Measures of Success:
Addressing Environmental Impairments
in the
Saginaw River and Saginaw Bay

August 2000

Prepared by Public Sector Consultants, Inc.
Prepared for The Partnership for the Saginaw Bay Watershed

This project has been supported with funds from the Dow/PIRGIM Settlement through the Saginaw Bay Watershed Initiative Network (WIN) and the Great Lakes Environmental Collaborative through the Bay Area Community Foundation.

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PREFACE

It has been nearly 30 years since the Saginaw River and Saginaw Bay were first identified as one of the most significant water quality problem areas of the Great Lakes. After numerous studies and the expenditure of literally hundreds of millions of dollars to address problems, it is time for an accounting of the progress that has been made to restore the area's water resources. The purpose of this *Measures of Success* report is to encourage public comment that will result in a consensus for action among those who have a stake in the future of the river and bay.

The report makes the following recommendations:

- What the river/bay restoration targets should be to have the Saginaw River/Bay removed from the list of Great Lakes Areas of Concern
- How success should be measured
- What steps are required to address remaining pollution sources and/or document restoration

As this report is circulated among stakeholders in the area, the targets, measures, and action steps can be modified to reflect the comments received. This report represents the collective thoughts of technicians, public officials, stakeholders, and watershed citizens who participated in the Measures of Success process. It documents the nature and extent of problems, past and present. It also describes actions that have been taken to address those problems and the results of those actions. Finally, it sets targets for the restoration of Saginaw River/Bay and its watershed, describes how progress toward those targets will be measured, and recommends actions to attain them.

This *Measures of Success* report focuses on the concerns that originally led to the designation of the Saginaw River/Bay as an Area of Concern. The report is not meant to be a comprehensive analysis of all the problems impacting the river and bay, many of which have emerged over the last 30 years. Instead, it provides a foundation for redirecting and refocusing efforts required to achieve and sustain the full potential benefits of this valuable natural resource.

The report has been prepared and produced under the guidance of the Partnership for the Saginaw Bay Watershed, with the financial support coming from the Saginaw Bay Watershed Initiative Network (WIN) and the Bay Area Community Foundation. The results of the project will be used as a basis to initiate the process of removing impaired uses of the Saginaw River/Bay from the list of those previously identified by the Water Quality Board of the International Joint Commission. This project has been supported with funds from the Dow/PIRGIM settlement through the Saginaw Bay WIN and the Great Lakes Environmental Collaborative through the Bay Area Community Foundation.

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INTRODUCTION

The International Joint Commission (IJC) was established from the 1909 Boundary Waters Treaty between the United States and Canada. It was created in response to each country's recognition that actions by either government could affect the lakes and river systems they hold in common. The IJC's role is to prevent and resolve disputes over shared resources, and it may be asked by either or both governments to monitor situations and recommend actions. The Saginaw River/Bay area (see Exhibits 1a and 1b) was first cited by the IJC as one of the major pollution problem areas in the Great Lakes in 1973, a year after the first Great Lakes Water Quality Agreement between the United States and Canada was signed in 1972.

Under the 1978 amendments to the agreement, the Water Quality Board of the IJC designated areas that failed to meet the terms of the agreement. These Great Lakes Areas of Concern (AOCs) were targeted for remedial actions by the two nations and the cooperating state and provincial governments. The Saginaw River/Bay area was designated as one of the 43 AOCs based upon impairments caused by changes in the chemical, physical, and biological integrity of the bay watershed ecosystem.

In each of the AOCs listed by the IJC's Water Quality Board, specific impairments were identified by states and provinces. The following impairments were listed in the *Saginaw River/Bay Remedial Action Plan* in 1988:

- Restrictions on fish or wildlife consumption
- Tainting of fish or wildlife flavor (taste and odor concerns)
- Degradation of fish and wildlife populations
- Degradation of fish and wildlife habitat
- Bird or animal deformities or reproductive problems
- Degradation of *benthos* (bottom-dwelling organisms)
- Restrictions on dredging
- *Eutrophication* (nuisance algal blooms, oxygen depletion, and nutrient loadings)

EXHIBIT 1a
Location of the Saginaw River/Bay Watershed

SOURCE: Michigan Department of Environmental Quality, 2000.

EXHIBIT 1b
Features of the Saginaw River/Bay Watershed

SOURCE: Michigan Department of Environmental Quality, 2000.

- Restriction on drinking water (taste, odor, or other problems)
- Beach closings (exposure to waterborne human pathogens)
- Degradation to aesthetics
- Degradation of phtyoplankton and zooplankton

This report provides a brief account of the historical practices responsible for each impairment, celebrates progress to date in addressing problems, and proposes measurable goals for the future. The purpose of the report is to build a consensus among bay area stakeholders on (1) the restoration targets and (2) the actions needed to document when the targets have been achieved. Once the targeted restored conditions have been met, the intent is to petition the IJC's Water Quality Board to remove the Saginaw River/Bay from the list of Great Lakes Areas of Concern. The process for "delisting" an AOC is not well defined. While one individual AOC (Collingwood, Ontario, Canada) with limited, narrowly defined impairments is being considered for delisting, no large AOC with complex and numerous impairments such as those cited for the Saginaw River/Bay area has been removed from the list.

For the past 25 years, the focus of the IJC's Water Quality Board—and that of the cooperating federal, state, and provincial agencies—has been to develop and implement remedial action plans (RAPs) for the AOCs. The nearly 600-page *Saginaw River/Bay Remedial Action Plan*, submitted by the State of Michigan to the Water Quality Board in September of 1988, expands the scope of the concerns originally linked to the AOC designation. All of the issues discussed and actions proposed in the Saginaw River/Bay RAP are important to the water quality of the watershed and the bay. Certainly because an issue or action identified in the RAP is not included in this report does not diminish its importance to the future of the river or the bay, or its priority. This report is not intended to be comprehensive; rather it is a focused effort to enable those who have invested in restoration efforts to establish attainable targets. When the targeted restored conditions are achieved, the appropriate recognition that would accompany removal from the AOC list could encourage and empower local stakeholders to invest the additional resources needed to better protect and enhance the Saginaw River/Bay ecosystem.

This report groups the impairments to the Saginaw River/Bay into the following five sections:

- Bacteria (beach closings and other impacts on human health related to microorganisms)
- Contaminated Sediments (restrictions on dredging and related issues)
- Fisheries (restriction of consumption; tainting; and habitat degradation)
- Wildlife (deformities and reproductive problems and habitat degradation)
- Bay Ecosystem (restrictions on drinking water; aesthetics; eutrophication; and degradation of benthos, phytoplankton, and zooplankton)

Each section of the report is subdivided into subsections that (1) describe the nature of the impairment(s), (2) outline "Where We Have Been," (3) summarize "What We Have Accomplished," (4) propose a "Goal(s)," (5) suggest ways for "Measuring Success," including the identification of a "Targeted Restored Condition(s)," and (6) recommend "Next Steps." Finally, important "Emerging Issues" that potentially could affect the targeted restored condition or the speed at which the targeted condition can be actualized are summarized at the end of each section.

BACTERIA

(Contamination by Microorganisms)

Bacteria levels that exceed the state water quality standards for body contact recreation (partial or full) pose an unacceptable health risk to boaters, anglers, and anyone else who comes into contact with the water. Untreated human waste can transmit a variety of bacterial, viral, and parasitic diseases that threaten public health. In fact, the high bacteria level in the Saginaw River and near shore areas of Saginaw Bay was one of the primary impairments identified in the *Saginaw River/Bay Remedial Action Plan* in 1988. While bacteria levels downstream of major urbanized areas throughout Michigan remain a problem, the high use of the Saginaw River and Saginaw Bay for swimming, fishing, boating, and other water-related recreational activities makes this public health concern a priority.

WHERE WE HAVE BEEN

Bacteria contamination from untreated human waste entering the Saginaw River has been a problem since European settlement and development of the area began in the mid-1860s. While few enclosed sewers to transport human waste were constructed prior to the 1880s, sanitary waste (or sewage) in urban areas was dumped into gutters and open drains and eventually found its way to the river. Steady population increases and urbanization along the river and increasing concern over the health and aesthetics of exposed sewage led to the construction of enclosed collector sewers that dumped waste directly into the river. As early as 1887, there were 14 miles of main sewer lines and 10 miles of connecting lateral sewer lines in Bay City. Efforts to treat raw sewage being transported to the river from nearby urban areas were under way by the 1940s, though it was not until 1954 that the last large city on the river, Bay City, constructed a wastewater treatment plant. As late as 1965, several smaller communities were still dumping untreated human waste into the river.

Comprehensive monitoring in Saginaw Bay and the Saginaw River, initiated for the first time in the 1970s, indicated that the water quality of the bay and the river was below state water quality standards for a variety of parameters, including bacteria levels. On the Saginaw River in the mid-1980s,

measuring and monitoring of "indicator" bacteria (types of bacteria that reflect the presence of other microorganisms associated with human sanitary waste) disclosed problems: While the water quality standard for partial-body contact recreation was at times being met, the maximum annual bacteria levels recorded were nearly four times the standard for full-body contact recreation.

There are a number of potential sources of bacteria from human waste that could be polluting the Saginaw River. Combined sewers carry both storm water and sanitary waste. During heavy rainstorms or snowmelts, these sewers can overflow and discharge untreated human sewage into lakes and streams. These are called *combined sewer overflows*, or CSOs. Similar overflows occur even in separate sanitary sewer systems, which carry only sewage, when excessive storm water enters the sewers through (1) basement footing tiles, (2) downspouts which connect to sanitary sewers, or (3) improper cross connections with storm sewers. Groundwater may also infiltrate into separate sanitary sewers through poorly sealed pipe connections or structural failures. These untreated discharges from separate sanitary sewers are called *sanitary sewer overflows*, or SSOs.

In some cases, the sewers are large enough to transport the storm-related waste flows to the treatment site, but the facility cannot adequately treat the increased volumes. To avoid damage to the treatment facility during high-flow conditions, the facility is bypassed and the excess sewage is discharged, untreated, directly into the river. This type of discharge is called a *treatment plant bypass*. In addition, untreated human waste finds its way into water through the failure of *on-site treatment systems* (commonly a septic tank with a drain field) and illicit connections from sanitary sewers into separate storm drains. The primary cause, however, of human waste contamination in the Saginaw River and near shore areas of Saginaw Bay observed in the 1970s and 1980s were from three sources—wet-weather plant bypasses, CSOs, and SSOs.

In the late 1960s, the State of Michigan began issuing permits or orders under state law requiring corrective actions for all sources of untreated sewage in the Saginaw River. In the 1970s, it began enforcing new federal wastewater treatment requirements. By the 1980s, municipalities with CSO discharges were required to construct either separate sewers or storage facilities to assure adequate treatment of all wastewater up to design-standard wet-weather events. Municipalities experiencing frequent treatment plant bypasses were also required to expand their facilities under permits and orders reissued during the 1990s.

In 1978, wastewater treatment facilities serving Bay City, Buena Vista Township, Carrollton Township, Essexville, and the City of Saginaw all released untreated sewage discharges into the Saginaw River. In addition, Saginaw Township was responsible for a CSO discharge into the Tittabawassee River just upstream from its confluence with the Saginaw River. In the 1980s, the cities of Flint, Midland, and Frankenmuth also had CSOs, SSOs, and/or treatment plant bypasses on tributaries upstream of the Saginaw River that could have affected the bacteria levels observed in the river.

In 1982, the Bay County Department of Public Health began sampling for fecal coliform at three sites, one each on the Kawkawlin and Saginaw rivers and one on the Saginaw Bay. In 1996, the monitoring program changed from fecal coliform to *E. coli* bacteria sampling to conform with the new state water quality body contact recreation standard adopted in 1995. Six Bay County sites were sampled in 1996—two on the Saginaw River and four in Saginaw Bay. Since 1997, seven sites—selected on the basis of how frequently they are used for public bathing and whether they are key locations for evaluating water quality—have been periodically monitored for *E. coli* during the months of May, June, July, and August. The Bay County Health Department reports for 1996,

1997, 1998, and 1999 indicate that the *E. coli* bacteria levels did not exceed the state water quality standard for full-body contact recreation and no health advisories curtailing recreation use were issued. Only one of the seven sites sampled in Bay County during 2000, the Kawkawlin River in early June, showed *E. coli* levels slightly in excess of the state full-body contact recreation standard.

What We Have Accomplished

In the period from 1972 to 1988, 48 communities within the Saginaw River watershed spent more than one-half billion dollars in federal and state grants and local matching funds in the planning, design, and construction of new or upgraded wastewater transport and treatment facilities. In the last ten years (1989–1999), local public agencies within the watershed have obtained an additional 134 million dollars in low-interest loans from the State Revolving Fund to improve wastewater treatment facilities, eliminate SSOs, expand CSO capture and treatment capacity, and provide new sewer service.

A significant portion of these investments has been made by public agencies operating wastewater treatment systems that discharge directly to the Saginaw River or to nearby upstream tributaries. While a majority of the initial improvements were made before 1989, the following communities discharging to the Saginaw River have made substantial improvements to control and treat sanitary waste discharges in the last decade:

- **Saginaw** is completing construction of six new retention/treatment basins, the last of which will be operational by December of 2000. Also, the community (1) completed construction of a new chlorination system to improve disinfection of discharges from its wastewater treatment plant and (2) eliminated plant bypasses.
- **Buena Vista Township** made several improvements in its wastewater collection and treatment system to control CSOs, SSOs, and treatment plant bypasses in 1998.
- **Bay City** is upgrading its CSO facilities, built in 1980, so that when completed, they will provide better control and disinfection of discharges.
- **Essexville** improved CSO control in 1998 by expanding its retention/treatment basin, separating some sewers, and upgrading previously constructed basins.

Upstream sources of untreated human waste also may have contributed to the bacteria problems noted in the Saginaw River. Under cool temperatures, with ample nutrient and protein food sources, indicator bacteria and associated human pathogens can survive in the river for several days. The following communities' sanitary wastewater systems, which discharge into tributaries upstream of the Saginaw River or into rivers that are direct tributaries to Saginaw Bay, also have been significantly improved since 1989:

- **Saginaw Township** (on the Tittabawassee River) constructed a new wastewater treatment plant in 1984 and placed a new storage/treatment basin on-line in 1991 to control its CSO discharges into the Tittabawassee River just upstream of the Saginaw River. The community also constructed two more in-line storage systems tributary to the Saginaw River.
- **Pinconning** (on the Pinconning River) completed a project to control remaining SSOs in 1997.
- **Frankenmuth** (on the Cass River) made treatment plant improvements in disinfection in 1999 and completed a series of SSO control projects that were begun in 1977.

- **Chesaning** (on the Shiawassee River) addressed SSO discharges and upgraded its wastewater treatment plant in 1995 to improve disinfection.
- **Midland** (on the Tittabawassee River) completed work in 1991–1995 to address CSOs and upgraded its wastewater treatment plant.
- **Flint** (on the Flint River) is completing work on addressing SSOs.

While some issues still need to be addressed to improve wastewater treatment, increase storage capacity for CSOs, and provide sanitary sewer service where septic tanks are failing, the major sources of untreated sanitary waste that have caused unacceptable bacteria levels have been largely resolved. Recent improvements to municipal wastewater treatment facilities within the watershed have significantly reduced or eliminated plant bypasses. The number and frequency of SSO discharges also have been substantially reduced. By the end of 2000, all untreated CSO discharges of human waste into the Saginaw River will have been eliminated.

Bacterial contamination from human waste may soon be reduced to levels that occurred prior to the construction of the first sanitary sewers in the late 1800s. Human health threats due to untreated sewage have been significantly reduced since the Saginaw River/Bay was first designated as a major Great Lakes water quality problem area in 1973.

The Goal

The goal is to eliminate the health risks associated with human waste that have previously impaired recreational use of the Saginaw River. Actual monitoring of indicator bacteria levels is essential to (1) determining if and when this goal has been achieved and (2) documenting that the state water quality standards to protect full- and partial-body contact recreation have been met.

Measuring Success

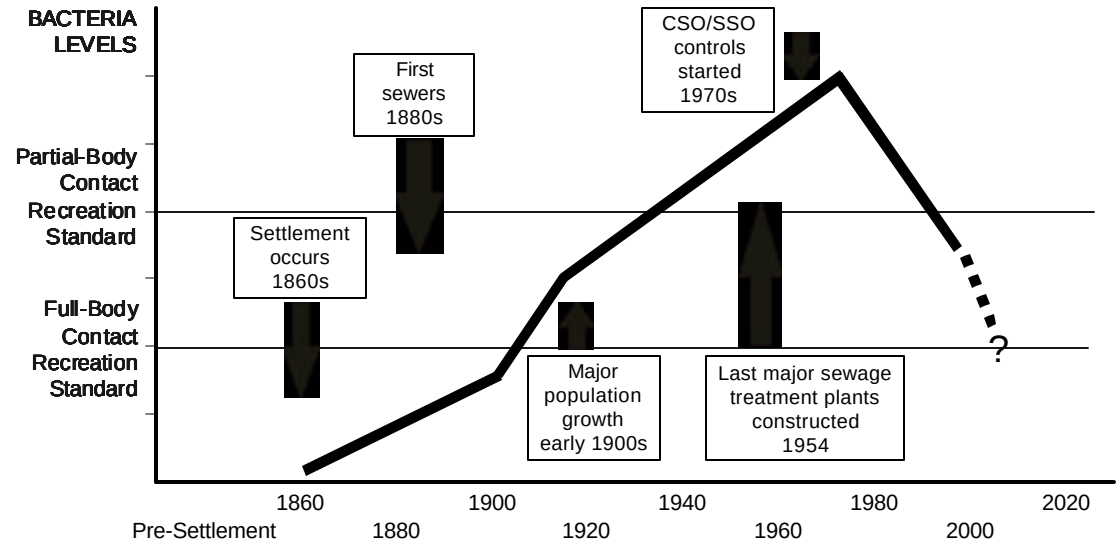
The following graph (Exhibit 2) provides an historical perspective on the bacteria contamination of the Saginaw River. It shows the major events that have contributed to unacceptable bacteria levels in the past and the actions that have resulted in improvements. Without more intense and systematic monitoring, however, we will not know with certainty whether the hundreds of millions of dollars invested to date have achieved complete success, or whether further targeted efforts are needed to eliminate health risks associated with human waste entering the river and bay.

Targeted Restored Condition

Microorganism Contamination

- Three consecutive years of testing for *E. coli* bacteria, an indicator of harmful microorganisms, confirm that the state water quality standards for full-body recreation are being met in the Saginaw River.
- No more than three swimming beaches are closed per year, and closures last no more than two days each in Saginaw Bay. (This has been achieved within Bay County, where routine sampling by the Bay County Health Department has demonstrated bacteria standards for full-body contact recreation are being met.)

EXHIBIT 2
Historical Perspective of Health Risks in the Saginaw River



SOURCE: Public Sector Consultants, Inc., 2000.

NEXT STEPS

The following actions are recommended to document when the targeted restored condition to protect public health has been achieved and contamination by microorganisms can be eliminated as a listed impairment for the Saginaw River/Bay area:

- Through the cooperative efforts of (1) the Michigan Department of Environmental Quality (MDEQ), (2) local wastewater treatment plant operators, and (3) local health officials, establish appropriate sampling methods (including frequency and location of sampling) to monitor bacteria levels in the Saginaw River.
- Eliminate all known SSOs and all untreated or inadequately treated CSOs.
- Encourage local health departments with public access sites on Saginaw Bay to monitor bathing beach areas from April through October.
- Establish a database and annually summarize (in a report made available to the public) the bacteria sampling results from the river and bay, particularly below wastewater discharge points.
- Conduct an annual review of the data collected to determine whether or not (1) sample numbers and/or locations should be increased or decreased and (2) new potential sources of human waste entering the river need to be addressed.

EMERGING ISSUES

Storm Water Management

Within three years, most storm water discharges will be regulated in Michigan. Based upon new federal rules, Michigan has adopted a general storm water permit that will require, among other things, cities, townships, and villages with a population under 100,000 in urbanized areas of the state to implement programs that identify and eliminate sources of untreated human waste entering sepa-

rate storm water systems. (Municipalities with a population of more than 100,000 served by separated sewers are already required to have a general storm water permit.)

The storm water permit program will require that communities address both illicit connections (inadvertent or illegal discharges from sanitary systems into separate storm water systems) and the discharge of inadequately treated sanitary waste from failed septic systems into storm drains. The recommended sampling program for the Saginaw River/Bay will help local communities target those areas where illicit connections and/or failing on-site septic systems are contributing to violations of water quality standards for indicator bacteria.

New Focus on SSOs

The U.S. Environmental Protection Agency (EPA) and the MDEQ have both announced new initiatives to control SSOs. In recent litigation, the federal court supported an EPA enforcement action under the Clean Water Act to require a municipality to correct SSO discharges, despite the local government's claim that its sewage treatment system was already operating at design capacity. The failure of a local government to report SSOs that had been affecting Lake St. Clair in Macomb County led to state and federal enforcement actions and the introduction of new state legislation earlier this year. The legislation subsequently adopted requires communities to report to the state and public all SSO discharges and mandates an annual report from the MDEQ that identifies, among other things, the actions taken to correct these illegal discharges of untreated human waste.

Similar state statutory reporting requirements for CSOs were a major factor in focusing public concern and stimulating corrective actions to eliminate this source of untreated waste in the last decade. These new reporting requirements for SSOs, coupled with stepped-up state and federal enforcement actions, will accelerate correction of any remaining untreated sanitary waste system discharges within the watershed. It is important to remember, however, that while such reporting increases the public visibility of SSO issues, it is *not* an indication that either the frequency or severity such discharges are increasing.

SEDIMENT CONTAMINATION

The accumulation of chemicals in the bottom sediments of the Saginaw River/Bay has severely affected a number of beneficial uses. Specifically, the concentration of chemicals in the sediments has impaired navigational uses by restricting dredging activities. Contaminated sediments also are implicated in other impairments listed for the river and bay, including restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, bird and animal deformities, degradation of *benthos* (bottom-dwelling aquatic organisms), and tainting of fish.

The layers of sediment at the bottom of the Saginaw River and Saginaw Bay provide a historical record of pollution abuses that have occurred in the watershed over the last 150 years. Unfortunately, even though most of the original sources of toxic contamination have been addressed, the contaminants still in the sediments remain an environmental concern. Both state and federal guidelines have classified dredge spoils—or sediments that are excavated during dredging—from the Saginaw River and significant portions of Saginaw Bay as polluted since the early 1970s. Thus the cost of maintaining navigational channels and dredging harbors and marinas in the river and bay has increased due to the special handling, confinement, and disposal requirements imposed on polluted dredge spoils.

WHERE WE HAVE BEEN

Concern over contaminated sediments is relatively recent. Some metals such as lead, copper, and zinc began accumulating in the sediments of the river and bay, particularly below wastewater discharges, as soon as sewers were built to carry waste to the river. The manufacturing boom beginning in the early 1900s, the chemical manufacturing expansion beginning in the 1930s, and the widespread agricultural use of chlorinated pesticides following World War II were the largest sources of contaminants now found in sediments within the Saginaw River/Bay watershed. Many of the organic chemicals of greatest concern were not even manufactured until after 1945. It was not until the 1970s that the amount of chemical contaminants contained in the sediments was widely known and the implications of the contamination to the uses of the river and bay were fully understood.

Sediments in the lower ten miles of the Saginaw River extending into Saginaw Bay contain a wide range of pollutants, including residue from oil and grease discharges, phosphorus and nitrogen in various forms, heavy metals, and organic chemicals. It is the latter two, heavy metals and organic chemicals, that comprise the greatest cause for concern. Heavy metals detected in sediments that when tested remain above acceptable levels include lead, zinc, nickel, arsenic, cadmium, chromium, copper, and mercury. The primary organic chemicals of concern in the river include pesticide residues (e.g., DDT, DDD, DDE, and related derivatives, dieldrin, and chlordane) and industrial compounds (polychlorinated biphenyls [PCBs], polybrominated biphenyls [PBBs], phenolic compounds, and various chlorobenzenes). These organic chemicals and heavy metals cause concern because at low concentrations they are toxic, they persist for a long period of time in the environment, and many increase in concentration as they are passed up the food chain (or *bioaccumulate*).

Chemical manufacturing on the tributaries to the Saginaw River has been a significant source of some of these contaminants. The Middle Grounds, a former municipal and industrial land disposal area adjacent to the Saginaw River, was once a major source of contaminants. At St. Louis, Michigan, on the Pine River tributary to the Tittabawassee River, the former Michigan Chemical Company produced PBBs, DDT, and a range of other organic compounds that were discharged into the river. Testing in the early 1980s indicated a wide array of heavy metals and organic chemicals above acceptable levels in the sediments downstream of chemical, plastic, metal container, and photographic industries located on the Tittabawassee River in the vicinity of Midland. PCBs and heavy metals were also a major concern in the Shiawassee River below the cities of Howell and Corunna/ Owosso, where metal casting, forge operations, and other industries were discharging these compounds in the 1960s and 1970s. Sampling of sediments below the Flint wastewater treatment plant in 1974 indicated that heavy metals from various manufacturing facilities located in that community were contaminating sediments in the Flint River.

Moderate to high levels of heavy metals in sediments also were found below the municipal and industrial wastewater treatment plant discharges in the Saginaw River during surveys conducted in the 1970s. The most severe problem, however, detected in the Saginaw River was very high concentrations of PCBs in sediments found below industrial and municipal wastewater discharges in the river and in Saginaw Bay. The 1970s studies indicate that PCB levels in some sediments of the Saginaw River contained almost 60 times the standard for classifying the dredge spoil as “heavily polluted.”

The contaminated sediments in the Saginaw River and near the mouth of the river in the Saginaw Bay pose the greatest long-term problem. Routine dredging of sediments in these two areas to maintain commercial and recreational navigation channels disturbs sediments that in turn release the contaminants into the water.

What We Have Accomplished

Control of Contaminant Sources

As a result of enforcement activities and the expenditure of hundreds of millions of dollars by area industries, the primary sources of heavy metals and organic chemicals that contaminated the sediments of the Saginaw River watershed have been reduced or eliminated. The contamination caused by the Michigan Chemical Company in St. Louis resulted in a major enforcement action by the state initiated in the 1970s that eventually resulted in the closure of the plant and an ordered containment of the chemical residues on the plant site adjacent to the Pine River. Similar legal actions by the state forced remedial actions at the Cast Forge manufacturing facility at Howell on the Shiawassee River.

Improved waste handling and treatment required at the Dow Chemical facility at Midland and at various other industrial facilities throughout the watershed in the 1970s and 1980s significantly reduced the quantity of heavy metals and organic chemicals being discharged into the river.

In the 1980s, state and federal regulations mandated that all major municipal wastewater treatment systems impose pre-treatment requirements on industries using their facilities. These pre-treatment requirements reduced the heavy metals contained in industrial waste discharges being sent to municipal systems.

Actions at the state and eventually national level severely curtailed the use and in some cases the manufacturing of many of the organic chemicals found in the contaminated sediments. Michigan established controls on the use of DDT in the early 1970s, and a federal ban on the use of this pesticide followed in 1973. Similarly, Michigan controls on industrial uses of PCBs were followed by a federal manufacturing ban in 1978. In the same year, federal restrictions on the general use of chlordane were adopted. Federal and state laws adopted in the 1970s to control the storage, handling, transport, and disposal of toxic materials also helped reduce the sources of heavy metals and organic chemicals that were contaminating sediments in the watershed.

Removal of Contaminated Sediments

Although the major sources of heavy metals and organic chemicals that have contaminated the sediments of the Saginaw River watershed have been reduced or eliminated, residual concentrations remain in the sediments themselves. It is not always practical or economically feasible to remove these contaminated sediments. In some cases, natural decomposition of organic chemicals can eventually break down the contaminants into non-toxic components. In some areas of the river system and bay, the deposit of new, uncontaminated sediments can isolate the heavy metals and organic chemicals, thus reducing the uptake by aquatic organisms. Where concentrations of contaminants are high, or where they are subject to re-suspension in the water due to dredging or river flows, removal may be necessary.

As part of the settlement in the state enforcement action against the Cast Forge Company in Howell, sediments contaminated with high concentrations of PCBs were initially removed from the Shiawassee River in the 1970s. Remedial investigations completed in 2000 by the U.S. Environmental Protection Agency (EPA) at this site indicate that additional soil removal in the flood plain of the river and sediment dredging within the Shiawassee River will likely be required in the future to adequately control sources of PCBs. Recent sampling by the state in the Pine River below the former Michigan Chemical Company site indicates that additional actions, including dredging of the river adjacent to the old plant site, are needed to control significant sources of toxic chemicals still entering the river system. New remedial dredging began in the spring of 2000 on the Pine River.

Since the 1970s, when regulations required polluted dredge spoils to be deposited in confined disposal areas, routine navigational dredging by the U.S. Army Corps of Engineers in the Saginaw River/Bay has removed large quantities of contaminated sediment. Sediment sampling in the Saginaw River indicates that the navigational channel in the Saginaw River contains much lower concentrations of contaminants than areas that have not been routinely dredged.

A 1998 court consent order between the defendants—General Motors, the City of Saginaw, and Bay City—and the plaintiffs—the EPA and the Michigan Department of Environmental Quality—resolved a long-standing dispute over PCB contamination of the river. The settlement agreed upon by

the parties provided $28.2 million for remediation and mitigation projects for the Saginaw River/Bay. Part of the agreement called for the removal of a total of 345,000 cubic yards of PCB-contaminated sediments, which began in April of 2000. This two-year project is expected to remove approximately 90 percent of the residual PCBs still contained in the sediments of the lower Saginaw River.

The Goal

The ultimate goal is to eliminate environmental impairments to the Saginaw River/Bay watershed caused by contaminated sediments. To address the primary impairment cited for contaminated sediments, the short-term goal is to reduce contaminant levels to the extent that the cost of navigational dredging is not higher due to the presence of organic chemicals or heavy metals in the dredge spoils.

Measuring Success

Other measures have been proposed in this report to determine progress in addressing the impairments indirectly related to contaminated sediments such as restrictions on fish and wildlife consumption, degradation of fish and wildlife populations, bird and animal deformities, degradation of benthos, and tainting of fish. For the impairments to navigation caused by contaminated sediments, the following measure is proposed:

Targeted Restored Condition

Restrictions on Dredging The level of contaminants in Saginaw River/Bay sediments no longer imposes additional costs due to requirements for the removal, confinement, and remediation of dredge spoils.

Next Steps

Beyond the planned and completed removal of contaminated sediments in the Saginaw, Shiawassee, and Pine rivers within two years, no additional remedial actions to remove contaminated sediments are scheduled for the Saginaw River/Bay watershed. To determine whether or not the targeted restored condition for restrictions on dredging has been achieved, the following actions are recommended:

- Document the improvements in PCB contamination levels in the sediments of the shipping channel of the Saginaw River/Bay following the remedial actions now under way.
- Following completion of the PCB-contaminated sediment removal project, conduct an economic analysis of the cost of routine navigational dredging in the Saginaw River/Bay compared to the cost of comparable dredging in rivers and harbors of the Great Lakes where sediments are not classified as polluted.
- Fully evaluate cuts/slips along the Saginaw River for sediment contamination and work to develop remediation alternatives for any significant sites of sediment contamination identified. In particular, remediation alternatives should be developed for the Weiss Street Channel.

Emerging Issues

Confined Disposal Area

The potential transport and ultimate fate of the toxic contaminants now contained in the confined disposal facility (Channel/Shelter Island) in Saginaw Bay is unknown. Further investigations may be needed to evaluate remediation options if toxic contaminants emanating from this site are demonstrated to impact fish and wildlife using this area.

Upstream Contamination

Once the removal of contaminated sediments planned for the Saginaw and Pine River is completed, water quality sampling, fish tainting, or contaminant levels may indicate that further remedial measures are required to control sources of toxic chemicals. The feasibility of the removal of additional contaminated sediments may need to be evaluated.

FISHERIES

The decline in abundance of important fish species, the associated losses of critical fisheries habitat, particularly marsh areas, and the limitations on fish consumption were significant impairments cited when the International Joint Commission (IJC) initially designated the Saginaw River/Bay as a Great Lakes Area of Concern (AOC). Specifically, the 1988 *Remedial Action Plan* (RAP) for the Saginaw River/Bay identified taste and odor problems as well as the toxic contaminant levels of fish as limiting factors affecting both commercial and sport fisheries in the river and bay. The RAP also identified habitat losses associated with shoreline development, wetland drainage, and other physical changes in the river and bay that limit reproduction, growth, and survival of certain fish species.

Persistent toxic chemicals from agricultural and industrial uses in the Saginaw River/Bay watershed were listed as a major concern from a public health perspective for those who consumed fish taken from the river and bay. The potential detrimental effects these chemicals were having on the reproduction and survival of certain fish species also were cited as a concern. Finally, the RAP noted that increased levels of nutrients from agricultural and urban runoff and inadequately treated sanitary waste discharges were resulting in accelerated *eutrophication* of Saginaw Bay. This further limited the abundance of certain sensitive fish food organisms and fish species.

Recent research has shown that increased bay sedimentation rates since the early to mid-1900s, specifically sediment transported from rivers, has virtually eliminated the inner bay rock reefs that were once a major spawning site for bay area walleye populations.

WHERE WE HAVE BEEN

The Saginaw River/Bay fisheries were important to the residents of the region even before European settlement of the area occurred in the mid-1800s. Native Americans relied on the abundant fish populations found in the river and bay as a significant source of food. Commercial fishing activities around Saginaw Bay flourished in the last half of the 1800s, supplying food for a growing population

in the area and the Great Lakes region. Commercial fishing became a major industry in many ports along Saginaw Bay, peaking just after the turn of the century when a record 14.2 million pounds of fish were harvested. In 1900, yellow perch, walleye, suckers, and catfish were the primary commercial species in the inner portions of Saginaw Bay, with lake herring, whitefish, and lake trout supplementing the catch in the outer bay areas.

Commercial Fishery

Major changes in the fish populations of the bay and river began to occur in the early 1900s. The abundance of many important species were affected by (1) water pollution, (2) the introduction or invasion of exotic species like carp, rainbow smelt, and (later) alewife, and (3) dams blocking major spawning tributaries in both the Saginaw River watershed and other tributaries to the bay. While there is some debate as to the role of the commercial fishery in causing the initial decrease in abundance of certain Saginaw Bay fish populations, there is evidence that excessive commercial harvest exacerbated the drastic decline recorded for several species. By the 1940s, several formerly abundant fish species in the bay were in serious trouble.

Lake sturgeon had all but disappeared from Saginaw Bay by 1940. In the outer bay, lake herring, lake trout, and whitefish all were declining in abundance, as evidenced by reduced commercial catches at the time. The growing numbers of introduced, invasive smelt and carp and increased abundance of chubs helped support a dwindling commercial fishery in the 1940s. The invasion of the sea lamprey that began in the 1930s, combined with extreme fishing pressure on native species, led to the explosion of alewife in the 1950s. By the early 1970s, the walleye, lake herring, chub, lake trout, and whitefish commercial fisheries in the outer bay were either closed or drastically reduced due to declines in abundance of these species. Yellow perch, carp, and catfish were the primary commercial species in the inner bay area in the 1970s. The total combined commercial harvest reported in 1974 of 1.4 million pounds was 10 percent of the peak catch recorded in 1902.

Recreational Fishing

Sportfishing activity from 1940 through the 1970s focused primarily on yellow perch, walleye, northern pike, smallmouth and largemouth bass, crappie, and bluegill in the relatively shallow inner bay areas rather than in the Saginaw River. What little fishing did occur in the river during this period often resulted in complaints from anglers about fish tainting (i.e., taste and/or odor problems). During the mid-1900s, the diminished aesthetics of the Saginaw River, frequently observed fish kills, and other pollution problems convinced all but the most determined anglers to find somewhere else to fish. Sportfishing and commercial fishing conflicts and competition for declining populations of perch and walleye in Saginaw Bay in the 1970s prompted the state to impose severe restrictions on commercial fishing for perch and eventually a complete ban on commercial walleye fishing.

Habitat Changes

The historical wetlands adjacent to Saginaw Bay and throughout the Saginaw River watershed provided a wealth of spawning and nursery areas for a variety of fish and wildlife species. Over the past 100 years, the construction of dams, draining of land for farming and mosquito control, increased sedimentation from drainage and land use activities, and filling of marsh areas for development has profoundly affected the quality and quantity of this wetland habitat, which many fish species depend upon during critical life stages. Studies indicate that the Saginaw River watershed had nearly 700,000 acres of wetlands in the pre-European-settlement period prior to 1850. Recent inventories suggest that there has been a reduction of more than 40 percent in wetland acreage in the last 150 years. While not all of the wetland losses represent lost fisheries habitat, a significant

percentage of the available wetland fisheries habitat in the Saginaw River watershed and adjacent to the Saginaw Bay has been filled or drained. In addition, more than 400 dams and impoundments in the Saginaw River watershed restrict the ability of fish to migrate to historical spawning areas.

Erosion of soils from urbanization and agricultural practices in the watershed has also adversely affected fisheries habitat. Increased sediment deposits in Saginaw Bay have covered rocky reef areas in the inner bay, formerly important spawning areas for walleye, yellow perch, and other species. In addition, the increase in sediments in the bay has limited the production of bottom-dwelling, fish-food organisms.

Pollution Sources

Major chemical, industrial, and municipal wastewater discharges into the Saginaw River and into upstream tributaries like the Tittabawassee, Cass, and Flint River have had significant impacts on fish populations in the Saginaw River and inner Saginaw Bay. Sugar beet waste discharges resulted in large fish kills nearly every year in the Cass and Saginaw rivers in the 1930s. By the early 1950s, physical barriers and/or pollution had effectively blocked major migrations of walleye and other species that previously had moved from the Saginaw Bay into the Saginaw River watershed to spawn. According to a *Bay City Times* report at the time, one industrial spill in the mid-1960s on the Tittabawassee at Midland killed an estimated 14,000 fish. Testing of the Saginaw River in 1965 indicated that the amount of dissolved oxygen had dropped to near zero due to pollution sources entering the river, making the survival of all but the most pollution-tolerant fish species impossible.

Beginning in the 1970s, new problems were uncovered in the river and bay. Improved testing techniques showed that the pesticide DDT and closely related breakdown products DDD and DDE were accumulating in fish in the river at high enough levels to make them unsafe to eat. Later polychlorinated biphenyls (PCBs), a group of related industrial chemicals, also were found in fish at levels that interfered with the reproduction of some species. This discovery resulted in the ban of commercial sales and issuance of consumption warnings for other species. Similarly, heavy metals like mercury, lead, copper, and zinc were being detected at high levels in the water, sediments, and fish samples taken from the river and the bay.

Phosphorus and nitrogen from farms and inadequately treated municipal wastewater were adding to the fishery problems in the Saginaw Bay. These two nutrients were identified as a major cause of nuisance algal blooms occurring in the bay in the 1960s. By accelerating plant growth and related dissolved oxygen depletion, the addition of these nutrients was cited as a primary cause for the decline of important, bottom-dwelling, fish-food organisms.

WHAT WE HAVE ACCOMPLISHED

Restoration of the Recreational Fishery

Concurrent with the major efforts in the Saginaw River watershed during the 1970s and 1980s to control industrial and municipal pollution sources, improve wetland protection, and control the use and production of certain persistent pesticides and industrial chemicals, new fish management programs were launched. In the late 1970s, the Michigan Department of Natural Resources (MDNR) in cooperation with local sportfishing organizations began a stocking program in Saginaw Bay to reestablish walleye as the predominant predator in the bay. In 1986, anglers caught more than 73,000 walleyes in the Saginaw River and Bay. The return of walleye fishing on the Saginaw River is celebrated annually at the Shiver on the River event, where more than 2,000 people registered as participants in 1999. While the return of the sport fishery has been dramatic, the current abundance

of walleye in the bay is estimated by some measures to be less than one-third of that which existed in the bay prior to the population collapse that occurred in the 1940s.

The return of the walleye fishery has made the Saginaw River/Bay area a major destination for anglers throughout the Midwest. While the long-term goal of the program is to establish a self-sustaining walleye population at a density consistent with the carrying capacity of the bay, annual stocking is necessary to support the fishery. Current studies indicate that naturally reproducing walleye make up approximately 20 percent of the annual local production.

Overfishing, pollution, and dams that block spawning runs caused sturgeon to be listed as a threatened species in 1974. However, federal biologists quoted in a December 31, 1997 *Saginaw News* front-page story—which reported that an angler had caught and released a 45-pound lake sturgeon in the Saginaw River—indicated that fishermen had reported catching more than 50 sturgeon in Saginaw Bay that year. After more than 75 years of decline, there is mounting anecdotal evidence that lake sturgeon populations may be on the increase in certain areas of the Great Lakes. Further investigations are needed to determine if in fact sturgeon reproduction, even at rudimentary levels, is occurring in the Saginaw River.

Sportfishing in the outer bay has become increasingly important as the control of sea lamprey in Lake Huron has allowed planted lake trout, brown trout, steelhead, and chinook salmon to survive. Since the late 1970s, seasonal sport fisheries for trout and salmon provide an attractive bonus to Saginaw Bay anglers in the outer bay areas.

Improvements in Habitat Protection

Michigan was one of the first states to obtain delegated authority from the U.S. Environmental Protection Agency to administer the wetland protection provisions of the federal Clean Water Act in the 1970s. State regulation controlling the dredging and filling of wetlands and other modifications to land adjacent to rivers and lakes has provided added protection for valuable fisheries habitat areas along the Saginaw River/Bay. The rate of fisheries habitat destruction leading to the designation of this impairment for the river and bay has been reduced. Projects to restore important wetland areas previously lost in the bay are under way.

While some progress has been made in reducing and controlling soil erosion in both urban and rural areas of the watershed, excessive sedimentation rates in Saginaw Bay remain a major concern. This issue is discussed more in depth in the "Bay Ecosystem" section of this report, under "Land Use and Sedimentation."

Control of Toxic Chemicals

Regulatory controls imposed in the 1970s and 1980s on the production, use, and discharge of certain toxic chemicals have resulted in a significant reduction in the concentration of these persistent chemicals in fish taken from the river and bay. In fact, these controls resulted in an almost immediate response in terms of reduced levels of these chemicals found in fish. While some fish species (or sometimes the smaller-sized fish of a species) have been removed from the fish consumption warning list, health advisories remain in effect for other species taken from the river and bay.

The level of contaminants found in fish varies considerably. The concentration of chemicals in the water and the species, size, age, and fat content of the fish are all factors that affect the contaminant levels. There is good documentation, however, that the levels of DDT, PCBs, chlordane, dioxins,

and mercury—the primary chemicals responsible for fish consumption warnings—in larger predator fish taken from Lake Huron, including Saginaw Bay, have declined since the 1960s.

In the 1990s, however, after the initial declines occurred in the 1970s and 1980s, concentrations of these chemicals in fish began to level off. There has been insufficient monitoring over the last decade to determine whether or not fish within the Saginaw River/Bay area have concentrations of contaminants greater than those found elsewhere in the Great Lakes for comparable species of the same age and size.

Lessening of Fish Tainting Problems

The chemical odors and taste problems frequently reported from the 1940s to the 1970s with fish caught in the Saginaw and Tittabawassee River and in the Saginaw Bay have now all but disappeared. Systematic sampling of fish for taste and odor in the Tittabawassee River in the early 1990s did not detect any problems. Cases of fish tainting are still reported with fish from the Saginaw River in isolated instances, though none were reported in 1999, and only one has been reported thus far in 2000. No fish tainting problems have been reported with fish taken from Saginaw Bay for several years.

Reduction in Nutrients and Improved Dissolved Oxygen Levels

The enhanced municipal and industrial wastewater treatment that has been implemented over the last 30 years and limitations on the phosphorus content of laundry detergents that began in the 1970s have significantly reduced *nutrient loadings* (additions of nitrogen and phosphorus) into the river and bay.

Dissolved oxygen measurements in the Saginaw River indicate that the levels of oxygen are now usually higher than state water quality standards require (the warm water fisheries minimum standard is 5.0 mg/l). Dissolved oxygen levels in the river are substantially higher now than the levels recorded in the river in the mid-1960s.

THE GOALS

Fish Populations

The MDNR has established tentative goals for sustainable fish production from Saginaw Bay based upon historic levels. To achieve these goals, continued progress in pollution control and increased habitat protection and restoration will need to occur. In general, the fisheries management goal is to take advantage of available forage species in the bay to enhance the abundance of larger predator species such as walleye, northern pike, muskellunge, and catfish through stocking, harvest regulation, and habitat protection. Specific harvest targets have been proposed by the state for a majority of the sport and commercial species taken from the river and bay.

Efforts are under way to enhance populations of the threatened lake sturgeon throughout the Great Lakes. Historically, the Saginaw River had significant runs of lake sturgeon. Now that the major pollution sources for the river have been addressed, the Saginaw River may become a target for a lake sturgeon reintroduction effort by the state in the future.

Habitat Protection and Enhancement

The primary goal is to protect existing fish-spawning and nursery areas from filling and dredging in shoreline areas of the Saginaw Bay and in large wetlands with a direct connection to the rivers of the Saginaw River/Bay. Secondary goals include targeted restoration of critical habitat that will partially

mitigate for past fish habitat losses and dam removal to make former upstream spawning areas accessible. In addition, the installation of new state-of-the-art fish passage devices is needed to provide access to upstream spawning areas. Conventional fish ladders over dams do not accommodate species like walleye and sturgeon that cannot jump. Research under way in Ontario and by the U.S. Department of the Interior may soon produce prototype devices that can be used to pass fish over structures like the Dow Dam on the Tittabawassee River in Midland. Ultimately, however, dam retirement and removal remains the best hope for restoring access to spawning habitat for migrating fishes.

Fish Contaminants

The long-term goal is to reduce all chemical contaminants so that fish consumption warnings can be removed. However, atmospheric deposition of materials from distant locations, which cannot be controlled by local efforts, is now a significant source of the contaminants. Thus the short-term goal is to focus on controlling all sources of contaminants within the watershed that elevate contaminant levels in area fish above the average levels found in comparable fish from the other areas in the Great Lakes.

Fish Odor and Taste Problems

Reports of odor and taste problems with fish in the area have diminished considerably. The goal is to eliminate fish odor and taste problems as a significant impairment to the recreational or commercial fisheries of the river and bay.

MEASURING SUCCESS

The abundance, diversity, and general health of fish populations in the Saginaw River/Bay area are some of the best measures of the overall status of this complex ecosystem. The four primary factors related to fisheries that led to the designation of the Saginaw River/Bay as a Great Lakes AOC were loss of fisheries habitat, chemical contaminant levels in fish, fish odor and taste issues, and accelerated eutrophication of the bay. Various actions over the past 25 years have improved the status of the fishery in both the river and the bay. The status of the fishery has been annually measured through creel census, survey netting, and trawling since at least the early 1980s. This section identifies each of the fisheries impairments originally listed for the Saginaw River/Bay AOC, explains the limitations on current methods of measurement, and provides recommended steps for reaching a targeted restored condition that would justify delisting the impairment.

Monitoring Fish Populations and Habitat

The condition of the fisheries habitat and the status of fish populations both need to be monitored. The two primary threats to the fisheries habitat that led to AOC designation were the poor water quality of the river and the potential destruction of critical coastal marshes on the Saginaw Bay that are essential to fish populations. Because these marshes are also vitally important to sustaining the wildlife populations of the area, the "Wildlife" section of this report will identify the targeted restored condition for the coastal marshes and the steps needed to document that adequate protection is in place.

Dissolved oxygen levels, once a significant factor limiting the use of the river by certain species, have improved; however, routine dissolved oxygen sampling in the Saginaw River was discontinued in 1992. Comprehensive monitoring of dissolved oxygen levels in the river is still needed to verify progress in meeting the state water quality standard developed to protect warm water fisheries. While dissolved oxygen levels in the Saginaw River during the summer period may not be as critical to

walleye and yellow perch abundance as other habitat factors, it is an important measure of the quality of the water, which is necessary to sustain fish populations and fish food organisms in the river and bay.

Sustainable fish harvest goals have been tentatively established for a wide range of species found in the bay. Two species—yellow perch and walleye—are perhaps the best key indicator species to document the recovery of conditions necessary to sustain fish populations in the bay, due to their importance to the current fishery, their historical abundance, and their sensitivity to environmental conditions. Any evidence of lake sturgeon reproduction in the Saginaw River would also be a significant indicator that major improvements in water quality have been achieved in the river. The long-term goal for the bay's walleye population, established by the MDNR Fisheries Division, is a self-sustaining population capable of supporting an annual yield commensurate with historic proportions (~1.0 million pounds, about five times more than the current yield) and existing at a density that fully utilizes the bay's carrying capacity. The long-term goal for annual yellow perch harvest of approximately 750,000 pounds per year has already been reached, although the average size is less than optimum. The following targeted restored conditions represent the interim, short-term goals that could lead to delisting of the river and bay as an AOC in the Great Lakes.

TARGETED RESTORED CONDITION

Habitat

- Dissolved oxygen levels in the river meet or exceed the state water quality standard of 5.0 mg/l during summer months.
- Critical coastal marsh areas are adequately protected (see "Wildlife" section, under "Targeted Restored Condition").

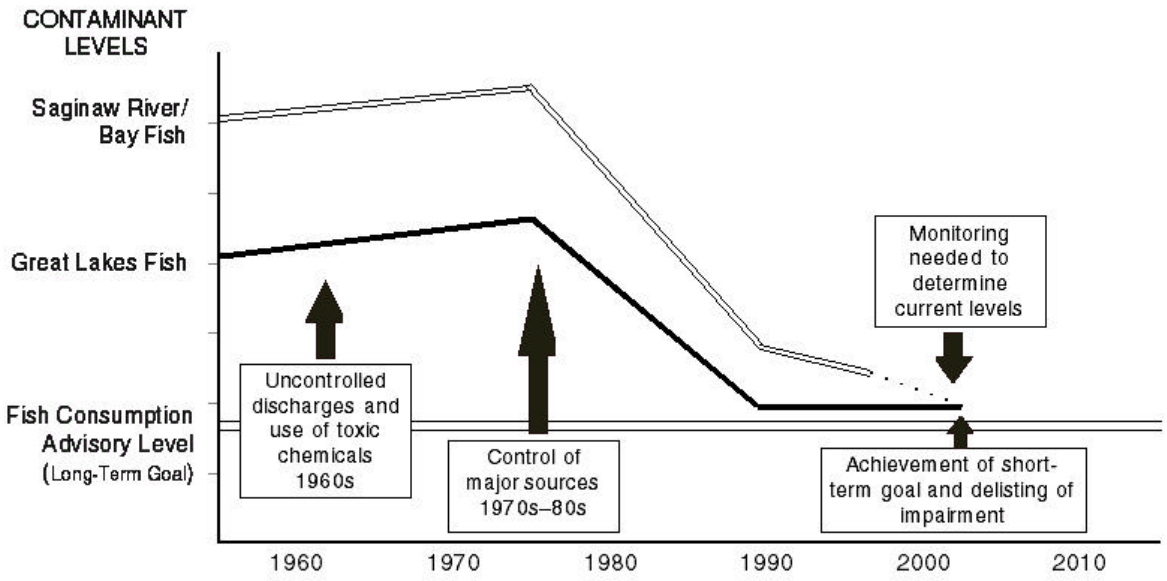
Fish Populations

- *Walleye* Increase abundance in the bay, ultimately through natural reproduction, such that growth rates approximate more closely statewide averages for this species and reflect improved use of available forage in the bay.
- *Yellow Perch* A sustained annual harvest of 750,000 pounds per year with increasing abundance of larger, faster growing individuals.
- *Lake Sturgeon* Documented evidence of natural reproduction in the Saginaw River.

Measuring Levels of Fish Contaminants

The following chart (Exhibit 3) depicts the general trend in levels of PCBs in large predator species in the Saginaw River/Bay over the last four decades compared to the levels found in similar fish from other Great Lakes. Levels of DDT, chlordane, and dioxin in fish show similar trends. Furthermore, the current fish consumption advisories for the Saginaw River/Bay area list only PCBs and dioxins. The monitoring over the last decade has been insufficient to determine whether or not fish within the Saginaw River/Bay area have concentrations of PCBs and dioxins greater than those found elsewhere in the Great Lakes for comparable species of the same age and size. Contaminant levels in fish, water, and sediments should be monitored to determine whether or not efforts to remove significant sources of toxic chemicals have been successful.

EXHIBIT 3
PCB Contamination Trends in Large Predator Fish in the Saginaw River/Bay



SOURCE: Public Sector Consultants, Inc., 2000.

TARGETED RESTORED CONDITION

Contaminants in Fish

- Levels of PCBs and dioxins in walleye taken from the Saginaw River/Bay are equal to or less than the levels found in comparable fish taken from other areas of the Great Lakes not listed as AOCs.
- PCB and dioxin levels in fish tissues from caged fish studies in the Saginaw and Tittabawasee rivers indicate that the former sources of these contaminants have been effectively controlled.

Documenting the Reduction in Fish Tainting

Taste and odor problems in fish from the river and bay have declined to the point that it may no longer be a significant problem. However, the absence of volunteered reports aside, no documentation exists to support the assertion that the former fish taste and odor problems have been resolved. A direct survey of the recreational fishery would be helpful in establishing a baseline of information on the frequency of taste and odor problems detected by anglers. Such a survey also may help locate any specific problem areas that need to be addressed.

TARGETED RESTORED CONDITION

Fish Tainting Taste and odor problems reported by anglers for any species taken from the Tittabawassee River downstream from Midland and the Saginaw River/Bay represent less than 1 in 10,000 of the estimated total annual catch for that species for three consecutive years. In addition, no specific sites of fish tainting have been identified that would justify remedial action.

Next Steps

The following actions are recommended to measure when the targeted restored conditions for fisheries have been accomplished so that the impairments listed for Saginaw River/Bay fisheries can be removed.

Habitat

- Reestablish effective dissolved oxygen monitoring in the Saginaw River during critical low-flow summer periods to determine whether or not the water quality standard is being achieved.
- Ensure that all dam releases are in compliance with Federal Energy Regulatory Control (FERC)/ state negotiated release levels to help maintain adequate flows and dissolved oxygen levels below dams.
- Work with individual communities/citizens/businesses within the watershed to identify dams for potential removal or for installation of fish passage devices.
- Expand public information and education efforts to inform the public about the critical role the watershed's rivers play in restoring and sustaining the bay's fisheries.
- Develop a computer-based geographic information system (GIS) to systematically inventory coastal marsh habitat areas critical to fish and wildlife. The system will identify those areas most at risk and allow for monitoring the success of programs intended to protect these areas.

Fish Populations

- Continue to monitor the annual harvest of walleye and yellow perch and conduct annual netting surveys to determine whether or not (1) targeted restored conditions are being met and/or maintained and (2) natural reproduction of walleye continues to provide evidence of improved habitat conditions.
- Identify opportunities provided by the MDNR Fisheries Division Lake Sturgeon Recovery Plan to expedite restoration of this important species in the bay area.

Fish Contaminant Levels

- Establish a baseline of data on the levels of PCBs and dioxins currently found in walleye in the Saginaw River/Bay that can be compared against contaminant levels in walleye taken from other areas of Lake Huron and/or other Great Lakes. Analysis of fish contaminant levels to determine trends is essential to understanding how effective efforts to control toxic pollutants have been and whether or not further remedial actions are required.
- Conduct caged catfish studies in the Tittabawassee River downstream of Midland and in the Saginaw River near the mouth following completion of remedial dredging to determine whether or not additional actions are required to control sources of PCBs and dioxins.
- Implement sediment monitoring on the Tittabawassee River downstream of Midland and on the Saginaw River and Bay after remedial dredging on the Saginaw River is completed to provide a comprehensive baseline for PCB and dioxin/furan levels in this AOC.
- Evaluate alternatives and develop a strategy to effectively disseminate information on Fish Consumption Advisories in the Saginaw River/Bay.

Fish Taste and Odor Concerns

- Conduct a survey of area anglers to determine the location and frequency of any fish taste and/or odor problems.
- Implement investigations/remediation at any sites identified as the source of a pollutant responsible for fish tainting.

Emerging Issues

The proliferation of exotic species in the Great Lakes has created serious concerns over the future status of the fishery. Numerous new fish species have found their way into the Great Lakes through purposeful introductions, accidental releases, and locks and canals constructed around natural barriers that once isolated the Great Lakes ecosystem. The relatively recent and dramatic increase in the number and types of exotic species from the ballast tank discharges of ocean-going vessels establishing themselves in the Great Lakes has had an enormous effect on the ecosystem of the bay and Lake Huron. Saginaw Bay is in the process of being colonized by the exotic goby and will likely be invaded by the ruffe within the decade. Both species have the potential to further alter the ecosystem in dramatic ways. If significant changes occur in Saginaw Bay as a result of exotic species, the targeted restored condition for yellow perch and possibly walleye may need to be reexamined.

WILDLIFE

Saginaw Bay historically contained the largest wetland/lake prairie complex in the Great Lakes region. Massive land use changes since the mid-1800s have significantly altered the quantity, diversity, and quality of habitat available to support wildlife. In addition, the manufacture, use, and subsequent discharge of persistent toxic chemicals into the waters of the area have had a significant negative impact on the growth and survival of a number of fish-eating wildlife species. The degradation of the wildlife populations, including the loss of essential habitat, observed deformities in certain fish-eating birds, and reproductive problems with fish-eating birds and mammals, were identified as impairments leading to the designation of the Saginaw River/Bay as a Great Lakes Area of Concern (AOC).

WHERE WE HAVE BEEN

Habitat

In the pre-European-settlement period, extensive Great Lakes marshes lined Saginaw Bay. The marshes in the southern portion of the bay extended lakeward to the five-foot depth contour and inland in some areas up to two miles. These wetland areas also encompassed several miles along the shorelines of the Saginaw and Quanicassee rivers. Along the western shore of Saginaw Bay, the pre-settlement marshes were somewhat narrower, seldom exceeding a half-mile in width. Shoreward of the marshes were extensive zones of lakeplain prairie. These wet prairies extended several miles inland along major tributaries of the bay, including the Saginaw, Quanicassee, and Kawkawlin rivers. Scattered between the wet prairies and coastal marshes were low beach ridges and sand spits. This diverse array of habitat types supported a wide range of resident fish and wildlife as well as a variety of migrating birds that depended upon this unique combination of habitat types.

Major losses to the wetlands along the Saginaw River occurred almost as soon as the area was first settled by Europeans in the early 1800s. The filling of wetlands to build docks, businesses, homes, and eventually facilities to process and transport lumber products accompanied early development of the area. The draining of marshes and wet prairies for agricultural production began in the late 1800s. By 1917, Bay, Tuscola, and Huron counties together had a total of more than 600 miles of agricultural drains.

Extensive land drainage also occurred in the area during the 1930s for mosquito control as part of the federal government's public works program. Based upon the historical record of pre-settlement land surveys, it is estimated that more than 40 percent of the wetlands in the Saginaw Bay watershed have been lost and that less than 1 percent of the original lakeplain prairie remains intact.

Toxic Chemicals

In the 1970s and 1980s, mounting evidence indicated that in the Saginaw River/Bay, fish-eating birds were accumulating persistent organochlorine compounds such as DDT and related derivatives, dieldrin, chlordane, polychlorinated biphenyls (PCBs), and dioxins. Studies in the 1980s linked high concentrations of organochlorines in terns, herons, and eagles in the Saginaw Bay area to egg-shell thinning and/or birth deformities. Fish-eating birds are particularly vulnerable to organochlorines, because these contaminants tend to increase in concentration as they pass up the food chain from fish to fish-eating predators.

Little was known in the 1970s about the effect of these contaminants on fish-eating mammals in the Saginaw River/Bay area. There was, however, laboratory evidence suggesting that environmental concentrations of PCBs were high enough in the 1970s and 1980s in the bay area to have caused injury to wild mink and perhaps otter. A comparison of statewide trapping records during this 20-year period suggests that populations of mink and otter in the Saginaw Bay area may have been reduced due to the increase in toxic contaminants in fish.

Specifically, the evidence that led to the determination that wildlife populations in the Saginaw River/Bay had been impaired included the following:

- Terns, herons, and eagles were injured due to PCBs and/or dioxins eco-toxicological effects on reproduction (i.e., chick deaths and birth deformities).
- The presence of contaminants were linked to death (Caspian terns); malfunctions in reproduction (Caspian terns, common terns, bald eagles); and physical deformations (black-crowned night herons, Caspian terns, common terns).

WHAT WE HAVE ACCOMPLISHED

Habitat Protection

Changes in federal and state laws regulating the filling and dredging of wetlands adopted in the 1970s provided additional protection to the remaining shore marshes and wet prairies in the Saginaw River/Bay area. While the protection of remaining wetland areas remains a priority, the potential for restoring bay area wetlands has been widely recognized in the last decade. The Saginaw Bay National Watershed Initiative and the 1988 *Saginaw River/Bay Remedial Action Plan* (RAP) helped to focus concerns on the status and importance of the wetlands in the bay area. Research projects conducted in the Saginaw River watershed and along the Saginaw Bay completed in the 1990s have mapped the pre-European-settlement wetland areas; identified remnant lakeplain prairies and potential seed banks of native wetland plant species; and evaluated several potential wetland restoration sites. This research culminated in a 1997 feasibility study involving the Michigan Department of Natural Resources (MDNR), Michigan Department of Environmental Quality (MDEQ), and Michigan Natural Features Inventory that outlined specific recommendations for restoring wetlands in Saginaw Bay.

Saginaw Bay has been recognized nationally as a rich biological resource representing the largest freshwater coastal wetland area (1,143 square miles) in the United States, supporting an annual

migrating population of more than 3 million waterfowl. Both the National Wetlands Policy Forum and the Michigan Wetland Advisory Committee have adopted specific objectives for assessing the effectiveness of their respective strategies to protect and restore wetlands. Both organizations have taken into account previous losses and propose to increase the amount of existing wetlands. The national objective proposes a net increase to wetland acreage over the long term. The state objective establishes an ambitious target of 50,000 new wetland acres by the year 2010 and long-term restoration, creation, and enhancement of 500,000 acres.

Despite wildlife habitat losses that have occurred, the bay's coastal wetlands still serve as a major concentration area for migrating waterfowl such as redheads and swans in the spring and fall. In addition, the bay provides nesting areas for many ducks such as mallards, blue-winged teal, and black ducks. The remaining wetlands are also important for shorebirds, songbirds, birds of prey, fish, frogs, salamanders, snakes, turtles, snails, mussels, insects, and crayfish. In addition, lakeplain prairies are home to many beautiful wildflowers, including rare species such as tall green milkweed and prairie Indian plantain. Quality coastal wetlands still exist at the Quanicassee, Nayanguing Point, Fish Point, and Wildfowl Bay State Wildlife Areas; and Bay City State Recreation Area (including Tobico Marsh).

Between 1987 and 1990, the MDNR purchased 9,845 acres of state park and wildlife areas as part of an intense focused effort to acquire land in the Saginaw Bay area. Purchases included parcels in Arenac, Bay, Huron, and Tuscola counties. Since 1990, the MDNR has acquired 5,265 acres in the above counties and Iosco County.

Federal land purchases have been limited to expanding the Shiawassee National Refuge boundaries. The boundaries were established around 1978, at which time expansion of the refuge slowed or ceased until the mid-1990s, when an active effort to expand its boundaries was undertaken. Since 1994, 320 acres have been added to the refuge, while an additional 380 acres have been acquired through long-term leases. In addition, the refuge recently expanded its authorized boundaries by 7,000 acres to target land on major tributaries.

Control of Toxic Chemicals

Over the last 30 years, state and federal actions to control the primary sources of contaminants in the bay area and the subsequent reduction in contaminant levels in fish (documented in other sections of this report) have reduced the impairments to the fish-eating wildlife populations in the Saginaw River/Bay area. Lake Huron has the highest number of fish-eating birds that breed along the shoreline of all the Great Lakes. Most populations of fish-eating birds (double-crested cormorants, Caspian terns, and osprey) are increasing, with Caspian terns and osprey no longer showing adverse effects of contaminants. While bald eagle nesting in the Saginaw River/Bay watershed area lags behind that found in the interior of the Lower Peninsula of Michigan, there is strong evidence that the population in the bay area is recovering through immigration of birds from other areas. The following table (Exhibit 4) compares the bald eagle reproduction for the Michigan portions of Lake Huron shoreline with that of the Saginaw Bay.

With the reduction in sources of persistent toxic contaminants such as PCBs, most of the fish-eating bird populations have recovered and populations of herring gulls, Caspian terns, black-crowned night herons, and double-crested cormorants have been re-established. However, reproductive failures continue to occur in a small percentage of populations in local areas.

EXHIBIT 4
Bald Eagle Reproduction
Michigan Portion of Lake Huron

Location	1985–87	1988–90	1991–93	1994–96	Total (1985–96)
Lake Huron (all Michigan areas)					
Fledged young	11	19	51	73	154
Occupied nests	15	28	64	81	188
Productivity	.73	.68	.80	.90	.82
Percentage success rate	40	46	53	60	54
Central Lake Huron Area					
Fledged young	0	10	12	26	48
Occupied nests	4	12	22	31	69
Productivity	0	.83	.55	.84	.70
Percentage success rate	0	58	36	55	46
Saginaw River/Bay (coastal area)					
Fledged young	2	1	7	11	21
Occupied nests	3	5	12	16	36
Productivity	.67	.20	.58	.69	.58
Percentage success rate	33	20	42	44	39

SOURCE: Lake Huron Initiative Action Plan, 1999.

Very little direct, hard evidence is available on the effects of toxic contaminants on fish-eating mammals in the bay area or their potential recovery. Some assumptions can be made based upon information collected from other areas and from anecdotal reports in the bay area. Fish-eating mammals (mink and otter) appear to be recovering in the bay area. Mink and otter both live in wetland areas near the shoreline and consume fish. Mink are among the most sensitive mammals to the negative effects of PCBs. The mink's diet consists mainly of other mammals, but it supplements its primary food source with birds, fish, and invertebrates. Statewide trends in mink populations have followed those of fish-eating birds; the population began to decline in the mid-1950s, was lowest in the early 1970s, and recovered somewhat in the 1980s. While otters may be less sensitive than mink to contaminants, they may be exposed to higher levels because their diet consists mainly of fish. Statewide data have not shown the same recovery trend for otter populations as for mink and fish-eating birds. Otter do, however, have a lower rate of reproduction and therefore would be expected to show a slower rate of recovery.

During the last five years, there has been an apparent increase in both the number and habitat range of river otter within the Michigan portion of the Lake Huron watershed. After an absence of at least 30 years, river otter are now being observed regularly at the Nayanquing Point Wildlife Area and nearby Tobico Marsh. River otter also have colonized the Crow Island State Game Area and the Shiawassee River State Game Area. In each of the last three years, otters also have been observed or trapped in Tuscola County.

THE GOALS

Coastal Marsh Protection (Wildlife and Fish Habitat Protection and Restoration)

The primary goal is to identify and protect existing high-quality wildlife and fish habitat sites as well as the ecosystem processes required to sustain such areas. The secondary goal is to implement strategies that will restore wetlands—particularly high-value coastal marshes and wet-prairie areas—to partially mitigate for the significant losses in these habitats that have occurred over the last 150 years.

Based on the Michigan statewide wetland restoration goal of 50,000 acres by 2010, the proportionate share of the goal for the Saginaw River/Bay watershed would be 7,500 acres of new wetlands. This means the creation of 500 acres of wetlands annually for the next 15 years in the watershed. While numerous sites have been identified for wetland restoration, it is not the physical limitations but rather the economic and social implications of wetland restoration that may make this targeted goal difficult to achieve in the short term. The social and economic cost of removing land from agricultural production may be too high. For this reason, protecting the ecological integrity of the remaining coastal marsh areas for use by fish and wildlife is the most important single goal in sustaining the diversity and abundance of species that make Saginaw Bay such a unique and valuable natural resource.

The Saginaw Bay Watershed Wildlife Habitat Conservation Framework Committee of the Saginaw Bay Watershed Initiative (WIN) has identified the area below the 585-foot contour within Saginaw Bay and the lower portions of the bay tributary streams as the critical coastal marsh areas in need of protection and restoration.

Wildlife Contaminants

The ultimate goal is to reduce the level of environmental contaminants in the Saginaw River/Bay area so that the reproduction, survival, and consumption of wildlife are no longer impaired. Two significant factors may impede the achievement of this goal in the short term. First, some contaminants like PCBs are attached to particles in the air that are transported from distant locations. Reducing the contribution of these atmospheric sources of contaminants is dependent on actions beyond the control of regional or even statewide efforts. Second, large quantities of contaminated sediments have been removed from the river and bay in the past and placed in a confined disposal area (Channel/Shelter Island) located near the mouth of the Saginaw River. Evidence suggests that herring gulls, herons, and terns using this confined disposal area for nesting may be exposed to toxic chemicals inadequately contained at this site. While recent evidence suggests that open water within the confined disposal area no longer exists to harbor contaminated fish, there remains a concern that wildlife and/or fish living in the immediate vicinity may still be vulnerable to chemicals leaching from this area. The most recent data from 1999 sampling of herring gull eggs by the Canadian Wildlife Service indicate that eggs sampled from nest sites from Saginaw Bay's Channel/Shelter Island had 27.1 ppm PCBs. These levels were five times higher than the average level of 5.8 ppm PCBs for eggs taken from two other monitoring sites in 1999 on the Canadian side of Lake Huron. It is not clear whether the higher levels of PCBs found in eggs from the Channel/Shelter Island site are due to PCBs leaching from the confined disposal site or from contaminant levels reaching the bay from the Saginaw River. A short-term goal should focus on successfully controlling watershed sources of contaminants that were responsible for the widespread impairments to wildlife resulting in the listing of Saginaw River/Bay as an AOC.

MEASURING SUCCESS

The following targeted restored conditions for wildlife focus on the importance of (1) protecting remaining coastal marsh habitat for both fish and wildlife and (2) lowering the level of toxic contaminants in two of the most sensitive species of fish-eating birds (bald eagles and herring gulls). If the ecological integrity of the remaining coastal marshes can be maintained and the toxic chemical levels in the two indicator bird species lowered to acceptable levels, habitat restoration efforts to expand wildlife populations will have a greater chance of success.

Coastal Marsh Protection (Wildlife and Fish Habitat Protection and Restoration)

The targeted restored condition is centered on coastal marshes, primarily because of the importance of this habitat to the fish and wildlife populations of the bay area. While current regulations may adequately protect critical coastal marshes from direct filling and dredging activities, unregulated activities on adjacent uplands may pose an even greater threat. Human alterations or even just occupation of uplands immediately adjacent to sensitive coastal marshes can seriously impair essential attributes needed to support fish and wildlife populations dependent upon these wetland areas. Even in small amounts, storm water runoff from adjacent developments and associated sediment and pollution can subtly alter the functions essential to sustain fish and wildlife. Thus the strategy should be to protect what coastal marshes remain lakeward and riverward of the 585-foot contour through conservation easements, public acquisition, landowner education, and enforcement of existing laws.

TARGETED RESTORED CONDITION

Coastal Marsh Protection (Fish and Wildlife Habitat Protection/Restoration)

- At least 60 percent of the coastal marsh areas (below the 585-foot contour) and adequate upland buffers representing essential fish and wildlife habitat is preserved through public ownership, covered under conservation easement, or otherwise protected under agreements with landowners.
- The most vulnerable portions of the remaining 40 percent of the essential coastal marsh areas have been clearly identified so that governmental agencies, local conservation/ environmental organizations, and concerned citizens can monitor their status, enhance enforcement of existing laws, and conduct public education programs to better protect these areas.

Wildlife Contaminants

Toxic chemicals in the Saginaw River/Bay area have impacted a wide range of fish-eating birds and mammals. Two species, bald eagles and herring gulls, have been monitored consistently over the past decade and offer the best indicators to measure success in the control of toxic chemicals. Bald eagles have shown sensitivity to a number of organic chemicals, and measurement of breeding success of this species within the bay area can be used to determine whether or not contaminant levels emanating from bay area sources are still a source of impairment. Herring gulls are common throughout the Great Lakes, and past monitoring of PCB levels in the eggs of this species has indicated that eggs sampled from birds in the Saginaw Bay area had much higher PCB levels than those found in eggs collected from nest sites in other areas of Lake Huron. Thus sampling herring gull eggs offers an effective means to monitor PCB control efforts.

TARGETED RESTORED CONDITION

Wildlife Contaminants

- *Bald Eagles* The reproductive success of bald eagles in the Saginaw Bay area is equivalent to that found in other Lake Huron coastal areas in Michigan.
- *Herring Gulls* PCB levels in herring gull eggs taken from Saginaw Bay area nest sites are not significantly higher than those found in other Lake Huron sampling locations.

Next Steps

The following actions are recommended to document when the targeted restored conditions for wildlife have been accomplished so that the impairments listed for the Saginaw River/Bay wildlife can be removed.

Coastal Marsh Protection (Wildlife and Fish Habitat Protection and Restoration)

- Incorporate existing information and compile new data within a computer-based geographic information system (GIS) that clearly identifies Saginaw Bay coastal marsh areas that are essential habitat for fish and wildlife. Parcel-based maps showing the area riverward or bayward of the 585-foot contour line will be essential for analysis.
- Coordinate with the county drain commissioners to evaluate opportunities for fish and wildlife habitat restoration.
- Establish a coastal habitat index and monitoring system that can be used to periodically document the status of a representative sample of vulnerable wetland areas important to sustaining bay fish and wildlife populations.
- Identify marshes that are particularly vulnerable to upland activities and implement actions to safeguard them and control upland threats.

Wildlife Contaminants

- Continue support for routine monitoring of bald eagle nesting success within Michigan's Lake Huron shoreline.
- Continue comparative analysis of PCB levels in herring gull eggs from nest sites within Saginaw Bay (i.e., Channel/Shelter Island and Charity Islands) and those in other areas of Lake Huron.

Emerging Issues

A habitat conservation plan for the Saginaw Bay watershed, funded through the Saginaw Bay Watershed Initiative Network (WIN), is currently being developed. The concept of the plan is to coordinate individual habitat management and preservation plans into a larger watershed perspective. This will provide a framework for groups actively pursuing the same or similar goals to identify opportunities for mutually beneficial projects. The WIN plan's recommendations in the current habitat conservation plan draft report extend beyond protecting coastal marsh by incorporating habitat protection and restoration initiatives covering the entire watershed of the bay. The next steps proposed above for coastal marsh protection are consistent with and complementary to the key actions currently proposed in the WIN habitat conservation plan.

BAY ECOSYSTEM

The 1988 *Saginaw River/Bay Remedial Action Plan* (RAP) identified impairments of the bay that reflected significant adverse changes in the ecosystem. Many of the impairments cited were directly linked to the effects of increased productivity and accelerated aging caused by excessive nutrient and sediment loading into the bay. These included degradation of the bottom-dwelling community of organisms (*benthos*), growth of nuisance algae in the bay, restrictions on drinking water due to taste and odor problems, and a general decline in the aesthetics of the bay.

WHERE WE HAVE BEEN

Eutrophication

Generally, the Great Lakes are *phosphorus limited*, meaning that the amount of phosphorus determines the basic productivity of the lake. Higher levels of phosphorus support increased plant growth and greater productivity. Scientists classify lakes based on the level of productivity. Lakes low in nutrients and productivity, like Lake Superior, are classified as *oligotrophic*. Historically, Lake Huron and Saginaw Bay were described as *mesotrophic*, or in the middle of the productivity scale. At least since the 1960s, Saginaw Bay waters have contained much higher levels of phosphorus than the remainder of Lake Huron, and the bay has moved up the productivity scale to be classified as *eutrophic*. While moving up the productivity scale (i.e., eutrophication) is a slow, natural evolutionary process for most lakes that occurs over thousands of years, human activities can accelerate eutrophication through the addition of nutrients. When rapid eutrophication occurs, many beneficial uses associated with lower productivity levels are impaired.

During the 1970s and 1980s, the Saginaw River added nearly two metric tons of total phosphorus per day to the bay, the largest contribution of phosphorus to the Great Lakes by any river in Michigan. Total phosphorus concentrations in the inner bay reached its highest level of 47.3 micrograms/liter (µg/l) in measurements taken in the spring of 1978. The added phosphorus increased the growth of nuisance blue-green algal that was likely responsible for the foul odors and poor taste of drinking water withdrawn from the bay.

In addition, increased biological productivity in the bay resulted in an increase in the organic debris washing up on area swimming beaches. This consisted of decomposing algae, aquatic plants, and small invertebrate animals. The smell and unsightliness of this beach debris prompted citizen complaints and concern about pollution entering the bay. Because of these complaints, reduced aesthetics was a listed impairment for the bay.

Benthic Community

The RAP defined the degradation of the benthos of Saginaw Bay as an impaired use because the benthic community structure in the bay is significantly degraded from that which occurs in unpolluted sites elsewhere in the Great Lakes. In 1998, the Great Lakes National Program Office of the U.S. Environmental Protection Agency conducted surveys of the benthic communities in the main basin of Lake Huron as well as in the Saginaw Bay. The survey results indicated that while there is no lakewide impairment of the benthic community, significant problems with the benthic community were observed in the Saginaw Bay.

The sporadic benthos studies in the bay have documented that what was once a rich array of small animal organisms characteristic of an unpolluted riverine benthic community has undergone dramatic changes in response to increased pollution. The high oxygen demand created by increased decomposition of organic debris in the sediments has decreased dissolved oxygen levels below that needed to support certain pollution-intolerant organisms such as mayflies.

Species in the bay are now characterized by those that are tolerant of pollution, a situation which is characteristic of a eutrophic system. Studies conducted during the 1980s found that all the benthic macroinvertebrate samples collected at a number of locations in the Saginaw River channel, from Carrollton to the mouth of the river, were dominated by pollution-tolerant species, principally bottom-dwelling worms and midges. The same study collected benthic macroinvertebrate samples at 11 locations in the Saginaw Bay navigation channel. All organisms collected were pollution tolerant. In neither sampling were pollution-intolerant species found. Significant changes have occurred over time in *oligichaete* (worm) populations, *amphipod* (crustacean) populations, and *pisidium* (fingernail clam) populations.

Perhaps the most striking change has occurred in the abundance of burrowing mayfly nymphs, most notably *Hexagenia* sp. These “fish flies” were once prolific in Saginaw Bay. Long-time residents remember the days when “fish flies covered buildings and streets after a big hatch.” Sampling by the National Oceanic and Atmospheric Administration (NOAA) since 1970 has identified only a few individual nymphs where once there were millions.

In addition to “traditional” pollution, the benthic community of Saginaw Bay has been affected by the introduction of exotic invaders into the system. The most influential of those is the zebra mussel, which was first found in Saginaw Bay in 1989. In just a few short years, its introduction has significantly altered the benthic structure of the bay. Its proliferation has compounded the challenge of measuring improvements in benthic communities.

Drinking Water

There are five communities that draw water from Saginaw Bay for public water supplies: Bay City, Saginaw/Midland, Caseville, Port Austin, and East Tawas. There has been a history of taste and odors in the drinking water taken from the bay, with the problem particularly pervasive before 1980.

The Saginaw/Midland water intake, which accounts for 85 percent of all drinking water taken from the Saginaw Bay, had significant taste and odor problems during the 1970s. In all but one of the years between 1974 and 1979, test results at the Saginaw/Midland water intake exceeded the federal threshold odor standard. The Bay City raw water intake also has had severe taste and odor problems. The RAP cited restrictions on drinking water taken from the bay as an impairment, since use of the water from the bay required treatment of raw water beyond the standard treatment for similar water supplies elsewhere in the Great Lakes. Ozonation was added to the Bay City treatment sequence in 1979 in order to address taste and odor problems and is still in use at the Bay City water supply treatment plant.

The serious taste and odor problems associated with water supplies withdrawn from the Saginaw Bay in the 1970s have been traced to two organisms that thrive under nutrient rich conditions—specifically, the blue-green algae *aphanizomenon* and *actinomycetes*, a common soil bacteria. High levels of nutrients were recorded in the period from 1974 to 1986. Nuisance algae blooms of blue green algae, *microcystis*, have occurred in Saginaw Bay since 1994. These recent nuisance blooms of microcystis have been linked to increases in zebra mussel densities in the bay rather than increases in phosphorus levels.

What We Have Accomplished

Steps toward Controlling Degradation of the Benthic Community

Eutrophication (with the associated decrease in dissolved oxygen and increase in sedimentation) and contamination due to the discharge of toxic chemicals are the two primary factors that have been linked to the changes that have occurred in the benthic community of the bay.

This report's section on "Sediment Contamination" documents the substantial progress that has been made over the last 25 years in the control of toxic organic chemicals and heavy metals within the area that drains to the bay. State and federal water pollution control programs, federal controls on the use of pesticides and certain industrial compounds, and enforcement actions for the targeted removal of severely contaminated sediments have significantly reduced the quantity of toxic chemicals reaching the bay. While residual levels of these toxic chemicals persist in the sediments of the bay, decomposition and physical covering of remaining contaminants may eventually remove this source of impairment to the benthic community.

Major steps also have been taken to control sources of phosphorus entering the Saginaw Bay. This report's section on "Bacteria" discusses how the nearly 700 million dollars spent by communities in the Saginaw Bay drainage areas has improved the treatment of sanitary waste since 1972. These investments in improved wastewater treatment were in large part responsible for the estimated 50 percent reduction of phosphorus inputs into the bay between 1975 and 1978. The statewide limit on phosphorus levels in home laundry detergents sold in Michigan since 1978 also has contributed to the reduction of nutrient loading in the bay. Phosphorus contributions from wastewater treatment plants in the Saginaw River watershed have been reduced by an estimated 70 metric tons/year since the early 1970s. Improved agricultural management practices to control fertilizer runoff in the watershed have resulted in an estimated phosphorus reduction of another 233 metric tons/year from these non-point (or diffuse) sources. Total phosphorus loads to Saginaw Bay declined from an estimated 1,700 metric tons/year in 1973 to 665 metric tons in 1982. The most recent measurements of average total phosphorus concentration in the Saginaw Bay indicate concentrations have decreased significantly from the levels observed in the 1970s and early 1980s.

Decrease in Undesirable Algae

Dramatic decreases in certain blue-green algal species have occurred in the Saginaw Bay in recent years. The nitrogen/phosphorus ratios (N:P) measured in the bay no longer favor the production of problematic blue-green algal. Chlorophyll "a" concentrations (a measure of algal growth in water) have declined significantly in both the inner and outer portions of the bay. Studies have concluded that the direct effects of phosphorus-induced phytoplankton overproduction in Saginaw Bay on the rest of Lake Huron also have been dramatically reduced.

Nevertheless, problems remain with non-point (diffuse) sources of phosphorus in many of the subwatersheds draining to the bay. Estimates indicate that 80–90 percent of phosphorus now entering the bay is coming from non-point sources. In 1998, a report entitled *The Impact of Watersheds on Tributary Water Quality in Saginaw Bay* was completed. It found increasing concentrations of total phosphorus progressing from the more natural areas on the western side of the Saginaw Bay toward the more agriculturally influenced tributaries on the east side of the bay. The report also found that phosphorus concentrations in the rivers studied were higher under high-water table regimes (wet weather) than under drier conditions.

Decline in Taste and Odor Problems in Drinking Water

While formal records have not been kept, it is clear from interviews with water treatment plant personnel that drinking water taste and odor problems from the bay water intakes have declined dramatically in recent years. One plant operator pointed out that complaints dropped significantly during the 1980s, spiked during the early years of zebra mussel invasion, and have been at relatively low levels since.

As mentioned previously, blue-green algal growth has been reduced in the bay, primarily as the result of an improved N:P ratio, as changes in the ratio of nitrogen to phosphorus can effect algal species composition. Under phosphorus-rich conditions, when nitrogen is limited, blue-green algae have a competitive advantage. Data shows that while nitrogen concentrations have declined somewhat, a much more dramatic decline has occurred in phosphorus levels in the bay. It is likely that the dramatic reduction in blue-green algal, particularly in the outer Saginaw Bay region, has been a major factor contributing to reduced taste and odor problem days for all five drinking water systems.

THE GOALS

Eutrophication

Control of phosphorus inputs was the principal pollution control strategy adopted under the 1972 Great Lakes Water Quality Agreement between the United States and Canada. The 1978 Great Lakes Water Quality Agreement led to specific targets for phosphorus in the bay (15µg/l). The goal was to reduce phosphorus loading into Saginaw Bay to levels that restore the bay to its historic mesotrophic condition.

The remaining challenges relate to non-point sources of phosphorus, and include addressing agricultural and residential use of fertilizers, animal wastes, failing septic systems, and the need for reducing erosion and sediment delivery from land adjacent to stream corridors.

Noteworthy progress in reducing non-point pollution in the watershed is particularly challenging because of the significant loss of the buffering capacity of wetlands and the amount of drainage systems (usually agricultural) that have been installed over the past 100 years. Further improvement

efforts will need to focus on subwatershed approaches, targeting the diverse sub-ecosystems in the watershed for phosphorus reduction.

Benthic Community
The goal is to reduce nutrient loading in Saginaw Bay to levels that allow restoration of the benthic community in the bay to its historical mesotrophic condition. If the benthic community is restored, it will mean that nutrient loading into the bay has been effectively controlled, the effects of toxic chemicals have been eliminated, and valuable populations of fish food organisms have been restored.

Drinking Water
The goal is to eliminate drinking water taste and odor complaints from those who use water supplies derived from the bay.

Measuring Success

Ever since the 1972 Great Lakes Water Quality Agreement was signed by Canada and the United States, it has been widely accepted that one of the major challenges to the long-term health of the Great Lakes is the control of excessive nutrient loading caused by human activity. Because the Saginaw Bay is shallower than the rest of Lake Huron, and because it possesses a unique shape and topography that prevents the mixing and circulation of water, the bay is particularly vulnerable to eutrophication.

While various actions over the past 30 years have resulted in improved water quality in the bay, the collection of data to demonstrate change has been inconsistent, often haphazard, and subject to the fiscal whims of public agencies. The following section recommends specific measures for each of the three ecosystem use impairments identified for the Saginaw River/Bay Area of Concern (AOC).

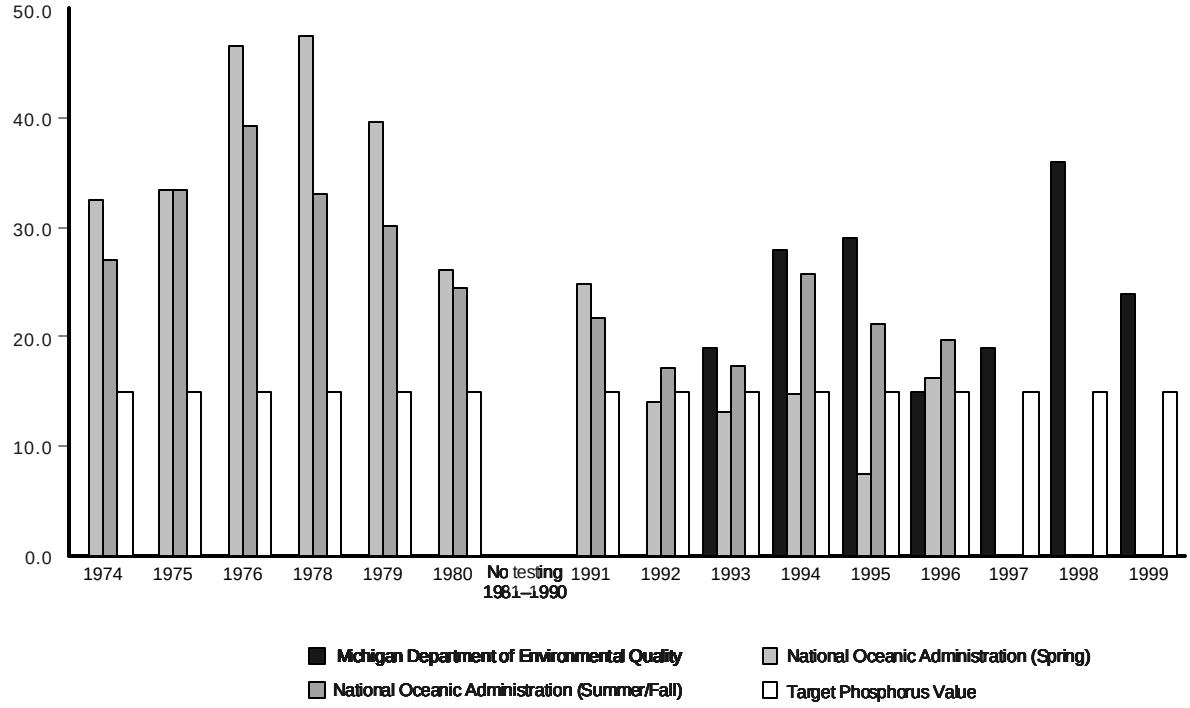
Eutrophication
Measurements of total phosphorus concentrations in the waters of Saginaw Bay were collected on a fairly regular basis during the 1970s and 1980s. However, as a result of significant cuts in monitoring expenditures by the State of Michigan, data collection has been sporadic. Nevertheless, it is clear that significant progress has been made in arresting eutrophication in the bay. While some pollution-tolerant benthic species have not yet returned, there have been dramatic reductions in blue-green algal in the bay. Exhibit 5 indicates the trends for total phosphorus concentrations for Inner Saginaw Bay as summarized by the Michigan Department of Environmental Quality's (MDEQ's) Office of the Great Lakes from data collected since 1974 by MDEQ Surface Water Quality Division and the NOAA Great Lakes Environmental Research Laboratory. The data indicates that since 1978, significant reductions in the total phosphorus concentrations in the inner bay have been recorded.

Targeted Restored Condition

Eutrophication The average concentration of total phosphorus is 15 µg/l or less, in accordance with the supplement to Annex 3 of the 1978 Great Lakes Water Quality Agreement.

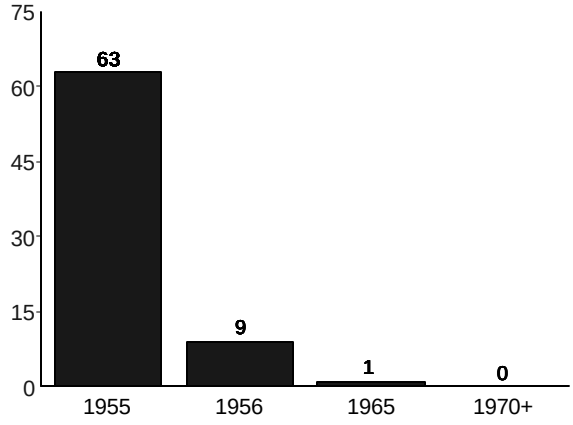
Benthic Community
Data has been collected since 1955 on the number of mayfly nymphs in the open bay. Mayfly abundance is a particularly good indicator of the status of bottom sediments. Burrowing mayflies, particularly those of the genus *Hexagenia* sp., are an important food source for many species of fish and are intolerant to pollution. The data shows that burrowing mayfly nymphs decreased in the

EXHIBIT 5
Total Phosphorus Concentration Value (µg/l) for Inner Saginaw Bay



SOURCE: National Oceanic Administration, Great Lakes Environmental Research Lab.
NOTE: Data for certain years (1977 and 1981–1990) are missing due to sporadic testing.

EXHIBIT 6
Number of Mayfly Nymphs in the Saginaw Bay (per square meter)



SOURCE: Public Sector Consultants, Inc., 2000.

open bay from 63/m2 in 1955, to 9/m2 in 1956, to 1/m2 in 1965, to 0/m2 in 1970. Measurements conducted by the NOAA since 1970 indicate that mayfly nymphs remain essentially absent from the bay. This trend is portrayed in Exhibit 6.

In recent years, there have been reports by reliable individuals of moderate, occasional "hatches" of mayflies occurring in the bay, although such observations have not been verified by benthos sampling. *Hexagenia* are intolerant of pollution but capable of making significant recovery once pollution has abated. In fact, *Hexagenia* production in Lake Erie nose-dived during the same period, but significant recovery of the population there has been noted in recent years.

While the NOAA has been collecting samples of *Hexagenia* sp. nymphs for 30 years, funding to

maintain that data record is currently in jeopardy. Return of significant populations of *Hexagenia* sp. nymphs to the benthic zone of Saginaw Bay would signal a dramatic improvement in the bay's water quality.

Using the number of burrowing mayflies as an indicator of success may have its limitations. Significant changes that are occurring in the bay as a result of the invasion of numerous exotic species, including benthic organisms, may preclude reestablishment of mayflies even when water quality is restored. Should conditions other than those responsible for designation of this AOC prevent the reestablishment of burrowing mayflies in the bay, a different indicator may be needed to measure restored benthic conditions.

TARGETED RESTORED CONDITION

Benthic Community Samples of mayfly nymphs collected in the open waters of Saginaw Bay exceed 30/m2 for two consecutive years, based upon established sampling methods.

Drinking Water

Current drinking water treatment systems have effectively eliminated most of the taste and odor complaints related to bay water supplies. Measurement of the nitrogen to phosphorus ratio in the bay is the best indirect evidence that conditions no longer favor odor-causing organisms. Data collected by the NOAA, Great Lakes Environmental Research Laboratory on N:P ratios in Saginaw Bay (summarized in Exhibit 7) indicate that conditions have improved in the bay since 1994 but that the targeted ratio of 29:1 has still not been achieved.

TARGETED RESTORED CONDITION

Drinking Water The N:P ratio measured in Saginaw Bay is at least 29:1, indicating that conditions once favoring blue-green algal populations responsible for former taste and odor problems in drinking water withdrawn from the bay are no longer present.

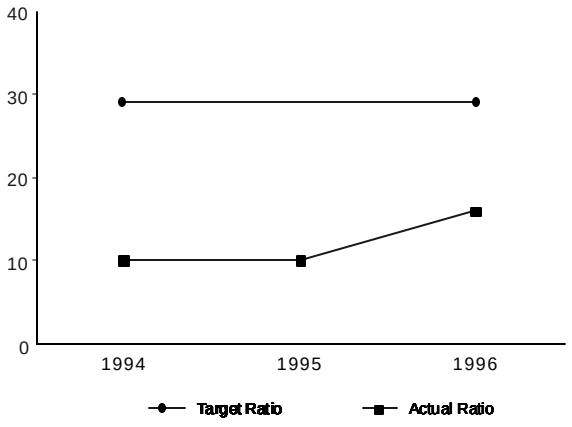
NEXT STEPS

Continuing progress toward eliminating beneficial use impairments in the Saginaw River/Bay AOC will require cooperation among units of government and a renewed commitment from citizens of the area. The following actions are recommended to both reduce remaining sources of phosphorus entering the bay and measure progress toward achieving the targeted restored conditions.

Eutrophication

- Prioritize subwatersheds (or smaller sub-ecosystems) that are tributary to the bay on the basis of how much phosphorus they contribute and develop and support plans that will result in significant reductions.
- Track the success of local programs (like the federally funded Conservation Reserve En-

EXHIBIT 7
Estimated N:P Ratio, Saginaw Bay



SOURCE: National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Lab.

hancement Program) that make full use of available state and federal funds to protect watercourses by providing *buffer strips*, or protective strips of land surrounding bodies of water that can trap and hold nutrients contained in runoff.

- Continue to support efforts to improve and document the management of crop residue, fertilizer, and animal and human waste applications on agricultural land in the basin.
- Monitor Saginaw Bay periodically to determine phosphorus concentrations.

Benthic Community

Support funding for annual monitoring and reporting of the abundance of *Hexagenia* sp. in the bay.

Drinking Water

Periodically determine N:P ratios in the bay, particularly at or near water system intakes.

Emerging Issues

Exotics

The Great Lakes themselves are now home to 146 species that did not exist here in pre-European-settlement times. Some of those species, like the sea lamprey and alewife, arrived in the lakes as a result of the building of the Welland Canal, which opened a route for species that previously had been blocked by the Niagara Falls. The canal provided species capable of living in both freshwater and saltwater with relatively easy access to the lakes.

Other non-native species, like chinook salmon and rainbow trout, were intentionally introduced into the Great Lakes by governments in response to declining populations of native species that had been dramatically affected by overfishing and the early exotic invaders. Still others, like rainbow smelt and pink salmon, were accidentally released into Great Lakes waters in Michigan and Canada, respectively.

Finally, ballast water released from ocean-going vessels has introduced species like the zebra mussel, round goby, and ruffe. While the federal government has taken steps to require lake-bound ships to exchange ballast water (ocean for fresh water) before entering the Great Lakes, nearly three-quarters of all ocean-going vessels entering the Great Lakes have "no ballast on board" (NOBOB). Nevertheless, they take up ballast upon entering the lakes and mix it with sediments already onboard, which may contain viable populations of exotics that are in turn released into the lakes when that ballast is discharged.

The wetlands landscape also has suffered from the introduction of exotics. Purple loostrife is an invasive Asian plant species that was originally brought to this country as an ornamental. It has the ability to out-compete many of Michigan's native wetland species and is now a common sight in wetland habitats along the bay. The gypsy moth, another invader, has had dramatic impacts on both the aesthetics and growth rate of some of Michigan's most important hardwoods, including many in the Saginaw Bay watershed.

The problem with invasive exotic species, whether land-based or aquatic, is that once established they are nearly impossible to completely eliminate. Eradication efforts have been attempted in many locations across the globe and have nearly always failed. Hence, management of the established invaders and prevention of new invaders are the wise public policy choice.

Land Use and Sedimentation

The 1992 *Michigan Relative Risk* report identified "the lack of coordinated land use planning that recognizes the importance of ecosystems" as one of the principal threats to the environment of the state. The issue of land use is many-faceted, and raises questions about

- the loss of agricultural, forest, mining, and tourism-related lands;
- the degradation of urban living, including the aging of infrastructure and the concentration of poverty; and
- the construction of impervious surfaces (including roofs, parking lots, streets, roads and highways) that increase the flow of water to watercourses that ultimately reach the Great Lakes, including the Saginaw Bay.

In pre-European-settlement times, the Saginaw Bay watershed was home to eight distinct biological communities, which provided for a unique blend of flora and fauna. These biological communities included Great Lakes marshland; lakeplain oak openings; lakeplain prairies; hemlock/white pine complexes; beech/sugar maple/hemlock complexes; hemlock/white pine/cedar complexes; white pine/hemlock/tamarack complexes; and beech/sugar maple forests.

The watershed today is dramatically different from that of early history when the Saginaw area was one of the focal points of Native American settlement and trade in the Great Lakes Region. Human-engineered changes to the landscape of the Saginaw Bay area have been massive. The pre-settlement forests (upland conifer/mesic pine and hemlock) that once covered nearly one-quarter of the landscape of Saginaw Bay now comprise less than one-hundredth of the land area of the watershed. While wetlands once extended as far as three miles inland along the bay, the remaining marsh and wet prairie zone along the bay is now only a narrow fringe. More than half of the landscape in today's watershed is agricultural, and nearly 7 percent is urban. There are only remnants of pre-European-settlement landscape conditions, as agricultural land has replaced forestland as the principal land type in the region. (See Exhibit 8.)

Michigan State University and the Center for International Earth Science Information Network (CIESIN) completed a study in the mid-1990s that projected growth patterns in the Saginaw Bay watershed over the next several decades. The projections, like those for much of Michigan, indicate a sprawling development pattern that will dramatically increase the amount of "urbanized" land at the expense of natural conditions. Studies of land use patterns in Michigan have projected that while population will grow at a moderate rate, the amount of land used per capita will grow dramatically. Resultant increases in impervious surfaces (such as parking lots and roads) and changing drainage patterns will only compound the difficulty of addressing the problems of non-point pollution, the most significant future threat to the Saginaw Bay ecosystem. Such projections portend difficult challenges to both the economy and the ecology of the Saginaw Bay watershed.

In 1992, a pesticide screening study was conducted on the tributaries to the Saginaw Bay. This screening study found that some pesticides were occasionally present during storm events in 23 of the 27 Saginaw Bay tributaries sampled. These screening data suggest that the presence of pesticides in the tributaries may be seasonal in nature. The intermittent presence of detectable levels of pesticides in these tributaries was expected since similar findings have been noted in studies in Michigan and other Great Lakes states. Of 11 pesticides measured, six were occasionally found above their respective Michigan Water Quality Standards Rule 57(2) guideline levels. Pesticides were detected above guideline levels in eight of the tributaries sampled. On the basis of these screening data, it

EXHIBIT 8
Type of Pre-European-Settlement and Modern Land Cover in the Saginaw Bay Watershed

	Pre-settlement		Modern	
Cover type	**Hectares**	**Percentage of landscape**	**Hectares**	**Percentage of landscape**
Northern hardwoods (beech, maple, hemlock)	307,096	13.79%	66,054	2.97%
Central hardwoods (beech, maple, oak)	708,662	31.82	130,657	5.87
Aspen, birch	13,973	0.63	126,436	5.68
Upland conifer - dry pine	24,356	1.09	39,510	1.77
Upland conifer - mesic pine and hemlock	517,059	23.26	3,560	.16
Wetland - conifer	283,477	12.73	13,600	.61
Wetland - hardwoods	212,369	9.53	259,034	11.63
Wetland - shrubs	3,711	0.17	43,240	1.94
Grassland and savanna	83,535	3.75	222,029	9.97
Marsh, wet prairie	54,902	2.46	18,410	0.83
Agriculture	0	.00	1,127,923	50.64
Urban	0	.00	153,554	6.89
Water	17,283	.78	23,416	1.05
TOTAL	**2,227,423**		**2,227,423**	

SOURCE: Michigan Natural Features Inventory, 1998.

cannot be concluded that there were adverse, long-term public or environmental health effects caused by pesticides in the Saginaw River/Bay watershed during the time of this study. The presence and concentration findings of this screening study suggest, however, that additional, more focused pesticide monitoring in the watershed may be warranted to allow a better evaluation of the potential for adverse effects.

MAINTAINING MOMENTUM FOR RESTORATION

The targeted restoration conditions outlined in this report are important steps in achieving restoration of the Saginaw River/Bay. Achieving the restoration targets may allow the Saginaw River/Bay to be removed from the list of worst polluted areas in the Great Lakes. They alone will not, however, assure restoration of the valuable natural resources that have been impaired over the last 150 years, particularly as issues have emerged that threaten this valuable natural resource. The restoration targets should be viewed as a major interim step in an iterative process of achieving full restoration, not as a final step that precludes further action. Many additional actions will be required to achieve sustainable development in the watershed and maintain the productive capacity of the natural resources upon which we depend for our economic wellbeing and quality of life. We now have a better understanding of the problems and solutions, however.

This goal is not unrealistic. The problems identified in the river and bay area 30 years ago when it was first designated as an Area of Concern appeared to many to be insurmountable. Through the persistent efforts of many people and organizations and the investment of literally hundreds of millions of dollars, however, major improvements have been realized. What has already been accomplished can be used to motivate the public to complete the task of fully restoring the river and bay.

If we have learned anything in the process of addressing past problems, it is that it is much more efficient and cost effective to prevent pollution problems than to remediate them. We now understand that not all problems can be addressed by simply treating them at the end of the pipe. Some chemicals are simply too toxic and persistent, or too difficult to contain once used to allow them to be manufactured. Others need to be restricted in use or recycled and recovered prior to entering liquid or solid waste streams. Individual residents, farmers, private businesses, and governments within the Saginaw Bay watershed need to change their behavior to achieve sustainable development of the region and protection of the river and bay.

Finally, the efforts to restore the Saginaw River/Bay have made it abundantly clear that we share common problems with other regions of the country and the world. Some of the mercury, PCBs and other chemicals affecting the quality of the area's water resources are transported to our watershed by global air streams from distant sources. In turn, environmental pollutants manufactured, used, or disposed of in our region contribute to problems in other areas.

The complex chemical, industrial, and agricultural activities of the area are crucial to the economic wellbeing of the residents of the region. Finding ways to support this economic activity without degrading the environment is a major challenge. This report documents what has already been accomplished, proposes the interim next steps, and provides the momentum to encourage stakeholders in the region to work together toward achieving a fully restored Saginaw River/Bay which can function as a model for the Great Lakes region.

Next Steps

A comprehensive plan for sustainable development of the Saginaw River/Bay area should be developed that includes specific recommendations for pollution prevention activities applicable to industrial and commercial enterprises, agricultural operations, government functions, and individual households.

GLOSSARY OF ACRONYMS AND TERMS

AOC	Great Lakes Area of Concern designated by the International Joint Commission.
Actinomycetes	Common soil bacteria.
Aphanizomenon	A blue-green algae which can cause taste and odor problems in drinking water.
Benthos	Organisms that live on a lake or river bottom.
Bioaccumulation	The increasing concentration of chemical substances through successive levels of the food chain.
Body contact recreation	Term used to define state water quality standards for bacterial contamination, to protect the health of people who participate in water recreation activities such as swimming (full-body contact) or fishing and boating (partial-body contact).
Buffer strips	Protective strips of land adjacent to bodies of water which can trap and hold pollutants and sediment contained in runoff.
CIESIN	Center for International Earth Science Information Network.
Combined sewer overflow or CSO	A discharge into a body of water, usually the result of a heavy rain or snowmelt that exceeds the capacity of the combined storm and sanitary system. Untreated CSOs are a major source of microorganisms that threaten public health.
DDT, DDE, and DDD	A group of closely related persistent organic pesticides. DDT was widely used in the United States until severely restricted by the EPA in 1972. DDE and DDD were produced through the breakdown of DDT in the environment, though they were also sometimes used as separate products. DDT = dichlorodiphenyl trichloroethane; DDE = dichlorodiphenyl dichloroethylene; DDD = dichlorodiphenyl dichloroethane.
EPA	The United States Environmental Protection Agency.
Eutrophication	Naturally, the slow evolutionary process of aging of freshwater lakes leading to an increase in productivity and decrease in depth. Accelerated lake aging due to man's activities (i.e., cultural eutrophication) describes artificial increases in productivity due to the addition of nutrients, usually phosphorus, and increased sedimentation due to soil erosion.
IJC	The International Joint Commission.

Impairment or impaired use	The degradation or destruction of a productive use of a water body (e.g., boating, fishing, fish and wildlife habitat or drinking water supply).
MDEQ	The Michigan Department of Environmental Quality.
MDNR	The Michigan Department of Natural Resources.
Microcystis	A blue-green algae. Its excessive growth can cause unsightly floating mats and harmful effects on fish and other aquatic organisms.
NOAA	National Oceanic and Atmospheric Administration.
NOBOB	Ocean-going vessels with "NO Ballast water On Board."
Non-point source pollution	Pollution entering water bodies that is diffuse, e.g., surface runoff from agriculture or urbanized areas.
On-site treatment system	Usually a septic tank with a drain field.
PBB	Polybrominated biphenyl, a class of persistent toxic organic compounds manufactured for use in applications where the chemical's fire retardant characteristics were desirable. Production in Michigan was responsible for a major food contamination problem in the 1970s.
PCB	Polychlorinated biphenyl, a class of persistent toxic organic compounds manufactured for use in a wide variety of industrial and product applications related to its fire retardant and electrolytic properties. Severely restricted in Michigan in 1977 due to environmental contamination problems related to its use.
Point source pollution	Pollution from concentrated, well defined sources such as wastewater treatment system pipes or storm water pipes.
RAP	Remedial Action Plan.
Sanitary sewer overflow or SSO	An unlawful, untreated sewage discharge into a water body from a sewer system designed to transport only sanitary waste.
Sedimentation	The deposition of eroded soil and sand particles in the bottom of water bodies. Alteration of natural landscapes to support residential, commercial, and industrial activity can increase erosion and flows that increase the rate of sedimentation.
WIN	The Saginaw Bay Watershed Initiative Network.