sediments have been removed from the harbor, and most of the hazardous waste sites have been cleaned up.

Table G-1. Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Manistique River	- Restriction on fish and wildlife consumption - Degradation of benthos - Restrictions on dredging activities - Beach closings - Loss of fish and wildlife habitat	Water	Heavy metals detected but below levels of concern
		Sediment	PCBs; chromium; copper; lead; heavy metals (zinc, lead, and cadmium); undecomposed sawdust; oil and grease
Lower Menominee River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Beach closings - Loss of fish and wildlife habitat	Water	PAHs; lead, cyanide, chromium, copper, mercury, and phosphorous are detectable but are below levels of concern; arsenic
		Sediment	Arsenic, mercury, PCBs, oil and grease, copper, zinc, lead, cyanide, cadmium, PAHs, and chromium

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Lower Green Bay and Fox River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Beach closings - Degradation of aesthetics - Degradation of phytoplankton and zooplankton populations	Water	Phosphorous and suspended solids, PCBs, ammonia, pesticides, PAHs, and volatile organics
		Sediment	PCBs, PAHs, chlorinated phenols, ammonia, cadmium, mercury, chromium, nickel, copper, zinc, lead, pesticides, oil and grease

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Sheboygan River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Degradation of phytoplankton and zooplankton populations	Water	Phosphorous, heavy metals, PAHs, nitrogen, and suspended solids
		Sediment	PCBs, PAHs, lead, copper, and chromium
Milwaukee Estuary	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Beach closings - Degradation of aesthetics - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	Oil and grease, heavy metals, and dissolved oxygen
		Sediments	Mercury, cadmium, chromium, copper, lead, arsenic, zinc, PCBs, pesticides, PAHs, oil and grease, ammonia, phosphorous, and nitrogen

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Grand Calumet River and Indiana Harbor Ship Canal	- Restriction on fish and wildlife consumption - Tainting of fish and wildlife flavor - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Beach closings - Degradation of aesthetics - Added cost to agriculture or industry - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	PAHs, oil and grease, arsenic, ammonia, chlorides, cyanide, and phosphorous
		Sediments	PCBs, PAHs, phosphorous, nitrogen, iron, magnesium, volatile solids, oil and grease, mercury, cadmium, chromium, lead, naphthalene, benzo(a)pyrene, zinc, and fluoranthene

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Waukegan	- Degradation of benthos - Restrictions on dredging activities - Beach closings - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	Total phosphorous, total ammonia, chloride, sulfates, cyanide, phenols, dissolved oxygen, pH, and total dissolved solids
		Sediment	PCBs, arsenic, barium, cadmium, chromium, copper, cyanide, iron, lead, manganese, nickel, phosphorous, Kjeldahl nitrogen (an estimate of organic nitrogen), chemical oxygen demand, and volatile solids
Kalamazoo River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Beach closings - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	PCBs and nonpoint source pollution (urban)
		Sediment	PCBs
Muskegon Lake	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	Phosphorous, un-ionized ammonia, dissolved oxygen, pH, and total dissolved solids at levels below concern; heavy metals, oil and grease, phosphorous, and nitrogen of concern in localized areas
		Sediment	PCBs, mercury, lead and arsenic, cadmium, chromium, copper, nickel, and zinc

Table G-1. (Continued)
Contaminants and Use impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
White Lake	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	Phosphorous, heavy metals, chloride, and nitrogen
		Sediment	Chromium, lead, arsenic, cadmium, manganese, mercury, nickel, zinc, PCBs, oil and grease

(Source: Lake Michigan Forum. 1996. Lake Michigan Areas of Concern. 1999. http://www.lkmichiganforum.org/areasofconcern.html)

G.2.5 Areas of Stewardship

Areas of Stewardship are broad landscape areas or nearshore aquatic areas with the following:

- Concentrations of species of special interest such as the endangered prairie white-fringed orchid, a lakeplain prairie species
- Outstanding examples of special communities, such as the coastal wetlands of the western shore of Green Bay
- Excellent representations of landforms or typical vegetation and wildlife communities, such as the Niagara Escarpment in Door County and the Garden Peninsula
- Exceptional levels of natural diversity, including both habitat and species diversity, such as the southern end of the lake with dunes, prairies, savannas, and wetlands and more than 350 species of plants alone
- High levels of ecological connectivity, such as the Crystal River, Michigan, watershed

During the 1996 State of the Lakes Ecosystem Conference (SOLEC), nearshore terrestrial Biodiversity Investment Areas were identified throughout the Great Lakes basin. Four Biodiversity Investment Areas within the Lake Michigan basin were identified: Michigan Islands, Chicago Wilderness, Door County Peninsula, and Green Bay Western Shore. At the regional Lake Michigan basin scale, additional smaller coastal areas and inland areas can be added to the four large-scale, nearshore areas: Seney Wildlife Refuge, Wilderness State Park, Grand Traverse Bay, Sleeping Bear Dunes, Allegan State Game Reserve, and Menominee Tribe Reservation.

Coastal wetland and nearshore aquatic Biodiversity Investment Areas were also identified for SOLEC 1998. Additional work needs to be done to characterize proposed areas and to understand the relationship of people to these sites.

Designating areas as Biodiversity Investment Areas or Areas of Stewardship does not mean there are no other significant areas of biodiversity in the Lake Michigan basin. In fact, numerous other high quality, but smaller, such areas exist. From a Lake Michigan basin perspective, however, the emphasis in these areas is their clusters of biodiversity values that warrant special attention.

Areas of Stewardship are not necessarily pristine. Several, such as the Michigan Islands, have very little disturbance to their natural features and processes, but others, such as Chicago Wilderness, have been substantially altered from their original state, yet retain remnant natural areas and ecological values of exceptional significance.

G.3 KEY LAKE MICHIGAN HABITAT TYPES AND AREAS

Section 4.2 of this document describes and assesses the major habitats in the Lake Michigan basin. The following section provides an overview of selected key areas within these Lake Michigan habitats.

G.3.1 Coastal Marshes System

Green Bay Western and Northern Shores

Green Bay's western and northern shores have low sand banks fronted with low beach ridges and numerous fringe wetlands. Huge bulrush beds flank the shore in Big and Little Bay de Noc and other protected bays. Behind the active beach barrier, inactive beach ridges may exist, which in turn flank large lagoons and interior marshes of cattails, open water, sedge meadows, and shrub zones. Some of the finest examples of Great Lakes marshes are in northern Green Bay and along the eastern side of the Door Peninsula.

Door Peninsula

The Door Peninsula has 4.2 percent of all of Wisconsin’s Great Lakes coastal marshes. Of these, most are ridge and swale complexes that run parallel to the lake. The Mink River estuary, Ridges Sanctuary, Mud Lake State Wildlife Area, and other reserves offer a diversity of plants and habitat for wetland birds (Scheberle 1999).

Eastern Lake Michigan

There are no littoral marshes along the eastern shore of Lake Michigan, but there are some extensive interdunal wetlands between the dune ridges, small intradunal wetlands in depressions within the dunes, and considerable wetlands tucked into and up every tributary. These are large "drowned river mouth" marshes that formed as lake levels rose from a lower previous level. Some are very extensive and all have been severely modified in their lower reaches due to marina and condominium development, housing, and other commercial enterprises.

The Grand River Estuaries in Ottawa County are a complex of estuarine marshes of high quality. It is an example of a Great Lakes Estuary Marsh community, which is globally imperiled. Because it is located at the intersection of the Atlantic and Upper Mississippi Flyways, these river marshes are important feeding areas and a migration corridor for waterfowl such as Canvasback, Lesser Scaup, Redhead, Goldeneye, and Bufflehead diving ducks, and dabbling ducks such as Mallard, Black duck, Baldpate, Pintail, and Blue-winged teal. Osprey forage in the marshes (The Nature Conservancy 1995).

A typical marsh system in this area is found in the Betsie River. A narrow, short channel separates Betsie Lake from Lake Michigan. The dune fields are thus interrupted by the river valley, and Betsie Lake has had most its shoreline wetlands eliminated by bulkheads or shore maintenance. Betsie Lake then narrows in its upper reaches and merges within the Betsie River and its associated floodplain. Large tracts of floodplain wetlands then characterize the river for many kilometers, becoming narrower upstream. As the water levels of Lake Michigan trend higher in some years, the wetlands near the channel recede to the floodplain and shore terraces because the water near the channel becomes too deep. When levels are low, mudflats often become exposed, quickly being colonized by new hydrophytes, and the wetlands expand to the channel margins. Thus, the diversity of the wetland vegetation is greatly enhanced by the natural fluctuations of the lake level.

North of Leland, through the Traverse Bays, and continuing north to the Straits of Mackinac, the shore of Lake Michigan changes again into rocky cliffs and bluffs, cobble beaches, and occasional embayed wetlands of small size. The high relief shores preclude any opportunity for lakeplain wetland development, and the actual shoreline is under constant wave attack from deep water. Along the offshore islands (such as Manitou, Fox, and Beaver) the situation is similar, although a few do exist as lagoon wetlands protected from Lake Michigan.

Northern Lake Michigan

From the Straits of Mackinac westerly, the Michigan shore becomes distinct again, with low relief, multiple sand ridges being interrupted by shallow, sheltered bays. Many of these bays have large shoreline wetlands that intergrade into beach swales, wet meadows, and shrub thickets before the more upland plants become apparent. All along this stretch, the forest dune and swale complex is well developed, leftover from ancient higher lake levels (Minc 1998). Where the major rivers or small creeks empty, riverine and lagoon wetlands flourish upstream, with good examples at practically every outlet. Along the Garden Peninsula, many embayed wetlands remain untouched, fronting on low relief uplands or tucked between large limestone cliffs.

Greater Calumet Wetlands

On the southern shore of Lake Michigan in Cook County, Illinois, and Lake County, Indiana, are the remnants of a formerly huge lake-related wetland complex called the Great Calumet wetlands. Embedded in a now urbanized and industrial setting on about 1,000 acres, Panne, Pond, Marsh, Wet Prairie, Sedge Meadow, and Shrub Swamp communities that lie among the old lakeplain ridges still support a rich diversity of boreal, Atlantic coastal plain, and Great Plains prairie species. The Interdunal Wetland community type is globally rare. More than 700 plant species, 200 birds, 14 mammals, 21 reptiles and amphibians, 22 fish, 29 macroinvertebrates, and 15 butterflies, many rare and endangered, have been recorded in the Greater Calumet Wetlands recently. Notable species are the Black-Crowned Night Heron *(Nycticorax nycticorax)*, the Least Bittern *(Ixobrychus exilis)*, and the Blandings Turtle *(Emydoidea blandingii)*. This area is a major stopover point for migratory birds (The Nature Conservancy 1995).

G.3.2 Inland Wetlands System

Seney Wildlife Refuge, Michigan

Seney Wildlife Refuge was part of the Great Manistique Swamp. This wilderness area contains many bogs interspersed among hardwood, spruce, fir, and tamarack forests. Over 25,000 acres, this refuge is home to many species of ducks, bald eagles, osprey, loons, trumpeter swans, otter, beaver, black bear, moose, and wolves. It is an important breeding and resting place for migratory birds (U.S. Fish and Wildlife Service 2000).

Turner Creek Wetlands, Michigan

At the headwaters of Turner Creek is a complex of Wet Prairie, Prairie Fen, Southern Wet Prairie, and Conifer Swamps. The area lies within the Barry State Game Area and may be a source site for rare fen plant species in the area. The globally imperiled Mitchell's Satyr butterfly *(Neonympha mitchellii)* is found here (The Nature Conservancy 1995).

Allegan State Game Area Marshes, Michigan

The Allegan Marshes are recognized as the least disturbed remaining complex of globally imperiled Inland Coastal Plain Marsh community in North America. The marshes were shaped by glacial runoff and differ in size, water depth, and amount of peat accumulation; therefore, plant species vary. Many of the plants are globally imperiled, including Hall's Bullrush *(Scirpus hallii)* (The Nature Conservancy 1995).

Mill Creek Wetlands, Michigan

The headwaters of Mill Creek in Cass and St. Joseph Counties is a complex of southern wet meadow, shrub swamp, and conifer swamp. Springs along the creek create fen habitat. The area is within the Three Rivers State Game Area and is home to rare and threatened species, including the globally imperiled Michell's satyr butterfly *(Neonympha mitchellii)*, Copperbelly water snake *(Nerodia erythrogaster neglecta),* and Eastern Massasauga snake *(Sistrurus catenatus catenatus)* (The Nature Conservancy 1995).

Pinhook Bog, Indiana

Pinhook Bog, part of the Indiana Dunes National Lakeshore, was formed when a large chunk of glacial ice melted, leaving a kettle hole lake. This bog is an example of a quaking kettle-hole bog and one of the few remaining in Indiana. The northern carniverous pitcher plant and the sphagnum moss are common plants that live on the thick peat mat. The deciduous tamarack tree, pink lady's slipper orchids, and yellow fringed orchids are found in the preserve (Indiana Dunes National Lakeshore 1992).

Cherry Lake Sedge Meadow, Wisconsin

Cherry Lake Sedge Meadow is located in a serpentine basin in glacial till. With only a few openings in the deep sedge mat, Cherry Lake is a misnomer. The sedge meadow contains both alkaline- and acid-loving plants. Of special interest are round-leaved sundew, shrubby cinquefoil, yellow twayblade, marsh St. Johns wort, marsh fern, and sphagnum. To the north of the sedge meadow is a small fen. Shrub-carr is scattered throughout the area, and a tamarack-poison sumac bog lies to the northeast. There has been some tamarack die-off, which promotes even more bushy growth. A portion of an esker runs along the west boundary. This upland area has been grazed in the past and is now brushy oldfield.

G.3.3 Tributary Systems

Manistique River, Michigan

The Manistique River flows southwest through Michigan's central Upper Peninsula. It has been identified as an AOC because the last 1.7 miles of the river, from the dam to the mouth of the harbor at Lake Michigan, have been significantly altered. Historical uses of Manistique River waters in the AOC include receiving wastes from sawmills, a paper mill, small industries, the municipal wastewater treatment plant, plus navigation for shipping, ferrying, recreational boating, and commercial fishing.

Current uses include receiving the wastewater discharges from municipal and industrial dischargers (Lake Michigan Forum 2000).

Grand Traverse Bay, Michigan

The Grand Traverse Bay watershed in Michigan is huge, consisting of more than 20 tributaries and 100 inland lakes in a 1,000-square mile area.

Manistee River, Michigan

The Lower Manistee River is a slow and wide river that meanders through rolling hills and rich marsh land. It is a good salmon fishing river.

Pere Marquette River, Michigan

The Pere Marquette, designated a Wild and Scenic River, is characterized by overhanging bluffs and grassy floodplains. It supports fine trout habitat.

Grand River, Michigan

The Grand River is the longest river in the Lake Michigan basin at 262 miles. It flows through Michigan's agricultural and orchard region. It is now becoming an area of development all the way to the lake. A new watershed group has been formed to deal with issues and problems of water quality.

Kalamazoo River, Michigan

The Kalamazoo River has been identified as a Great Lakes AOC due to historic releases of PCBs from de-inking operations at local paper mills (Lake Michigan Forum 2000).

Grand Calumet River, Indiana

The Grand Calumet River is approximately 16 miles long and has a basin area of about 62 square miles. Extending across the Indiana-Illinois border, it lies to the south of Lake Michigan in Northwest Indiana. Originally the river drained into Lake Michigan at mouths on both its western and eastern ends. A harbor built in the 1870s permitted water to flow westward more easily. The eastern mouth of the river receded into a lagoon at what is now Marquette Park in Gary. Inland Steel Company financed the construction of the Indiana Harbor Ship Canal in the early part of the twentieth century. Today, the river is considered one of the most polluted in the country, much of the original vegetation has been replaced by nonindigenous species, and sediments are contaminated. Remediation efforts are underway (Grand Calumet Task Force 2000).

Chicago River, Illinois

The Chicago River is an urban waterway much altered from its original state. Heavy industry and urban buildup forced the reversal of the river flow towards the Mississippi River and away from Lake Michigan early in the 20th century. Today, although still tremendously affected by urbanization, movement to restore the river and improve water quality are underway (Wallin 1995).

Milwaukee River and Swamp State Natural Area, Wisconsin

The east branch of the Milwaukee River is a slow, meandering warm water stream with a population of northern pike, black crappie, walleye, and other species. A spring feeds the river in the north. Adjacent to the river is a shrub zone, a lowland hardwood forest, a conifer swamp, and a small bog lake. This portion of the river is a natural area of some importance (Wisconsin Department of Natural Resources 2000). The lower part of the Milwaukee River, however, is an AOC with 11 of 14 beneficial uses impaired. Fish and waterfowl are contaminated and unfit for consumption. Species diversity is low, and habitats are impaired due to contamination and hardened shores (Lake Michigan Forum 2000).

Sheboygan River, Wisconsin

The lower Sheboygan River is an AOC. It is a sink for pollutants from three watersheds: the Sheboygan River, Mullet River, and Onion River watersheds. The area is lined with residential, industrial, and municipal development, with agriculture being the predominant land use at 67 percent (Lake Michigan Forum 2000).

Fox-Wolf Rivers, Wisconsin

The Fox-Wolf Basin in northeast Wisconsin drains 6,400 square miles before flowing into Lake Michigan at Green Bay. The fish, wildlife, benthic populations, and habitat of this watershed are degraded, primarily as a result of a variety of industries. Over the last three decades, while the health of the river has improved significantly, many important water resource issues remain. Walleye from the river, for example, is not safe to eat because of persistent toxic chemicals such as PCBs, mercury, and more than 100 other substances. The waters receive loads of soils and nutrients washed into hundreds of miles of streams and tributaries from lawns, streets, parking lots and agricultural fields. Exotic species are present. The Lake Winnebago pool lakes and the lower bay of Green Bay continue to experience algae blooms, inhibiting recreational use. This area was listed as a Great Lakes AOC by the International Joint Commission (Lake Michigan Forum 2000).

Wolf River, Wisconsin

The Wolf River originates north of Mole Lake Reservation in northeastern Wisconsin. In the upper part of the river, it is characterized by high granite walls, cascades, rapids, and waterfalls. It is considered a world-class whitewater rafting destination. In 1968, part of the river was designated as a National Wild and Scenic River. The river's water quality and fishery is the best in the Lake Michigan basin. Wisconsin has designated the river an Outstanding Resource Water. The Wolf is one of the premier brown, brook, and rainbow trout fishing rivers in the region. The Bald Eagle, Osprey, and other bird species nest and feed along the river. The Menominee and Chippewa Tribes have deep spiritual and culture connections to the river, which supports abundant wild rice beds and habitat for lake sturgeon (Menominee Tribe 2000).

G.3.4 Coastal Shore System Dunes

Wilderness Point State Park, Michigan

Wilderness Point State Park lies in the northernmost part of Michigan's lower peninsula. Low dunes and interdunal wetland communities are nesting habitat for the federal and state-endangered piping plover and other shorebirds. Several Great Lakes endemic dune species, including the Pitcher's thistle, Houghton's goldenrod, and the Lake Huron tansey are found here, along with a diversity of other hardy plants. This is a remote and wild park that offers passive recreational opportunities (Michigan Department of Natural Resources 2000).

Sleeping Bear Dunes National Lakeshore, Michigan

The highest dunes on the Lake Michigan shoreline are found at Sleeping Bear Dunes National Lakeshore. The dunes rise as high as 460 feet above the lake. Along the shore are beach dunes, and on plateaus above the shore are perched dunes. Constant exposure to wind, ice, and water keeps the dunes moving. Beachgrass and sand cherry are among the first dune colonizers. Inland are lakes and streams as well as beech-maple forests (National Park Service 2000).

Ludington Dunes, Nordhouse Dunes, Michigan

Combined, Ludington and Nordhouse Dunes are called Big Sable Dunes and are the largest freshwater expanse of dunes in North America. In addition to a healthy population of the Great Lake’s endemic pitcher’s thistle, the dunes have a rich variety of species in interdunal wetland habitats. Inland from the foredunes are older dune ridges with mature second-growth beech, maple, and oak forests (Michigan Department of Natural Resources 2000).

J.P. Hoffmaster State Park Wild Area, Michigan

The dunes at J.P. Hoffmaster State Park Wild Area cover more than 1 mile of the Lake Michigan shoreline. The high dunes contain large blowouts. Inland, the dune ridges are comprised of mature beech, maple, hemlock, oak, and black cherry trees (Michigan Department of Natural Resources 2000).

Saugatuck Dunes Natural Area, Michigan

Diverse dune and interdunal wetland communities are found at Saugatuck Dunes Natural Area. This relatively undisturbed site has nesting habitat for the federal and state endangered piping plover. Healthy populations of Great Lakes endemics Pitcher’s thistle, Lake Huron tansy, and Houghton’s goldenrod are found here (Michigan Department of Natural Resources 2000).

Grand Mere Natural National Landmark, Michigan

Grand Mere Natural National Landmark contains high-relief dunes formed more than 10,000 years ago. The inland lakes and interdunal wetlands at this site are unique in the region. Ecological community types range from aquatic to forest. This is a significant songbird and waterfowl migration area (Michigan Department of Natural Resources 2000)

Warren Dunes State Park, Michigan

Warren Dunes State Park includes stabilized dune ridges inland and active dunes close to Lake Michigan. Geologically, this is an unusual site because the dune ridges enclose smaller and interlocking dune ridges that are different ages. The site has large blowouts and habitat for a diversity of plants and animals. In the spring, the wooded, inland dunes are rich with woodland wildflowers (Michigan Department of Natural Resources 2000).

Indiana Dunes National Lakeshore and State Parks

The dunes along the 40-mile stretch of Lake Michigan shoreline from Michigan City to Gary, Indiana, are protected in the Indiana Dunes National Lakeshore and State Parks. Several live or moving dunes, including tall Mt. Baldy, constantly shift with the wind. Marram grass and cottonwood trees are the first dune colonizers along with populations of the rare Pitcher's thistle. The dune ridges are a unique blend of boreal plants such as arctic bearberry, southern dogwoods, northern jack pines, and prickly pear cactus. The beaches are wide in low lake-level years, and the sand is often called "singing sands" due to the sound made when it is walked on. Professor Henry Chandler Cowles studied the dunes here in the late 1800s and developed the principles of plant succession that are basic to the evolving history of ecology today (National Park Service 2000).

Kohler Park Dunes, Wisconsin

Kohler Park Dunes has 1 mile of sand beach and small, active, and stabilized sand dunes. Inland, from the dunes lies a dry, white pine forest. Interdunal pannes or wetlands contain rushes and sedges. Dune plants found here include sand reed, Canada wild rye, marram grass, northern wheat grass, junipers, sand cherry, and willows. This is a fall migration route for raptors (Wisconsin Department of Natural Resources 2000).

Wilderness Ridge, Wisconsin

Wilderness Ridge was formed when a rapid lake level fall exposed the sand ridges. Today these dune ridges are mature and vegetated with red and white pines, hemlock, sugar maple, red maple, and yellow birch, and a groundlayer of bluebead lily, wintergreen, starflower, Canada mayflower, goldthread, and trailing arbutus. Another part of the ridge contains several sedge meadows with 28 species of sedges and a variety of grasses (Wisconsin Department of Natural Resources 2000).

Whitefish Dunes State Natural Area, Wisconsin

Whitefish Dunes State Natural Area contains both sand beaches and active and stabilized sand dunes. The inland dunes are forests of sugar maple, American beech, white cedar, balsam fir, and hemlock. A small lake with a sedge meadow and a baymouth bar lake are on site as well. The site is rich in plant species including Canada yew. Red-eyed vireo, veery, black-throated green and Canada warblers, American redstart, and eastern wood pewee nest here (Wisconsin Department of Natural Resources 2000).

Jackson Harbor Ridges State Natural Area, Wisconsin

Behind the beach and low sand ridges at Jackson Harbor Ridges State Natural Area are interdunal calcareous wetlands. These wetlands contain many rare plants, including Kalm's lobelia, shrubby cinquefoil, arctic primrose, low calamint, slender bog arrow-grass, and bladderworts. Secondary dunes are vegetated with the boreal bearberry, horizontal juniper, and sand coreopsis. Inland dunes are a mix of conifer-hardwood forest of red and white pines, white cedar, balsam fir, and American beech. At the entrance to Jackson Harbor is a sand spit that attracts gulls, terns, shorebirds, and other waterfowl (Wisconsin Department of Natural Resources 2000).

Ridges Sanctuary, Wisconsin

The Ridges Sanctuary is a series of Lake Michigan sand dunes or ridges forested with black spruce, white spruce, balsam fir, and white pine. Wet swales lie between the ridges. Swamp conifers and marsh and bog plants are in the swales. Some of the ridges are wet and calcareous. The forest has boreal components, a disjunct from the boreal forest found on Lake Superior (Wisconsin Department of Natural Resources 2000).

G.3.5 Coastal Shore System Beaches

Illinois Beach State Park, Illinois

Just north of Chicago and the northern suburbs, Illinois Beach State Park's 6.5 miles of shoreline is the only beach ridge shoreline left in the state. The park has more than 650 species of plants, including prickly pear cactus, grasses, sedges, and wildflowers. Away from the wide beaches are low dunes followed by sandy ridges with black oak woodlands. The Dead River opens into the lake and is surrounded by interdunal ponds rich in aquatic life (Illinois Department of Natural Resources no date).

Bedrock Shore

The northern shoreline of Lake Michigan is characterized by rugged limestone and dolomite bedrock concentrated in the Garden Peninsula. Part of the Niagara Cuesta, the deposits are more than 400 million years old, deposited as reefs constructed of marine organisms (Albert 1997). Bedrock shores are shaped by wave and ice erosion. Cracks in the rocks contain plant life, and seasonal pools form in low areas carved into the rock.

Cobble beaches are common along rocky shorelines. Cobbles are rock chunks made up of limestone. Little vegetation is present due to exposure to severe wave and ice action. Lichens and mosses are most common because they grow even under harsh weather conditions. Although there is a possibility unique animals may inhabit bedrock shores, little is known about the fauna of this community. Additional research is needed to inventory animals.

In addition, an increase in second home development along the northern shore may soon impact bedrock shore areas.

G.3.6 Lakeplain System Prairies

Hoosier Prairie, Indiana

Hoosier Prairie is a tallgrass prairie remnant, one of few remaining black soil prairies in Indiana. Hundreds of plant species, such as big bluestem grass, bush clover, and rough blazing star, are found in a diversity of habitats ranging from mesic prairie to oak savanna to prairie marsh. The prairie is a registered National Natural Landmark (Indiana Department of Natural Resources No Date)

Somme Prairie Nature Preserve, Illinois

Hundreds of flowers bloom throughout spring, summer, and fall in Somme Prairie Nature Preserve, a small tallgrass prairie remnant. Flowers include hoary puccoon *(Lithospermum canescens)*, rattlesnake master *(Eryngium yuccifolium)*, wild quinine *(Parthenium integrifolium)*, and prairie dock *(Silphium terebinthinaceum)*. Skipper butterfly caterpillars feed on the grasses and sedges, and orange and black fritillaries feed on the violets. The preserve has an abundance of snakes, salamanders, and birds such as meadowlarks (Chicago Wilderness No Date).

Chiwaukee Prairie, Wisconsin

Once connected to no longer present coastal marshes and the lake itself, this preserve still maintains a diverse population of plants and butterflies. In the spring it is not unusual to see thousands of pink shooting stars blooming. Management is focused on eradicating exotic invasive species and using prescribed burns to control brush.

G.3.7 Lakeplain System Oak Savannas

Allegan Pine Plains, Michigan

The Allegan Pine Plains is a black oak savanna and prairie with vegetation that includes little blue-stem grass, Pennsylvania sedge, bird's-foot violet, ragwort, wild lupine, hairy puccoon, and dwarf blazing star. The landscape is adapted to fire, and prescribed burning is used to manage this natural community (Michigan Department of Natural Resources 2000).

Miller Woods, Indiana

Miller Woods is a black oak savanna in the westernmost part of the Indiana Dunes National Lakeshore. It is set in the middle of U.S. Steel, the City of Gary, and Lake Michigan. It is dune and swale topography shaped about 3,000 years ago. Between ridges lie richly vegetated interdunal ponds. The flora of Miller Woods is significant because its pre-European settlement integrity has been maintained. Miller Woods also has numerous bird residents such as the Red-Headed Woodpecker, as well as a population of the federally endangered Karner blue butterfly (Peloquin No Date).

Middle Fork Savanna, Illinois

Middle Fork Savanna in Lake County, Illinois, is an outstanding example of an oak savanna community. It has much of the understory diversity original to the area. It is now under management by the Lake County Forest Preserve District. Controlled burns have been reintroduced, and invasive species such as garlic mustard, honeysuckle, and European buckthorn are being eliminated (De Vore 1997).

G.3.8 Lakeplain System Sand Barrens

Shakey Lakes, Michigan

Shakey Lakes is the largest area of pine and oak barrens in northern Michigan. Five savanna ecosystems are found at the site. Before European settlement, the savanna was maintained by native peoples who set fires on a regular basis to improve habitat for game and shrubs such as blueberries (Michigan Department of Natural Resources 2000).

Dunbar Barrens State Natural Area, Wisconsin

Dunbar Barrens State Natural Area is a pine barrens located on an outwash plain. This gentle topography is forested with jack pine, aspen, and oak. Grasses, sedges, and shrubs dominate the groundlayer. Other plants include rice grass, poverty oat grass, bearberry, blueberries, sweet fern, barrens strawberry, and hawkweeds. Lichen is also present and diverse. Common barrens birds found here include Upland Sandpiper, Eastern Bluebird, Rufous-sided Towhee, Vesper Sparrow, Field Sparrow, and Clay-colored Sparrow (Wisconsin Department of Natural Resources 2000).

G.3.9 Inland Terrestrial Systems

Warren Woods, Michigan

Warren Woods is a 179-acre virgin beech-maple forest, the last of its type known in Michigan. Tree species are diverse and large, with some more than 5 feet in diameter and 125 feet in height. The understory has a profusion of spring wildflowers (Michigan Department of Natural Resources 2000).

Lulu Lake, Wisconsin

Lulu Lake is a 95-acre, 40-foot deep, hardwater drainage lake in southeastern Wisconsin. A small bog is surrounded by tamarack forest and northern bog species. An inlet stream is banked by a richly vegetated sedge meadow and a fen. The uplands are glacial moraine covered with oak forest and oak openings dominated by bur, white, and red oaks (Wisconsin Department of Natural Resources 2000).

Kewaskum Maple-Oak Woods State Natural Area, Wisconsin

Located east of the Milwaukee River, Kewaskum Woods is a sugar maple, red oak, white ash, and basswood forest. The rich groundlayer contains uncommon woodland species, including orchids, golden seal, large-fruited snakeroot, broad-leaved puccoon, dog violet, and smooth bank cress. Common nesting birds include Black-billed and Yellow-billed Cuckoos, Great-crested Flycatcher, Eastern Wood Pewee, Wood Thrush, Blue-gray Gnatcatcher, Red-eyed Vireo, and Scarlet Tanager (Wisconsin Department of Natural Resources 2000).

Toft Point State Natural Area, Wisconsin

Toft Point State Natural Area contains a narrow strip of relict boreal forest dominated by balsam fir and white spruce. The peninsula also includes a forest of sugar maple, yellow birch, hemlock, and scattered white pine. Along Moonlight Bay lies an extensive sedge meadow. A wet-mesic forest is dominated by white cedar with occasional paper birch and black ash. Seventeen species of nesting warblers are found at the site (Wisconsin Department of Natural Resources 2000).

Miscauno Cedar Swamp State Natural Area, Wisconsin

Miscauno Cedar Swamp is a conifer forest of white cedar, balsam fir, and black spruce. Black ash and elm are found along Cedar Creek. Tamarack snags indicate this tree was historically present. Orchids, bunchberry, starflower, bluebead lily, gaywings, Canada mayflower, and several fern species are found in the ground layer. Mosses and lichens are found in headwater springs. Breeding birds include the Raven, Hermit Thrush, Black and White Warbler, Pine Warbler, Scarlet Tanager, and Black-billed Cuckoo (Wisconsin Department of Natural Resources 2000).

Menominee Reservation

The Menominee Reservation is located at the tension zone that divides the northern and southern forests. Therefore, it contains a diversity of tree species not found elsewhere. The dominant forest types are northern hardwoods; hemlock hardwoods; jack, red, and white pines; aspen; scrub oak; and swamp forest. More than 2.5 billion board feet of lumber have been harvested here in the past 150 years. The volume of standing timber today, however, is greater than when the Wolf River Treaty defined the reservation in 1854. Sustained yield forestry is the management used. The Menominee Tribal

Enterprises is a company with a Menominee forest-based sustainable development tradition that is widely recognized as a leader in sustainable forest management (Menominee Indian Tribe of Wisconsin 1997).

APPENDIX H

REGION 5 GUIDE FOR DEVELOPING ENVIRONMENTAL GOALS, MILESTONES, AND INDICATORS

CONTENTS

REGION 5 GUIDE FOR DEVELOPING ENVIRONMENTAL GOALS, MILESTONES, AND INDICATORS

H.1 OVERVIEW

In the era of increased public and political scrutiny on government agencies, it is imperative for EPA Region 5 to focus its limited resources on achieving environmental results for the most important environmental problems facing public health and the environment. By developing an appropriate mix of environmental indicators and performance measures, the Region will be better positioned to evaluate environmental conditions, identify existing and emerging environmental problems, set environmental priorities, and make program-specific decisions to address the highest priorities. Environmental indicators will also allow for more effective means of communicating environmental successes and remaining challenges to the public and other stakeholders.

The purpose of this document is to provide the Region 5 Teams and Program Managers with some guidance for developing Regional environmental goals, milestones, and indicators. This document was developed by the Region 5 Environmental Indicators Workgroup and is based on the "Pressure-State-Response" approach being taken by EPA's National Goals Project, the Interagency Sustainable Development Indicators Workgroup, and the Region 5/State Watershed Indicators Development Workgroup. The Pressure-State-Response approach involves linking environmental indicators to stressors that affect the environment and to program activities. Use of this approach should promote consistency in the development and application of environmental indicators within Region 5 and will result in Regional goals that are consistent with EPA's 12 national goals.

H.2 DEFINITIONS

In order to implement the Pressure-State-Response approach that is recommended in this guidance, it is critical to understand the following terms:

Pressure or stressor: A factor that can adversely affect environmental conditions. Pressures and stressors can be human-induced or nature-induced. Examples of human-induced pressures include toxic pollutants, nutrients, habitat loss, sedimentation, hydrological changes (flow), and exotic species introduction. Examples of some natural pressures include predation, volcanic eruptions, and floods.

State or condition: The actual biological, chemical, or physical quality of the environment, including ecosystem and human health. Some examples of environmental conditions include toxic chemical concentrations in air, water, soil, or blood; species diversity; and number of respiratory illnesses.

Response or program activity: For the purposes of the Pressure-State-Response approach, "response" is not a biological, ecological, or ecosystem response. Rather, "response" refers to the regulatory or voluntary actions taken by government agencies or other parties (for example, industries) to address or remedy an identified stressor/pressure on the environment. The ultimate goal of the response or program activity is to improve the quality of the environment. Some examples of responses include passing legislation, promulgating regulations, installing new treatment technologies, issuing permits, taking enforcement actions, implementing best management practices, and remediating a "hotspot." The administrative response actions taken by environmental agencies are often tracked by performance measures, program measures, or program indicators.

Goal: A broad statement that identifies the overall desired, future environmental condition. Goals are generally long-range targets. If very broad goals are used, they are often broken down into subgoals or objectives that have specific desired end points. EPA has developed 12 national goals that will provide a very useful framework for developing Regional goals. An example national goal is as follows: "America's rivers, lakes, and coastal waters will support healthy communities of fish, plants, and other aquatic life and will support uses such as fishing, swimming, and drinking water supply for people."

Milestone: A specific interim step that is necessary to meet a stated goal. Milestones are check points that are established to identify "shorter-term" responses in environmental stressors or conditions that will lead toward the overall goal. Usually, a goal will have several milestones that will have to be met to achieve the goal. An example milestone is as follows: by 2005, the average mercury concentrations in fish tissue from lakes with mercury fish consumption advisories will be reduced by 50 percent. In terms of timeframe for milestones, the National Goals Project uses a 10-year duration.

Environmental indicator: A measure of environmental conditions (for example, human health, quality of life, and ecological integrity) or stressors that provides useful information on patterns and trends. Indicators are invaluable for measuring achievement of the milestones and progress towards the environmental goal. Indicators can also function as early warning signals for detecting relatively small adverse changes in environmental quality. Three examples of environmental indicators are as follows: concentration of total and methyl mercury in walleye fillets; concentration of total mercury in ambient waters; and total pounds per year of mercury released to waterways by NPDES facilities. The timeframe for monitoring, assessing, and reporting on an environmental indicator may range from as little as several times per year to once every year or longer. Also, a change in ecological or human health conditions may not be manifested or discernable for several or perhaps many years.

Performance measure or program indicator: A program, policy, or administrative response to an environmental problem. These measures are commonly referred to as "beans" when tracked routinely and represent a large portion of what environmental agencies have tracked and reported in the past. Performance measures may or may not lead to detectable improvements in environmental conditions. Two examples of performance measures are as follows: number of NPDES permits issued with water quality-based permit limits for mercury, and number of enforcement actions taken that involve mercury. In terms of timeframes, performance measures are usually tracked on an annual or more frequent basis.

H.3 PRESSURE-STATE-RESPONSE APPROACH

The "Pressure-State-Response" approach is a way of conveniently classifying and understanding the interaction between the pressures on the environment, the state of the environment due to these pressures, and the response or action taken by environmental agencies or other parties to address the environmental conditions and pressures. The Pressure-State-Response is the organizing framework used in or by the National Goals Project, the State Environmental Goals and Indicators Project, the Interagency Sustainable Development Indicators Workgroup, and the Region 5/State Watershed Indicators Development Workgroup.

One way to display the Pressure-State-Response approach is in a straight continuum that shows the movement from a program activity, to a stressor control, and to the desired outcome or environmental condition (see Figure 1). Regardless of how the Pressure-State-Response approach is displayed, in order to be successful, it is absolutely necessary to select indicators that are measurable and can be monitored and to link the pressures with the environmental conditions.

Otherwise, it will be difficult or impossible to tell whether the changes in environmental trends are due to program activities and agency actions or something else.

H.4 STEPS FOR DEVELOPING ENVIRONMENTAL GOALS, MILESTONES, AND INDICATORS

Listed below are some steps designed to assist in developing environmental goals, milestones and indicators under the Pressure-State-Response approach. The first set of steps involves setting environmental goals and identifying environmental priorities. Nationally, EPA has developed a set of national goals and milestones that provide a very useful framework for the Region. The second set of steps involves identifying the stressors and pressures on the environment that have caused or contributed to the environmental problems. Finally, the third set of steps involves identifying what actions and responses are necessary to address the stressors and pressures and ultimately address the environmental problem and achieve the environmental goals.

The steps listed below are provided as guidance. Each situation will be different when developing goals, milestones, and indicators. Some of these steps may be unnecessary or may be more useful when taken in a different order. The order of the steps is not as important as the content and focusing on the following key concepts: (1) develop a good set of overarching environmental goals that represent the suite of desired future conditions; (2) develop milestones for the goals that are reasonable and that track interim progress towards the desired changes in environmental conditions and pressures; (3) select a mixture of indicators that measure environmental conditions and pressures; and (4) select key program activities and performance measures that are linked to the milestones and indicators.

If assistance is needed in developing goals, milestones, or indicators, the Regional Environmental Indicators Workgroup is available and can be consulted by contacting Linda Holst at (312)886-6758.

H.4.1 DEVELOP ENVIRONMENTAL GOALS, ANALYZE ENVIRONMENTAL CONDITIONS, AND IDENTIFY ENVIRONMENTAL PROBLEMS

Step 1. Form a stakeholders group to assist in developing goals, milestones, and indicators. Appropriate stakeholders may include other federal agencies (for example, U.S. Fish and Wildlife Service and Natural Resources Conservation Service), state environmental and natural resource agencies, environmental groups, the regulated community, public interest groups, and local church or civic groups. Implement the remaining steps with this stakeholder group, as deemed appropriate. In some situations, it may be feasible and effective to have all stakeholders involved throughout the process. In other cases, it may be more appropriate to have stakeholders brought in under a phased approach, where a smaller group of stakeholders develops some initial goals, milestones, and indicators and presents it to a larger group of stakeholders for their reaction and modification. Whatever approach is used, it is critical to have stakeholders involved and to get broad representation and buy-in to the goals, milestones, and indicators that are ultimately developed.

Step 2. Identify the desired future environmental conditions (that is, environmental goals). These goals may take decades or longer to achieve. It is desirable for the goal to be consistent with the national goals. If the goal selected is very broad, it can be divided further into subgoals or objectives, if desired, in order to make it easier to develop milestones and indicators.

Step 3. Examine existing reports, survey information, and data on environmental conditions to determine the state of the environment. Existing information could include comparative risk studies, public opinion surveys, monitoring reports, and other studies. For each environmental goal, identify environmental problems that need to be addressed and environmental conditions that need to be maintained or protected in order to meet the environmental goal.

Step 4. If necessary, prioritize the environmental problems or conditions in order of importance (for example, risk) and ability to be addressed. In some cases, the prioritization may have already been done. In other cases, the number of environmental problems may be sufficiently few that prioritization is not warranted. If prioritization is necessary, comparative risk techniques are very useful tools for ranking issues. If assistance or information on comparative risk is needed, please contact Carole Braverman in the Office of Strategic Environmental Analysis at (312) 886-2910.

Step 5. For each environmental goal (or subgoal), identify interim targets (such as state milestones) to achieving the desired environmental condition. These milestones should focus on environmental conditions and should have quantifiable targets (for example, 50 percent reduction in a contaminant in surface water) and a specific target date (for example, by the year 2005). The National Goals Project contains more than 60 milestones that may provide a useful starting point.

There is some imprecision in developing milestones because of the difficulty in being able to predict changes in environmental conditions based on future actions. Care should be taken to select milestones that will be challenging to attain but not totally unachievable.

Step 6. For each state milestone, select environmental measures (such as state indicators) that will track progress towards the milestone and goal. The state indicators would correspond to level 4-6 indicators on the continuum. In order to ensure maintenance of a healthy environmental condition, it is critical to have some indicators that will act as an early warning for pending or potential problems before they are actual environmental problems. Selection of indicators should not be solely reactive to existing environmental problems but should also be proactive and preventative, when possible.

For each indicator, identify possible data sources that will provide a sufficient amount of information with sufficient quality to track the indicator. Information may be housed in national, regional, state, or local data systems.

When finalizing the list of indicators, consideration should be given to whether data of sufficient quantity and quality will be available in the future to be able to monitor trends. If it is determined that the indicator is valuable but sufficient information is not available, this indicator should be "flagged" for further discussion by the stakeholder group to determine if appropriate data can or should be collected in the future.

H.4.2 IDENTIFY CAUSES OF ENVIRONMENTAL PROBLEMS OR ISSUES

Step 1. For each environmental problem or issue, identify the stressors or pressures that cause or contribute to it. Classify the stressors or pressures as "known or strongly suspected" or "possible."

Step 2. For the stressors or pressures classified as "possible," identify what additional data or information are necessary to link the cause to the environmental problem or issue. Flag these as items that need to be investigated further.

Step 3. For each "known or strongly suspected" stressor and pressure, identify interim targets (such as pressure milestones) that will achieve the environmental goal by addressing the pressure or stressor. Again, the milestones should have quantifiable targets (for example, 20 percent reduction in discharges of mercury) and a specific target date (for example, by the year 2005).

Step 4. For each pressure milestone, select environmental measures (such as pressure indicators) that will track progress towards the milestone and goal. Pressure indicators would correspond to level 3 indicators on the continuum.

H.4.3 ACTIONS TO ADDRESS ENVIRONMENTAL PROBLEMS OR ISSUES

Step 1. For each state and pressure milestone, identify possible programs that can affect the environmental conditions or address some of the environmental pressures.

Step 2. For each program, develop a list of activities or actions that the program conducts or could conduct to affect the environmental condition, or address the state and pressure milestones.

Step 3. For each activity, identify performance measures that will track progress of the activity. It is critical for the state and pressure indicators and performance measures to be linked to each other and to the milestone. The objective is to select performance measures and indicators that are meaningful and not duplicative. In addition, where performance measures or program activities have been shown to be correlated with an environmental indicator, it may be appropriate to track only one of them.

For each performance measure, identify possible data sources that will provide a sufficient amount of information with sufficient quality to track the measure. Again, information may be housed in national, regional, state or local data systems.

Step 4. Monitor the indicators and performance measures and determine their utility in measuring progress towards the goal and milestones. Report results back to the public and solicit feedback.

Step 5. Make necessary adjustments to the environmental goals, milestones, indicators, and performance measures, based on their usefulness, data availability, and public input.

H.5 EXAMPLES OF GOALS, MILESTONES, AND INDICATORS FOR THE GREAT LAKES

Listed below are some draft goals, milestones, and indicators for the Great Lakes that are being developed by the Region 5 Great Lakes Teams. These will likely be revised but are provided here for illustrative purposes.

Goal: Human Health in the Great Lakes Ecosystem is not at risk from contaminants of human origin.

Objective 1: Concentration of toxic chemicals in fish and wildlife are below levels that limit consumption by humans.

Milestones:

1. By 2015, concentration of contaminants in fish fillets have decreased by X percent (per contaminant).

2. By 2005, concentration of contaminants in water has decreased by X percent.

3. By 2005, loadings of key parameters have decreased by X percent.

4. By 2005, effluent emissions of key parameters (such as mercury, PCBs, dioxin, aldrin, and toxaphene) have decreased by X percent.

5. By 2002, reduce chlorine use in pulp/paper process by X percent or annually chlorine use is reduced by X percent.

6. By 2002, 80% of Great Lakes Basin counties have participated in clean sweeps activities.

7. By 2005, remedial activities have been completed at X percent of contaminated sediment sites. Remediation activity completed means sediments are removed or managed in place.

8. Annually X percent of PCBs are removed from use in the Great Lakes Basin.

9. By 200X, pollution prevention and other emission controls result in decreases of X percent of PCB, dioxin, and mercury releases.

10. By 200X, emission controls and pollution prevention activities result in a decrease or, at a minimum, no increase, in pounds of mercury and dioxin released per user population.

<u>Indicators</u>:

1. Concentration of contaminants (such as PCBs, toxaphene, aldrin, and DDT) in fish fillet of coho and chinook salmon (for Lakes Superior and Michigan) and walleye (for Lake Erie).

2. Concentration of contaminants in water.

3. Contaminant loadings of key parameters. Although this is a good indicator, current available data may not be sufficient for total load estimates, except under Lake Michigan Mass Balance.

4. Effluent and emissions of key parameters. Sources of effluent and emissions data include Toxic Release Inventory (all media), Permit Compliance System (water), and Regional Air Pollutant Inventory Development System (air).

5. Chlorine use in pulp/paper industry (tons).

6a. Number of counties participating in Clean Sweeps.

6b. Volume of materials recovered.

7a. Volume of sediment removed or managed.

7b. Number of complete remedial activities.

8. Amount and percentage of PCBs removed from use. Indicators need to be refined through interaction with programs.

9. Emissions of PCBs, dioxins, and mercury (in pounds) released from hazardous waste incinerators, municipal incinerators, and medical waste incinerators.

10a. Emissions of mercury and dioxin from electric generating boilers (in pounds).

10b. Pounds of mercury and dioxin released per user population.