Section V. System Stressors and Specific Responses

V. A. Land Development and Urban Expansion

Land development and urban growth can be viewed as the ultimate stressor–the source of the collective impacts of all human activity across the landscape, including the impacts listed under separate subsections within this section. Although all development impacts habitat, not all development impacts habitat equally. Development can be viewed as any conversion or change in the land cover due to a human activity, such as agriculture (since it involves a range of landscape modifications) as well as urban development, which includes cities, towns and villages. Urban development includes the buildings (houses, stores, office buildings, factories, etc.), the roads and highways necessary to connect those buildings, the other infrastructure and facilities needed to service these areas, including water and sewer networks, treatment plants, and a variety of other networks and facilities–from rail lines and yards to ports and marinas.

V. A. 1. Urban Expansion

One of the most significant land use issues in the Great Lakes region is the continuing growth of major metropolitan areas and sprawl of residential areas and related development[1]. C-CAP data show that 23 percent of the project area, or approximately 175,000 acres (70,819 hectares) is "developed" land, including both high and low intensity developed lands. Most development occurs in the Michigan portion of the project area, in Detroit and its northern suburbs[2]. Only about 9 percent of the Canadian side of the project area is considered developed while about 43 percent of the land on the U.S. side is developed (See Figure #___ in Section IV. A. 1.).

> **HIGHLIGHT**
> Since World War II, the human footprint on the land around the Great Lakes has been transformed by a major shift in land development patterns from high-density urban development to low-density suburban and rural development.

Urban development and expansion on the U.S. side of Lake St. Clair increased sharply in the early 1900s. Since World War II, the human footprint on the land around the Great Lakes has been transformed by a major shift in land development patterns from high-density urban development to low-density suburban and rural development[3]. Over the past half century, distinct cities, towns and rural areas evolved into a sprawling metropolis. Dominated by strip malls and subdivisions, the older suburbs are connected by a vast network of wide lane roads and boulevards. In newer developments, rural roads are congested with traffic loads that they were never intended to accommodate. The causes and consequences of sprawling development are the subject of much debate, some of which has been discussed in Section II. B. of this document.

Urban expansion is predominant on the U.S. side of Lake St. Clair while the Canadian side remains primarily agriculture with pockets of urban development. Analysis of the C-CAP land cover data for 1995 and 2000 shows a net increase of 4,800 acres (1,942.5 hectares) in total high and low intensity development within the project area and a commensurate reduction in all non-developed land categories[4]. (See Section IV. A.). On Walpole Island First Nation, although development tends to be lower density, the pressure to develop housing and infrastructure is growing as the population increases. Pristine natural areas are often used for home sites, in spite of a pervading respect for nature among community members, as land for building is difficult to acquire.

Urban development and expansion destroys and degrades habitat in numerous ways. Construction activities remove all or nearly all vegetation on the construction site and the soil is compacted and graded, decimating the natural habitat once provided by the site. Without vegetation to intercept the flow of rainfall, construction sites generate large volumes

FACT

Without vegetation to intercept the flow of rainfall, construction sites generate large volumes of sediment that readily runs off into nearby storm drains, streams, rivers and lakes.

of sediment that readily runs off into nearby storm drains, streams, rivers and lakes. Section V. A. 5. discusses the impacts of soil erosion and sedimentation.

Urban development results in impervious land cover in the form of roads, parking lots, sidewalks and rooftops. Impervious cover threatens water quality by preventing precipitation from slowly infiltrating into the ground. Specific issues associated with improper stormwater handling will be addressed in the following subsection. Although all development results in some impervious cover, the impacts of development are exacerbated by sprawling (e.g., low-density) development that requires more roads, rooftops and parking lots to connect the shops, homes and workplaces and house the automobiles necessary to get there. The "green" areas around these developments rarely compensate for the impervious cover as the soil is compacted and vegetation is usually comprised of lawns and ornamental shrubs and trees with lower water absorption and filtering capacity than native grasses, trees and shrubs.

There is growing interest in policies and programs, often known collectively as "smart growth" that aim to redirect public investments into existing developed areas, protect existing open spaces and guide urban development in a more sustainable and less environmentally-damaging, manner. In Michigan, efforts are underway to implement a series of recommendations made by the Governor's Land Use Leadership Council in 2003. Smart growth initiatives in Ontario have primarily been focused in what is known as the "golden horseshoe" area, generally those counties that border Lake Ontario, but interest in smart growth appears to be growing.

CASE STUDY

Macomb Town Center

The Macomb Township offices have been master planned into a large scale new urbanist development in the north central portion of Macomb Township which integrates commercial and residential development in a compact urban form. The new municipal offices, civic center, community recreation center, and senior center are all focal points in this two square mile area of new urbanism. The civic portion of development is well under way and residential development is now proceeding. This is one of the largest new urbanist developments within the Midwest (personal communication, Gerald Santoro).

However, urban sprawl has become entrenched in North American culture and significant changes in land development patterns will take concerted long term efforts that cut across all public policy arenas. Changes in tax policy, transportation policy, real estate policy and others will be required before a more planned or sustainable urban form or development pattern becomes well established.

V. A. 2. Stormwater

Historically, rain was viewed as something positive; farmers relied on rain for the success of their crops and rainwater recharged aquifers and the water table. Much of the water soaked gradually into the ground and was filtered through soil and plants. In the process, it was cleansed and cooled. Infiltrated stormwater moderated the flow of rivers and streams because it was released gradually throughout the year. As impervious surfaces have increased dramatically with increasing urbanization, however, stormwater has become one of the major sources of pollution degrading our water resources[5,6].

HIGHLIGHT

Urban sprawl has become entrenched in North American culture and significant changes in land development patterns will take concerted long term efforts that cut across all public policy arenas.

Traditional stormwater management practices have focused on directing stormwater into ditches and drains as rapidly as possible. Once water enters the drain system, it is routed directly into rivers and streams, and

CASE STUDY
Anchor Bay Watershed Management Plan

The Anchor Bay Watershed Management Plan was developed by a committee comprised of representatives from both county and community agencies, to fulfill their respective requirements under the Michigan Department of Environmental Quality Phase II Watershed-based Storm Water Permit. The Plan identified stakeholders, gathered available water quality, stormwater flow and habitat information, identified known impairments, identified and prioritized pollutant sources and established goals for the watershed. It then identified actions for which the communities would take responsibility, highlighted gaps between goals and planned activities and developed a list of recommended activities to be implemented by the local governmental agencies. With the completion of the plan, the individual communities qualify for Clean Michigan Initiative (CMI) grant funding to implement the activities recommended in the plan.

Additionally, the EPA has just awarded a $95,000 grant to study sources of identified pollutants and the hydrology of the waterways. Studying the hydrology, or flows, of the waterways will help the municipalities and the county identify whether the storm water retention requirements currently in place will prevent flooding and erosion as more land is developed. Below is the link to the Anchor Bay Watershed Project webpage.
http://awp.stclaircounty.org

can cause considerable damage downstream both to riparian lands and overall water quality[7]. Impervious surfaces add not only to the amount and rate of storm water entering our surface waters, but they also carry a number of pollutants such as fertilizers, pesticides, oil and bacteria from animal waste. The net result is increases in the frequency and duration of flood events, reduction in aquatic biodiversity, increased stream bank erosion and decreased infiltration into the groundwater table[8].

Governments on both sides of the border treat stormwater as a serious pollutant and implement stormwater control programs. Michigan has been delegated authority from the federal government to implement the Phase II stormwater program under the National Pollutant Discharge System (NPDES) permit program. Under this program, communities are required to develop Stormwater Management Plans to reduce pollutants being discharged through stormwater. Individual communities may obtain jurisdiction–based stormwater general permits or they can cooperate with other municipalities to obtain a watershed-based storm water general permit. Although the requirements are similar for both permits, the watershed-based permit provides far more flexibility in how these requirements are met and offers the opportunity for cost-sharing for some stormwater controls, as well as improved water quality throughout the entire watershed[9].

In Ontario, the Province of Ontario has required municipalities to address stormwater as part of the planning and development process. A combination of stormwater management practices are usually required to meet the multiple objectives of stormwater management. In 2003, an updated Storm Water Management Planning and Design Manual was released by the Ontario Ministry of the Environment. The manual serves as a baseline reference document for review of stormwater management applications for approval under Section 53 of the Ontario Water Resources Act, and is available online at: *www.ene.gov.on.ca/envision/gp/4329eindex.htm.*

FACT

Current best management practices for stormwater handling focus on watershed based planning, with the goal of reproducing pre-development hydrological conditions.

Current best management practices for stormwater handling focus on watershed based planning, with the goal of reproducing pre-development hydrological conditions[10]. They generally include an emphasis on protecting critical areas such as floodplains, wetlands, recharge areas, shorelines, stream courses and open spaces during the development process. In the remaining areas which can be developed, features such as vegetated swales, water gardens, green roofs, buffer strips, permeable paving and the use of native plants can slow the movement of water across the landscape and increase infiltration on site[11,12]. The Center for Watershed Protection has a number of useful publications, many of which can be downloaded from their website at: *www.cwp.org*.

V. A. 3. Habitat Fragmentation and Destruction

While there are a number of negative effects on natural systems associated with land development and urban expansion, the most direct impact is simply the outright destruction of complex functioning natural communities and the replacement of these communities with simplified, ecologically depauperate landscapes. Healthy ecosystems provide a multitude of services for both humans and wildlife; erosion control, sediment retention, soil formation, nutrient cycling, waste treatment, pollination, water supply and water regulation are just a few examples[13]. Short of outright habitat destruction, however, fragmentation of the remaining habitat results in myriad negative effects on ecosystem function, habitat quality, species diversity and species abundance. As discussed in Sections II. B. and II. D., demographic shifts and the expansion of urban/suburban development across the landscape have resulted in less wildlife habitat and a higher degree of fragmentation of the habitat that remains.

> **FACT**
> Healthy ecosystems provide a multitude of services for both humans and wildlife; erosion control, sediment retention, soil formation, nutrient cycling, waste treatment, pollination, water supply and water regulation are just a few examples.

The impacts of fragmentation vary widely, depending on the natural community under consideration, and the particular barriers separating fragments. Roads, for example can be crossed easily by most birds, but for earthbound animals like turtles, they are a source of dramatically increased mortality rates. An agricultural field presents a foraging opportunity for species such as white-tailed deer, but may completely prevent dispersal for some salamanders or woodland soil organisms. The size and shape of fragments, the distance and type of barriers by which they are separated, and the existence of connections or corridors between them can all contribute to the impact of habitat fragmentation on species richness and abundance, and ecosystem stability[14, 15].

Fragmentation can affect species richness and abundance in a number of ways. In general, animals requiring interior habitat are the first to decline[16]. Forest breeding birds, for example require large areas of forest interior. In smaller parcels, as the ratio of forest edge increases relative to the interior, nest predation by cowbirds can eliminate successful breeding efforts. Parcel shape can also be critical in determining available interior; circular parcels have low amounts of edge relative to their interior area, while long narrow parcels or those with irregular edges can consist almost entirely of edge. Edge-related increases in nest predation may extend as far as 200 meters into temperate forests, and accordingly, many interior bird species need at least several hundred hectares of forest for successful reproduction[17].

> **HIGHLIGHT**
> Demographic shifts and the expansion of urban/suburban development across the landscape have resulted in less wildlife habitat and a higher degree of fragmentation of the habitat that remains.

Animals with large territories are also first to disappear from an area as habitat becomes fragmented. Animals with smaller territories, in contrast, tend to persist longer, and in some cases, may become more abundant in small areas, as crowding increases.

Animals that specialize in edge habitats can increase significantly with fragmentation, but this is not always a good thing. White-tailed deer, for example, specialize in woodland edge, and their numbers are far higher than they were prior to European settlement. Because they wander widely, they can affect forest quality significantly and in some areas, they are a significant threat to plant communities because of over browsing[18]. In general weedier plant species tend to proliferate along habitat edges, and invasive species such as garlic mustard can become a serious problem.

As habitat fragments become increasingly isolated, movement between individual parcels is limited. As populations of plants and animals become increasingly isolated, gene flow between them is reduced, and with it, genetic diversity[19]. At the point when the dispersal of individuals between habitat fragments is eliminated, the possibility of local populations becoming extinct becomes increasingly likely. Conversely, when fragments are close, or connected by corridors, vacant habitats can be recolonized by dispersing individuals from adjacent habitats[20].

HIGHLIGHT

Careful planning is needed to provide a network of suitable habitat patches and effective corridors to maintain connectivity between them.

Habitat fragmentation can result in particular problems for plants. In a number of rare plants, as habitat fragments become smaller, seed output and seedling viability are reduced. Because plants don't move around, gene flow can be limited; for plants that depend on specialized pollinators or seed dispersers, as the size of habitat patches decreases, so do the opportunities for successful reproduction. Often, a population of plants may survive for many years; plant reproduction, however, is affected far more rapidly, and the decline in numbers of a particular species is often not noticed until it is too late[21, 22].

Careful planning is needed to provide a network of suitable habitat patches and effective corridors to maintain connectivity between them. Planning for conservation areas is discussed later in greater detail in Section 8.

V. A. 4. Fire Suppression

Although it may seem counterintuitive, fire is a critical process in many natural communities. Its benefits are discussed as a natural stressor in Section V. F. 2., but its suppression also needs to be examined as a significant cause of habitat loss and transformation. A number of the natural communities considered most at risk within the project area are considered fire-dependent systems: lakeplain oak opening, lakeplain mesic sand prairie and lakeplain wet-mesic prairie[23, 24, 25]. Historically, lightening strikes caused some fires and when population densities were lower, they were allowed to burn unhindered. Native Americans also used fire as a management tool: to clear land for planting, to encourage the new growth of vegetation for game and to maintain open conditions in the forests to facilitate passage through them[26].

CASE STUDY

Cultural traditions, traditional knowledge and habitat

The loss of cultural traditions and traditional knowledge constitutes a significant stressor for natural habitat on Walpole Island First Nation. The Walpole Island community is justifiably proud of its rich natural heritage, but community surveys have indicated that many community members are unaware of just how important this natural heritage is to other Canadians. In recent surveys, respondents listed forest, wetland and shoreline as important components of their natural heritage, but not a single person listed prairie by name. The Walpole Island prairies and species that they contain – so rich and rare throughout Canada – are collectively known as "weeds" by the Walpole Island community, although this term does not carry the same connotation that it might among non-native people. At the same time, the traditional value that the land once held for community members is subtly changing.

There are few fluent speakers of the Native languages on Walpole Island and most of them are elders. The collective (cont.)

In grasslands, periodic fire prevents gradual succession to brush or forest. It clears away dead vegetation from previous years, releasing nutrients, permitting light to reach smaller, more conservative plants and warming the soil surface. In some cases, some species of plants may actually require fire to germinate; the seed of New Jersey tea, for example, requires heat before it will germinate[27]. As fires were suppressed, many historical prairies and savannas in the U.S. and Canada have been replaced by forest, leaving only a few open grown oaks, or lingering prairie indicator species as evidence of their former existence. In forest ecosystems, in the absence of fire, many oak woodlands are being invaded by red maple or beech and sugar maple[28].

Although early settlers initially followed Native practices in burning to prepare fields for planting, as more and more buildings were constructed this was no longer practical. As towns and cities developed, natural ecological and cultural knowledge about the ecosystems of Walpole Island has by tradition been passed down orally and is not shared with outsiders. Much of this knowledge is being lost. Documentation of some of these values and traditions would safeguard against loss, but at the same time, would represent a weakening of the oral traditions.

While many traditions are maintained and handed down by elders to succeeding generations, others have lost their original context. Traditional methods of hunting and harvest, in many cases, have been supplanted by a reliance on modern conveniences that include chain saws, motor boats, ATVs and rifles. Individual rights to hunt, fish and harvest are an important part of First Nations identity and are often a source of income to the people who practice them, but without the feedback mechanisms and respect for the land that are part of the tradition of community involvement, over exploitation of the resources is possible.

Harvesting species such as sweetgrass is a traditional activity of cultural importance. It used to be done within a context of holistic habitat management, but now is often seen as a purely economic activity. Current harvest levels are probably not sustainable and damage to other species may occur during harvesting also.

Walpole Island Heritage Centre has been active in taking the lead in activities that will address some of the stressors and knowledge gaps that have been identified. Community input is of prime importance because initiatives are unlikely to be successful without endorsement from the population. An engaged population, however, will provide much of the habitat protection required. Traditional respect for the natural world and Native philosophies of appropriate interactions with nature are fundamental to the identity of First Nations peoples and are considered sacred obligations. Conservation of natural habitats cannot be separated from cultural issues[33].

fires could no longer burn freely, but were instead suppressed. On Walpole Island First Nation, fire has long been a part of traditional land management[29], and its prairies, savannas and oak forest reflect this. Tiny species such as pink milkwort, small white lady's slipper orchid and yellow stargrass, which are rare, protected or extirpated elsewhere are abundant[30].

The same concerns which have restricted the use of fire elsewhere, however, are beginning to take their toll on Walpole Island as well. The overall frequency and extent of burning has decreased as danger to people and property has increased with the intensity of development. Complaints about air pollution from neighboring communities in Canada during burns are frequent. In addition, many of the cultural aspects of the use of fire are no longer being transmitted effectively. Many fires are not planned as management activity and very few formally prescribed fires have been conducted. Many fires that do occur are the result of arson, diminishing community support for a dwindling practice[31].

Estimates based on the examination of aerial photos suggest that Walpole Island's prairies have been reduced from 1,804 acres (730 hectares) in 1972 to about 1,161 acres (470 hectares) in 1998, a loss of 36 percent. Some of this is the result of conversion to agriculture and housing, but most is due to encroachment by forest and open woodland in the absence of fire. Similarly, oak savanna has been reduced from 1409 acres (570 hectares) in 1972 to 890 acres (360 hectares) in 1998, a loss of 37 percent, mainly attributable to closing in of the forest canopy[32]. Walpole Island's grassland communities provide the best remaining example of what much of the region once looked like, but they are as vulnerable to the effects of fire suppression as the extensive prairies and savannas that once existed throughout the lakeplain.

V. A. 5. Agriculture

Agricultural lands typically include cultivated lands (orchards, nurseries, crops) as well as animal farming operations. This distinction is important when evaluating land use impacts, particularly in light of evolving agricultural practices. As noted in Section IV. A. 3., cultivated lands make up the single largest category of land cover within the project area, occupying nearly 50 percent of the total area[34]. Cultivated lands impact habitat by altering the natural vegetative cover. Habitats are destroyed as forests, wetlands and other natural vegetation are cleared, drained and/or diked for agriculture. In most areas within the project area, new lands are no longer being cleared for agriculture, with the exception of Walpole Island First Nation where economic pressures often encourage the conversion of natural areas to agriculture, which provides a steady income stream through agricultural leases[35]. For the plants and animals living on the land, both on Walpole Island and elsewhere, their habitat is simply and completely lost when the land is converted to agricultural uses.

Agricultural lands are an important source of soil erosion and sedimentation, chemical runoff (herbicides, pesticides, and insecticides) and nutrient runoff (nitrogen and phosphorous). (See Section V. B. 3. for a more detailed description

HIGHLIGHT

Agricultural lands are an important source of soil erosion and sedimentation, chemical runoff (herbicides, pesticides, and insecticides) and nutrient runoff (nitrogen and phosphorous).

of non-point source impacts). Impacts to habitats near cultivated land can range widely depending on the specific crop and farming practices. Practices such as no or low-till farming allow all or some crop residue to remain on the land, reducing soil erosion and sedimentation. Crop rotation and contour farming improve soil quality and crop productivity. Organic farming and integrated pest management eliminate or reduce use of agricultural chemicals, thus their runoff into nearby streams, rivers and lakes. These are but a few of a plethora of farming techniques evolving under the umbrella of "sustainable agriculture" and "whole farm planning" that reduce the ecological impacts of agriculture[36]. A number of Canadian and U.S. federal, state and provincial programs have been developed to encourage farmers to adopt practices that provide some conservation and/or habitat value[37]. Programs under the U.S. Farm Bill to promots conservation of agricultural lands are discussed in Section VI. A. 6. Programs for Private Landowners.

The impacts from cultivated land are a much greater issue on the Canadian portion of the Lake St. Clair coastal habitat project area due to the greater amount of land dedicated to agriculture. As of 2000, 77.6 percent of the Canadian side of the project area is cultivated land, while only 16.6 percent of the U.S. project area is cultivated land[38].

Another form of agriculture, animal husbandry, generally has some distinct ecological impacts. Land clearing is still an issue, but depending on the type of animal, the farming operation may actually require much less land. Chemical runoff diminishes with little need for pesticides, but the ecological impacts on and off-site from nutrient runoff are generally far greater and the main source is manure. Over the past several decades, the livestock and poultry industry has become more concentrated, developing into fewer and larger operations. These operations, known as Confined Animal Feeding Operations, or CAFOs, raise concerns over the use and disposal of animal manure. When used as a fertilizer, manure can produce valuable nutrients for crop and pasture growth. However, these same nutrients can pollute the water resources, and degrade or destroy aquatic habitat through runoff when too much is applied to the land. Such is often the case with CAFOs. Since 2002, under rules developed by the U.S. Department of Agriculture and the U.S. Environmental Protection Agency, CAFOs in the U.S. are required to obtain a permit, show that they are not discharging waste into surface waters, and also develop and implement a nutrient management plan[39].

HIGHLIGHT

Broader implementation of sustainable agricultural practices and whole farm planning can help offset the impacts of producing food and fiber and improve the relationship between habitat and agriculture.

Notwithstanding impacts, agricultural land uses are perhaps the least damaging form of development and the most reversible. Once land is paved over and built upon, there is very little chance of that land reverting to any sort of natural vegetative cover that can provide a quality habitat. Agricultural lands, on the other hand, provide the future possibility of habitat, by simply reverting to a natural state over time. Although it may not be particularly high quality habitat if left on its own, it has the potential to provide quality habitat through restoration. Programs under the U.S. Farm Bill to promote conservation on agricultural lands are discussed in Section VI. A. 7.

Broader implementation of sustainable agricultural practices and whole farm planning can help offset the impacts of producing food and fiber and improve the relationship between habitat and agriculture. Additional incentives and rewards are needed for farmers. Governments at all levels can augment education and outreach to the farming community and vice-versa so that policy is responsive to and reflects actual field experience.

V. A. 6. Soil Erosion and Sedimentation

Erosion is the detachment of soil particles by wind, rain and other forces. Sedimentation is the deposition of soil in streams, bays, wetlands and harbors, after it has eroded off of land. Impacts of soil erosion are diverse and are influenced by complex hydrological, physical, chemical and biological factors While erosion and sedimentation are natural processes, the rates at which they occur have accelerated due to human activities.

Sediment is made of different sized particiles which contain a combination of different minerals, bacteria types, and other organisms and may also include man-made chemicals, such as fertilizers and pesticides that bind to are bound to the soil particles

> HIGHLIGHT
> Increased erosion and sedimentation are directly related to land-use changes or to poor land management.

Erosion and sedimentation can negatively impact the health and function of stream channels. Changes in the balance between flow and sediment load can alter channel size and configuration, and consequently alter the system's hydrology[40]. Erosion and sedimentation can also degrade or destroy the aquatic habitat in rivers and streams (e.g., increased turbidity, reduced light penetration, increased temperature, reduced productivity, the elimination of pools and riffles necessary for spawning and feeding) as well as the species that inhabit them (e.g., gill abrasion, egg abrasion, reduced bivalve pumping rates, and direct mortality).

Increased erosion and sedimentation are directly related to land-use changes or to poor land management. This is a regular occurrence in agricultural areas, where many farmers must plow the soil to plant seeds. It can also occur when vegetation is removed for construction of new roads and buildings. Clear-cutting of forests can also expose soil to erosion, as can forest fires. This dislocated soil is then transported by wind and water. Some of this dislocated soil is deposited in ditches and stream channels, while the remainder passes through the system and contributes to the "sediment yield" or the total sediment that leaves a drainage basin (usually measured in tons/acre/year).

> GAP
> There are no precise measurements for how much soil is eroding in the watershed and being deposited in Lake St. Clair and information on sediment transport and yield is lacking.

Unfortunately, there are no precise measurements for how much soil is eroding in the watershed and being deposited in Lake St. Clair and information on sediment transport and yield is lacking[41, 42]. The only comprehensive soil erosion data available for the Great Lakes region, the National Resources Inventory (NRI), is only for agricultural lands and it is likely that a significant amount of sediment in Southeastern Michigan is eroding from developed areas. The NRI data demonstrates that regional and national erosion and sedimentation rates have declined over the past twenty years, yet appear to have leveled off in recent years with little change since 1992[43].

Lake St. Clair wetlands are highly sensitive to river flow and lake level fluctuations, which make understanding sediment transport, deposition, and resulting impacts particularly important[44]. Several key programs that address soil erosion and sedimentation are described below.

County Conservation Districts provide assistance to local landowners, organizations and governments to address natural resource issues. They provide technical assistance, conduct education and outreach, and implement conservation practices for soil erosion and sediment control. The Environmental Quality Incentive Program (EQIP), which was discussed in the previous section, provides resources for farmers to address problems with soil erosion and sedimentation.

The Great Lakes Basin Program for Soil Erosion and Sediment Control is a federal/state partnership designed to coordinate the efforts of the various levels of government on soil erosion and sediment control activities. The Basin Program (*www.glc.org/basin*) provides grants for program and technical assistance, demonstration and education projects. The Great Lakes Commission coordinates the Program, in partnership with the U.S. Department of Agriculture (National Resources Conservation Service), the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers.

HIGHLIGHT
It is not necessary to know exactly how much erosion is occurring to experience the impacts, or to prevent erosion and sedimentation. Greater effort is needed to apply existing programs and tools to reduce the impacts from land development and land use practices.

The U.S. Army Corps of Engineers is currently developing a sediment transport model for the Clinton River watershed to predict the amount of surface runoff and sediment that is being delivered to the river. The Macomb County Office of Public Works is also conducting a study on how land use changes over time have affected the geomorphology of the Clinton River. These models could be applied to a number of current planning efforts in the watershed, including Phase II stormwater permits, Total Maximum Daily Loads (TMDL), spill response and water quality modeling.

V. B. Altered Hydrology

A variety of habitat stressors can be classed under the general heading of altered hydrology; these stressors include filling and draining wetlands, dredging and regulation of water levels. Activities such as draining, dredging, diking and filling have modified the natural flow regime of Lake St. Clair, particularly in the delta, which has been extensively diked.

HIGHLIGHT
Activities such as draining, dredging, diking and filling have modified the natural flow regime of Lake St. Clair, particularly in the delta, which has been extensively diked.

All of these activities are regulated at the Federal level under Section 404 of the Clean Water Act (CWA) of 1972. Under this section, the U.S. Army Corps of Engineers (ACOE) is granted principal permitting authority, although the U.S. Environmental Protection Agency (EPA) is authorized to veto permits issued by the Corps for filling of wetlands. Michigan is one of two states that have authority to administer section 404 of the CWA, and its Department of Environmental Quality (MDEQ) shares jurisdiction with the Corps in some areas. State regulations that support the provisions of section 404 of the CWA are found in Part 303, Wetlands Protection, of the Natural Resources and Environmental Protection Act (NREPA), PA 451 of 1994, as amended[45]. Some wetlands in coastal areas are given further protection under Part 323, Shorelands Protection and Management, of NREPA.

In spite of improved wetland protection laws in the United States, isolated wetlands that are smaller than five acres are not protected. This gap in regulations has allowed the piecemeal conversion of wetlands to urban and agricultural uses and continues to pose threats to fish and wildlife habitat. A local unit of government has the authority to create wetland regulations that address wetlands not protected by the state, by implementing wetland ordinances. Wetland ordinances and other planning tools will be discussed in more detail in Section VI. C. Local planning tools for protecting habitat.

GAP
Wetlands smaller than 5 acres are unprotected by U.S. federal and state law and ther is no specific legislation to protect wetlands in Ontario. Local wetland ordinances are critical to protect and unregulated wetlands.

There is no specific wetlands legislation in Ontario or Canada. In Ontario, wetlands receive indirect protection through Ontario's Planning Act, Fish and Wildlife Conservation Act, Environmental Assessment Act, and Ontario Water Resources Act, among other legislation. However, other legislation, such as the provincial Drainage Act, still works against wetland conservation by permitting wetland drainage for agricultural purposes. At the federal level, the Canada Wildlife Act, Fisheries Act, Migratory Birds Convention Act, and Canadian Environmental Assessment Act provide some protection to wetlands through species and habitat conservation measures. Most often, wetlands are protected through policies and agreements. While certainly valuable, these vehicles do not have the same clout as legislation.

Wetland Permits in the US

A joint state and federal permit process has been established between the MDEQ and the U.S. Army Corps of Engineers (ACOE) for proposed projects in areas which have both state and federal jurisdiction. The MDEQ's Land and Water Management Division will determine whether a permit application requires joint state and federal review, and when appropriate, will forward these permit applications to the COE Detroit office for federal permitting review[46].

Permits are required for the following activities:

- Depositing or permitting the placement of fill material in a wetland
- Dredging, removing or permitting the removal of soil or minerals from a wetland
- Constructing, operating or maintaining any use or development including dikes, seawalls and docks in a wetland or (cont.)
- Draining surface water from a wetland

Wetlands and shorelines are regulated if they if they fall into any of the following categories:

1) connected to one of the Great Lakes or Lake St. Clair;
2) located within 1,000 feet of one of the Great Lakes or Lake St. Clair;
3) connected to an inland lake, pond, river, or stream; located within 500 feet of an inland lake, pond, river or stream;
4) Not connected to one of the Great Lakes or Lake St. Clair, or an inland lake, pond, stream, or river, but are more than 5 acres in size and located in counties with a population of more than 100,000; or
5) not connected to one of the Great Lakes or Lake St. Clair, or an inland lake, pond, stream, or river, and less than 5 acres in size, but the DEQ has determined that these wetlands are essential to the preservation of the state's natural resources and has notified the property owner[47].

V. B. 1. Water Level Changes

Natural fluctuations in water levels are an important part of the coastal area's ecological dynamic and productivity and are discussed in Section V. F. 5. Fluctuations can result in dramatic changes within Lake St. Clair's gently sloping marshes and lakeplain. Variable water levels create greater diversity among plants and animals that adapt to and depend on a highly changeable wetland environment. However, some changes in water levels are a result of explicit human intervention and tend to disrupt natural processes.

Human-induced changes in water levels are usually part of larger efforts to control and maintain desired levels of water for specific purposes. Human control of the outflow of Lake Superior affects water levels in the lower Great Lakes, including Lake St. Clair. The marshes of Walpole Island First Nation, parts of the St. Clair Flats areas in the delta, and much of the eastern shore of Lake St. Clair have been extensively diked; pumping stations and water level gauges have been installed so that water levels can be maintained at levels that are optimal for attracting and sustaining populations of game birds. Hunting and fishing are the foundation of Walpole Island First Nation's leading industry--recreation and tourism, and are significant revenue sources throughout the region. As such, management of these diked wetlands in a manner that can ensure their sustainability as an economic resource is of utmost importance.

In spite of their potential benefits, however, water levels that are artificially maintained at a constant level interrupt natural fluctuations that are beneficial to coastal ecosystems and result in negative impacts over the long term, particularly for natural communities such as lakeplain prairie, which require periodic flooding to persist. Water in shallow impoundments and drainage canals, when isolated from the flow of the Great Lakes, tends to have low oxygen levels and warms up rapidly, diminishing its value as habitat for fish and other aquatic organisms. Dredging in the St. Clair River is believed to have significant, yet temporary affect on water levels in the lake.[48]

V. B. 2. Draining

Wetland loss has been significant in both Michigan and Ontario and much of this can be attributed to the draining of wetlands for agricultural and urban development. Since 1873, over 70 percent of the wetlands have been lost on the U.S. side of Lake St. Clair, both for agriculture and urban development[49]. The Canadian portion of the watershed has experienced a similar loss of coastal wetlands. Between 1873 and 1968, much of this land was drained for agricultural and residential purposes. By the mid-1960s more than 40 percent of the wetlands directly associated with the lake were destroyed. By 1982, Kent County and its surrounding counties had lost 80-100 percent of their original wetland areas. Essex County lands draining to Lake St. Clair have lost over 97 percent of the wetland area and 95 percent of the original forests to agricultural and urban development[50]. Currently 92 percent of the Essex County lands are in agricultural use and 5 percent urban infrastructure with only 3 percent remaining as natural lands. The rate of conversion to agriculture has slowed in recent years, and some of the drained pasturelands and poorer cropland in the areas have been reflooded. While this allows some agricultural land to re-convert to wetland habitat, the quality of habitat provided by these wetlands is uncertain.

HIGHLIGHT

Since 1873, over 70 percent of the wetlands have been lost on the U.S. side of Lake St. Clair and the Canadian portion of the project area has experienced similar losses.

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Wetland Mitigation Banking

Michigan and federal wetland permits typically require that wetland lost through development, be mitigated[51]. Mitigation may be accomplished through creation of new wetlands, restoration of existing wetlands, or acquisition of approved credits from a wetland mitigation bank. Wetland mitigation banking refers to the process of creating or restoring wetlands which are used to offset future authorized wetland fills in a watershed. In Michigan, wetland mitigation banking is regulated under the wetland protection part of the Michigan Natural Resources and Environmental Protection Act[52].

Wetland mitigation projects are most likely to succeed on sites that were historic wetlands as their soils and hydrology are most conducive to reestablishment. In a 1997 MDEQ study funded by the USEPA, it was determined that the vast majority of mitigated wetland sites did not provide the ecological functions of the wetlands that they replaced. Only 22 percent of the projects studied were considered successful overall[53].

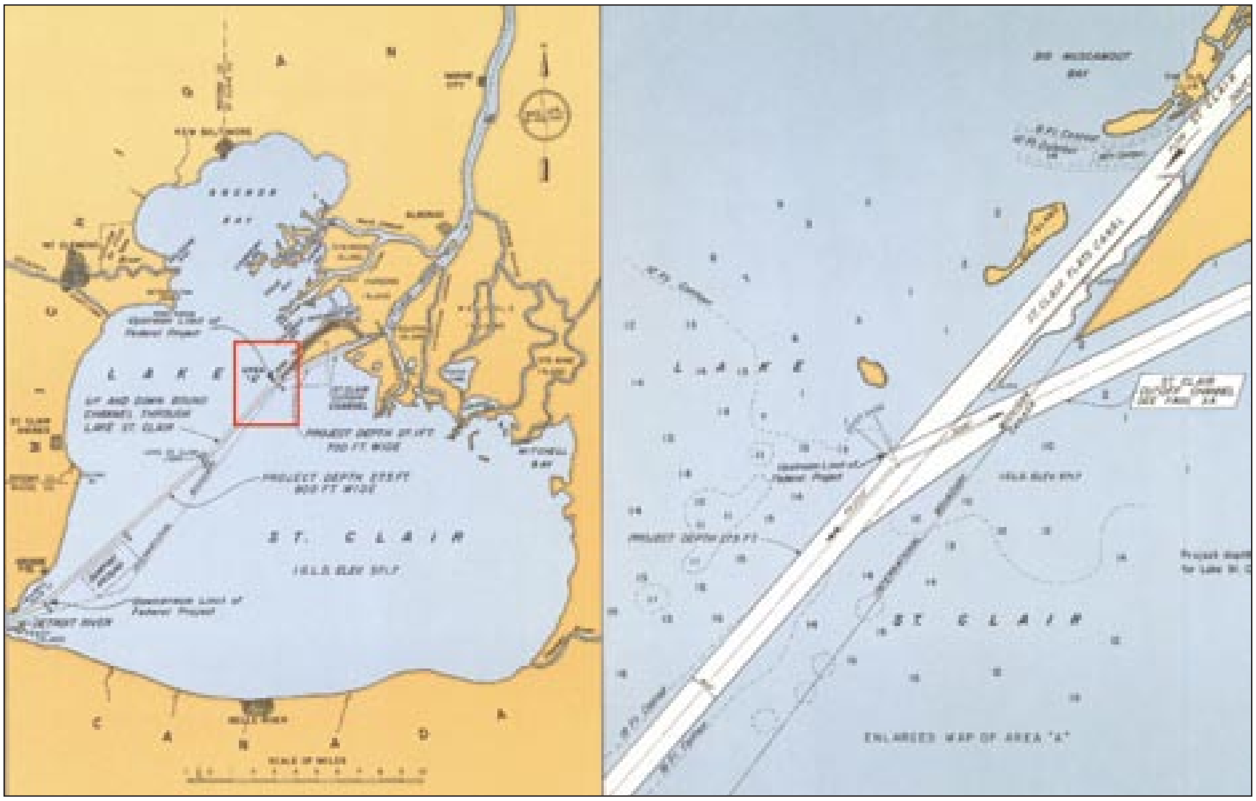
Successful wetland mitigation can be extremely expensive; although historic wetlands can be restored and monitored for as little as $5,000.00 US per acre, the average cost of a created wetland is $40,000.00 US per acre, not including the cost of the land[54]. Beyond the costs involved, however, and the mixed track record of mitigation projects, high quality wetlands simply cannot be recreated and their preservation is imperative.

V. B. 3. Filling and Dredging

Filling has severe effects on wetland areas, completely destroying them and eliminating all their beneficial functions[55]. Filling occurs primarily in developing areas as wetlands are converted to urban (residential, commercial, and industrial) uses. Although wetlands larger than five acres are protected, parcels smaller than five acres have been routinely filled. Filling often accompanies dredging, where accumulated sediments are removed from the bottom of waterways to maintain adequate depth for safe and efficient vessel operations. Dredged material that is removed must go somewhere and too often in the past it was used to fill wetlands.

Dredging of the St. Clair River is shown to have permanently lowered the levels of lakes Huron and Michigan by almost 1 foot (27 centimeters)[56]. Dredging of the navigation channel in the Lake St. Clair itself is known to alter water levels in the lake, but only temporarily[57]. Maintenance of the Lake St. Clair navigation channel has been authorized by the U.S. Congress numerous times, with the first record of authorization going back to 1886. Dredging to maintain the Lake St. Clair navigation channel (and all U.S. commercial navigation channels on the Great Lakes) is done by the U.S. Army Corps of Engineers. The navigation channel bisects Lake St. Clair in a northeast-southwest direction between the St. Clair Delta and the Detroit River.

The current U.S. Congressional authorization provides for an improved channel 800 feet wide and 14.5 miles long in Lake St. Clair that extends from the lower end of the Southeast Bond Cut-Off Channel in the St. Clair River to the Detroit River, all to a depth of 27.5 feet[58]. This dredging increased the lake's maximum natural depth of 21 feet (6.4 meters) to its current depth of 27.2 feet (8.3meters).



Outside of commercial navigation channels, dredging of lake bottoms is also considered as a remedial technique to remove excess sediment, increase lake depth for recreational boating, or remove toxic or nutrient-rich sediment from the lake environment. Dredging has impacted the St. Clair River and Lake St. Clair system by redirecting how the water moves through the system. Dredging temporarily increases turbidity in the lake which can lead to environmental degradation. The sediment may be a nutrient sink and dredging may reintroduce the nutrients back into the lake. Dredging also replaces productive shoal-water habitat with less productive channel habitat. The disposal of dredged material can be a problem, especially if the sediment is contaminated. Together, dredging and filling can completely destroy marshes and impact adjacent marshes by increasing sediment loading, reducing habitat diversity, altering natural flow patterns, and changing nutrient regimes and plant communities[59].

V. B. 4. Diking and Breakwalls

Dikes and breakwalls are often constructed to reduce flooding and erosion along the Great Lakes shoreline and to protect residential areas, cottages and agricultural lands from ship or boat wakes. In the St. Clair Flats region, construction and maintenance of a complex network of dikes permits the control of water levels in the delta to attract and sustain waterfowl populations for hunting, wildlife viewing and related recreation. These structures have a diverse array of impacts on the coastal habitat. They reduce the natural sediment supply that nourishes wetland communities, interfering with sediment processes that maintain wetlands[60]. Hard shoreline structures can shift wave energy and increase ero-

HIGHLIGHT

Construction and maintenance of a complex network of dikes permits the control of water levels in the delta to attract and sustain waterfowl populations for hunting.

sion rates in other parts of the coastal zone. They can restrict the landward movement of wetland communities during high water periods, causing a "backstopping" effect that reduces the size and diversity of wetland communities[61]. Shoreline modifications can also impact wildlife communities as they isolate wetlands from natural interactions with upland communities[62]. For more information on shoreline modification, see Section V. D. 2. Shoreline Hardening.

V. C. Contaminants

A variety of contaminants act as stressors within the project area, ranging from obvious toxins such as polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), lead, and mercury, to excess nutrients and pesticides.

HIGHLIGHT

Excessive nutrient loading can result in potentially harmful algal blooms that lead to oxygen declines, an imbalances among aquatic species, public health threats and a general degradation of the aquatic resource.

V. C. 1. Nutrient Loading

Nutrients - in particular nitrogen and phosphorous - occur naturally in the environment and are essential building blocks for plant and animal growth. Excessive nutrient loading, however, can result in the accelerated growth of macrophytes or phytoplankton, potentially harmful algal blooms that lead to oxygen declines, imbalances among aquatic species, public health threats and a general degradation of the aquatic resource . Nonpoint sources are the primary cultprit of excessive nutrient loadings into Lake St. Clair and include agricultural runoff, eroded soils, urban stormwater runoff and wastewater runoff. Point sources of concern include quarries, mines and industrial and municipal discharges. Research has shown that the key factors that cause eutrophication - or over-enrichment - of waterbodies are excessive concentrations of the primary nutrients phosphorus and nitrogen[64].

A primary source of excess nutrients is agriculture[65]. While proper application of nutrients produces healthy crops, lack of buffers, over-fertilization and misapplication can contribute to water quality problems. In Ontario, approximately 75 percent of the land in the Lake St. Clair watershed used for farmland[66], while agriculture is estimsted to account for only 32 percent of the watershed on the U.S. side.[67] (See Section IV. A. for a discussion of agriculture in the project area.)

CASE STUDY
CURB - Clean up Rural Beaches

The St. Clair Region Conservation Authority's Clean Up Rural Beaches (CURB) studies identified manure as Ontario's second largest pollution contributor to Lake St. Claor after faulty septic systems. Implementation programs to reduce livestock access to watercourses, correct pollution sources and improve local water quality followed the CURB studies. Several soil and water conservation programs, such as Healthy Futures and the Great Lakes Sustainability Fund, encourage the use of Best Management Practices to improve local water quality and habitat. The new Ontario Nutrient Management Act is expected to enhance water quality by improving the use and handling of manure and other fertilizers and requiring buffers adjacent to watercourses.

Manures and chemical fertilizers are the primary sources of nutrients from agriculture. Manure can contaminate streams and waterways through the spread of manure on fields, runoff from manure storage and by allowing cattle to access streams where their waste can be directly deposited into the water. Livestock facilities can also release wastes. Manure spills are reported to have caused more fish kills in Ontario between 1988 and 2000 than all other types of spills. Nutrient management and best management practices for manure handling and spreading are critical to maintaining healthy watersheds.

GAP

Research is needed to document the impacts of CAFO's on water quality.

Another concern is the increasing trend on both sides of the border toward Concentrated Animal Feeding Operations (CAFOs)[68]. Traditionally, manure, litter, and wastewater produced at animal feeding operations have been applied to cropland as fertilizer. The growing number of CAFOs and the increased amount of agricultural waste has resulted in nutrients that exceed crop needs. It is unclear to what extent CAFO waste contributes to water quality degradation and research is needed to document its impacts[69].

Urban areas discharge nutrients to the environment as well. Excessive use of fertilizers is a major source of nutrients from golf courses and urban homeowners. F Urban homeowners can typically apply many times the amount of fertilizer needed to support their lawns or gardens. The excess fertilizer runs off the property, flows into sewer systems and accelerates plant growth downstream. Natural wetlands can remove some nutrients from storm water runoff but development has reduced these natural filtration areas, increasing the nutrient loads to the region's habitat.

FACT

Urban homeowners can typically apply many times the amount of fertilizer needed to support their lawns or gardens. The excess fertilizer runs off the property, flows into sewer systems and accelerates plant growth downstream.

Other urban nonpoint sources include combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), failing onsite sewage disposal systems (OSDSs, also known as septic systems) and discharge from municipal and industrial wastewater treatment plants, which can all contribute excess nutrients to the region's water bodies. The primary concern about these sources is bacteria loadings that can impact human health as well as aquatic communities.

Excess nutrient loadings from improperly treated stormwater and sewage, illicit sewer connections and stormdrains, and failing septic systems are thought to have been the catalyst for the large floating mats of submersed aquatic vegetation found along the western shoreline of Lake St. Clair in 1994.[70] At that time, an estimated 500 million gallons of improperly treated stormwater and sewage were discharged into Lake St. Clair from five CSO basins[71] (Jaski 1994).

The U.S. EPA's National Nutrient Strategy[72] is an effort to reduce and prevent nutrient overenrichment of water bodies on a national scale (USEPA, 1998). The strategy requires each state to complete a plan for developing and adopting nutrient criteria into water quality standards. The Michigan Department of Environmental Quality developed and submitted a Nutrient Criteria Adoption Plan for Michigan's surface waters to the USEPA in January 2002. In addition, Michigan is required to determine the Total Maximum Daily Load (TMDL) of nutrients for watersheds that are impaired by excess nutrients. Proper TMDL calculations will require accounting for nutrients derived from all sources, including agriculture, and may lead to mandated reductions of agricultural loadings.

Recently, Ontario has established legal requirements for the storage and handling of manure and other nutrients. The new Ontario Nutrient Management Act is expected to improve water quality by improving the use and handling of manure and other fertilizers and requiring buffers adjacent to watercourses. The Act provides a framework for setting clear consistent standards for nutrient management on farms. It is enabling legislation that supports the development of regulations for nutrient management and other related farm practices. One of the most important features of the Act is the requirement for farms to prepare nutrient management plans and nutrient management strategies. Through the General Regulation under the Act, farmers are required to prepare Nutrient Management Strategies and/or Nutrient Management Plans.

Canada also has several soil and water conservation programs, such as Healthy Futures, Environmental Farm Plan and the Great Lakes Sustainability Fund, that encourage the use of Best Management Practices to improve local water quality and habitat.

There is a lack of research on the effectiveness and benefits of BMPs to reduce nutrient loadings[73]. Specific needs include: 1) Research on the changes in nutrient transport to receiving waters due to specific BMPs or combinations of BMPs. 2) Evaluations of BMP effects on nutrient concentrations and discharges are needed at the farm and watershed scale. 3) Specific BMPs for the management of nutrients to protect water quality need development and refinement. 4) Tools for developing farm nutrient management plans based on nutrient budgets.

V. C. 2. Toxic Contamination

While the passage of stringent laws and regulations have led to declines in discharges of toxic chemicals, many still persist in the system and are available to plants, fish and wildlife. Examples of toxics of concern in coastal Lake St. Clair include polychlorinated biphenyls (PCBs), Hexachlorobenzene (HCB), organochlorines (OCs), polynuclear aromatic hydrocarbons (PNAs), mercury and lead. These contaminants enter the system through a variety of pathways, including both point and nonpoint sources.

> HIGHLIGHT
> While the passage of stringent laws and regulations have led to declines in discharges of toxic chemicals, many still persist in the system and are available to plants, fish and wildlife.

Toxic contaminants can have lethal and sublethal effects on fish and wildlife, affect species reproduction, impact the food supply, degrade habitat and affect overall ecological productivity[74]. Because such contaminants become more concentrated as they move up the food chain through the processes of bioaccumulation[75] and biomagnification[76] they have the greatest impact on animals at the top of the food chain, such as predatory birds, fish, and mammals[77, 78, 79, 80, 81, 82, 83, 84]. Some of the effects that have been documented include thinning of egg shells and deformities among Great Lakes birds that prey on fish, and lower hatching success and increased deformities in snapping turtles.

The long-term effects of toxic chemicals on plants are not as well understood[85]. Studies have shown that herbicides can alter planktonic species composition and inhibit photosynthesis of aquatic plant communities[86]. However, recent studies have shown that these damaging impacts may be short-term and reversible[87]. More permanent effects may occur in areas receiving large amounts of agricultural runoff with little dilution, such as barrier beach wetlands[88]. Road salt runoff is also a concern as it has been shown to alter algal, macrophyte and faunal communities of wetlands[89].

Both point and nonpoint sources of pollution contribute toxic contaminants to the environment. Point sources include industrial discharges, effluent from municipal wastewater treatment plants and waste disposal sites. Point source discharges from industry are generally well regulated in the study area[90, 91], but have the potential to stress the environment if there is an accidental spill[92], runoff or leakage, or due to cumulative impacts of low levels discharges over time.

Accidental spills along the St. Clair River corridor have been a problem in the past. However, the number and size of spills or releases has reduced dramatically over the last several years due to measures implemented by both U.S. and Canadian industries. On-going monitoring must continue to assure that the number of spills and the quantity of materials spilled continues to decline.

CASE STUDY
Pesticides in Lake St. Clair

The U.S. Geological Survey recently investigated the distribution of pesticides in the Lake Erie-Lake St. Clair watershed as part of its National Water Quality Assessment Program (NAWQA). Concentrations in streams were in the top 25 percent in the nation and many public water supplies must treat water to reduce herbicide concentrations. The pesticides detected most frequently were among those applied in the greatest quantities to agricultural and mixed land use areas. Atrazine, acetochlor, cyanizine, metolachlor, and simazine were detected in 50 to 100 percent of samples.

Other point sources, such as municipal wastewater treatment plants and waste disposal sites are also a concern. Municipal wastewater treatment plants may discharge low levels of metals and organic pollutants from treated industrial waste and household chemicals. Even when in compliance[93] with regulated guidelines, these facilities can contribute substantial loads into the Lake St. Clair system over time. Though well regulated, waste disposal sites are also a suspected source. Historic dumping sites and abandoned landfills, which are not well regulated, could also be a source of toxic contamination.

Nonpoint sources of chemicals include runoff containing pesticides and other chemicals, contaminated sediments and airborne deposition. Airborne deposition, is also a nonpoint source of contaminants, particularly mercury. Airborne deposition directly to the St. Clair River represents a minor source because of the small surface area relative to its very large flow although inputs from Lakes Huron, Michigan, Superior and their watersheds could be significant due to their large surface area. Due to their nature, nonpoint sources are more difficult to regulate and in many areas are believed to be the primary source of current contamination.

HIGHLIGHT
Environment Canada and the U.S. EPA are working toward a goal of virtual elimination of persistent toxic substances resulting from human activity.

The Great Lakes Binational Toxics Strategy (the Strategy)[94] provides a framework for actions to reduce or eliminate persistent toxic substances, especially those that bioaccumulate, from the Great Lakes basin. Pursuant to the Great Lakes Water Quality Agreement Environment Canada and the U.S. EPA, (in consultation with other federal departments and agencies, Great Lakes states, the Province of Ontario, tribes and First Nations), are working toward a goal of virtual elimination of persistent toxic substances resulting from human activity. While this is the long-term objective, the current focus is on a framework that will achieve specific reductions through 2006.

V. C. 3. Sediment Contamination

The United States Environmental Protection Agency estimates that of the 12 billion cubic yards of surface sediments (the first five centimeters of sediments) which lay within the United States, ten percent, or 1.2 billion cubic yards, of these sediments are contaminated to levels at which there is potential risk for aquatic organisms. They also estimate that between 3 million and 12 million cubic yards of dredged material are also contaminated[95].

HIGHLIGHT
Areas of Concern around Lake St. Clair are important sources of contaminated sediments that impair beneficial uses of the Lake and compromise aquatic health.

The Areas of Concern (AOC) around Lake St. Clair (St. Clair River, Clinton River and Detroit River) each have elevated levels of pollutants in the sediments that impair the beneficial uses of those areas[96] and where aquatic health has been compromised. (Figure 1.)

The Upper Great Lakes Connecting Channels have reports of elevated organochlorine compounds, polycyclic aromatic hydrocarbons and trace metals (Table 1.). The highest levels of the organochlorines, total chlordane, total DDT, total hexachlorocyclohexane and lindane for the entire Lake Erie – Lake St Clair drainage area are in the Clinton River or at its mouth. Lake St Clair also has elevated organochlorines. PCBs are at least 10 times the probable effect level (PEL) at the center of Lake St Clair near the dredged channel cutting across the lake[98]. (Rheaume, 2000)

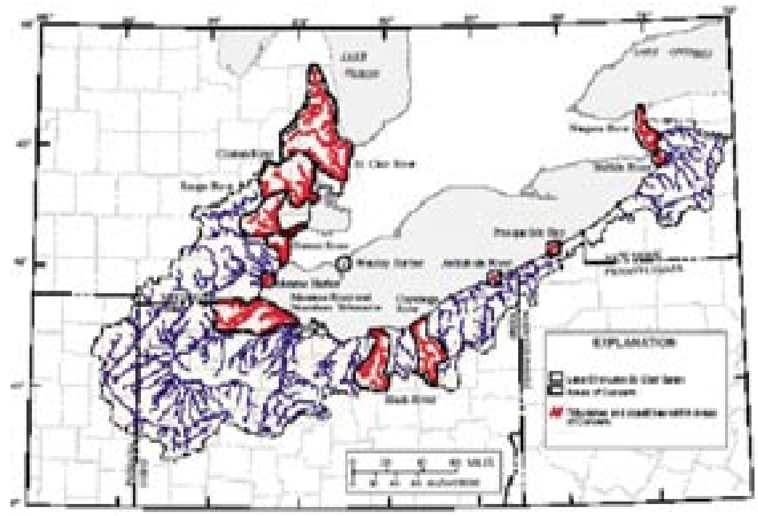


Figure V C 3 - 1
Areas of concern are spread throughout the Lake St Clair – Lake Erie basin. Areas of concern are shown in red[97].

Polycyclic aromatic hyrdrocarbons (PAHs) are also common in the sediment of Lake St Clair's tributaries. In the upper Clinton River the PAH levels were 138 to 171 times the Probable Effect Level (PEL). The main stem of the Clinton River and the Detroit River had elevated levels greater than 10 times the PEL. Anthracene and Benz[a]anthracene also exceeded PEL in the sediments of the Clinton and Detroit Rivers. Benz[a]pyrene is elevated so high that it is 11.9 to 141 times the PEL in the sediments of the Clinton and Detroit Rivers. Chrysene was found between 10.1 and 209 the PEL in sediments of the Detroit and Clinton Rivers. Phenanthrene was found at 10.1 to 1165 times the PEL[99].

FACT

PEL = Probable Effect Level
TEL = Threshold Effect Level
These sediment quality guidelines are used to calculate a hazard quotient by comparing concentrations of a contaminant at a site with concentrations that are associated with/cause adverse effects on aquatic biota (Smith 1996).

Trace metals are also found in abundance. Arsenic, cadmium, copper, and zinc were all found in the sediment of Lake St Clair and its tributaries. Cadmium was found at the highest levels in the Clinton River sediment at 7.9 the PEL. It also exceeded PEL in the main body of Lake St Clair. Copper was found in sediments in Lake St Clair and at the mouth of the Clinton River between the Threshold Effect Level (TEL) and PEL or in smaller amounts then the TEL. Zinc exceeded PEL in the Clinton River sediments[100].

Lake St Clair sediment has moderately elevated levels of copper, nickel, zinc, chromium, cobalt, volatile solids and phenol. Mercury and cyanide are found at especially high levels. Mercury was concentrated as high as 2.71 mg/kg (Figure 1.) and cyanide as concentrated as 0.6 mg/kg, however, it should be noted that in virtually every sample where cyanide was present, it was at or smaller than the calculated limit of detection of 0.1 mg/kg. The Environment Canada and Great Lakes sediment guidelines show the threshold effect and probable effect levels for mercury at 0.174 mg/kg and 0.486 mg/kg respectively. The USEPA considers values of cyanide greater then 0.1 mg/kg as toxic[101].

The elevated levels of sediment contaminants have been shown to have high potential costs[103]. Sediment contaminants can cause disease in aquatic organisms including tumors, fin rot and the loss of species and communities. These sediments can also poison the food chain through biomagnification resulting in high concentrations of toxics in predator fish. Societal costs include the loss of recreational fisheries, revenue from polluted areas and even worse – potential long term health effects such as cancer or neurological damage and IQ impairment to children[104].

Table V C 3 - 1
The Clinton and Detroit Rivers have some of the highest concentrations of pollutants, most several times the Probable Effect Level (PEL), in the region. (Rheaume, 1990-1997) Ten River basins with the highest level and frequencies of bed-sediment contamination in the Lake Erie – Lake St. Clair Drainages, 1990-97.

Ten river basins with highest level and frequencies of bed-sediment contamination in the Lake Erie-Lake Saint Clair Drainages, 1990–97

[Rankings based on the degree and frequency that bed-sediment samples exceed Probable Effect Level (PEL) guidelines; ● (purple) = concentration in at least one sample exceeded 100 times the contaminant's PEL; ● (red) = concentration in at least one sample exceeded 10 times the contaminant's PEL; ● (orange) = concentration in at least one sample exceeded the contaminant's PEL; ● (green) = concentrations in all samples were below the contaminant's PEL.]

River basin names listed in degree of exceedance of PEL's	Contaminants of Concern listed in frequency of exceedance of PEL's																
	Anthracene	Total PAH	Phenanthrene	Total PCB	Benz[a]anthracene	Chrysene	Benzo[a]pyrene	Total Chlordane	Mercury	Lindane	Dieldrin/aldrin	Lead	Zinc	Cadmium	Arsenic	Copper	Total DDT
Ottawa River at Toledo, Ohio	purple	purple	purple	red	purple	purple	purple	orange	green	orange	red	orange	orange	orange	orange	orange	green
River Rouge, Mich.	purple	red	purple	red	red	red	red	green	orange	green	green	orange	orange	orange	green	orange	green
Clinton River, Mich	red	purple	red	red	red	red	red	red	orange	red	green	orange	orange	orange	orange	green	orange
Detroit River, Mich.	purple	red	red	red	red	red	red	green	red	green	green	orange	orange	orange	orange	orange	green
River Raisin, Mich.	green	orange	orange	purple	orange	orange	orange	green	orange	green	green	orange	orange	orange	orange	orange	green
Lake St. Clair, Mich.	orange	green	orange	red	orange	orange	orange	red	orange	green	green	orange	green	orange	green	green	green
Cuyahoga River, Ohio	orange	red	orange	orange	orange	orange	orange	orange	green	green	orange	orange	orange	orange	orange	orange	green
Maumee River, Ohio	orange	red	orange	orange	orange	orange	orange	orange	green	orange	green	orange	orange	orange	orange	green	green
Little Cuyahoga River, Ohio	green	green	orange	green	orange	orange	orange	orange	red	green	green	orange	orange	green	green	green	green
Ashtabula River, Ohio	orange	green	red	green	orange	orange	orange	orange	green	green	green	green	orange	green	orange	green	green

Remediation plans primarily include the removal of contaminated sediments and improved wastewater treatment, but are also beginning to address non-point source pollution, habitat restoration and pollution prevention among others. The cost of this remediation is estimated to be $7.4 billion dollars (USD) for the removal of toxic sediments and the improvement of wastewater infrastructure[105]. The United States approach to raising funds for the clean up is to target the primary polluters of the AOC when possible and require these groups to pay for the costs of remediation. When this is impossible, funds must be obtained from elsewhere. Within the Lake St Clair – Lake Erie corridor, $1 billion dollars (USD) has been spent to assist in upgrading the waste water treatment infrastructure. The major hurdle pre-

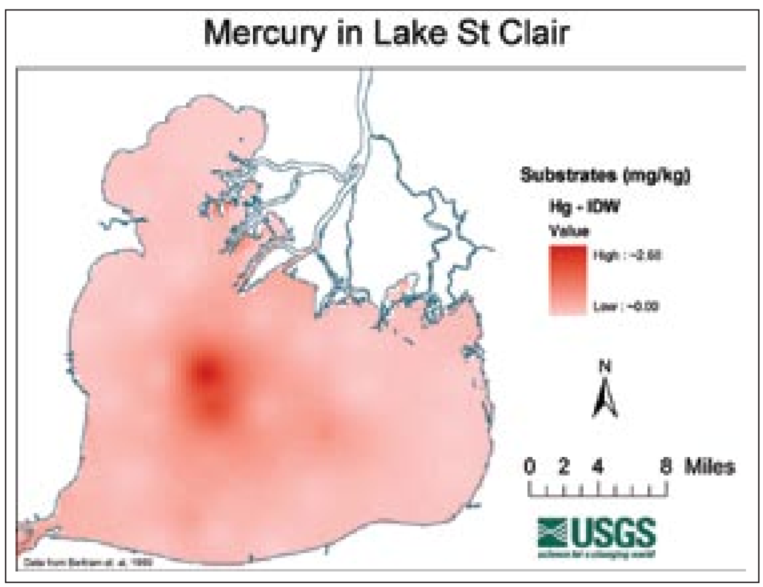


Figure V C 3 - 2
Interpolation using inverse distance weighted shows the distribution of mercury contaminants in silty sediments around Lake St Clair as being extreme in the center of the lake. The Environment Canada and Great Lakes Guidelines show levels greater then .171 mg/kg to be above the threshold effect level (TEL), and levels greater then .486 mg/kg at being above the probable effect level (PEL)[102].

venting progress for many AOC's is that the high costs have not been supported[106]. (See Section VI for more discussion on AOCs and remediation efforts.)

V. D. Shoreline Modification, Shipping and Boating

Much of the Lake St. Clair's region's appeal, both historically and today, is derived from its extensive shoreline and access to the rest of the Great Lakes system, as well as its proximity to urban centers. At the same time, this position has also subjected it to a number of stressors: shoreline development, both residential and commercial, with the attendant shoreline modifications, physical alterations to the lake itself, to accommodate the shipping industry, physical stresses related to the passage of ships and the ecological impacts of one of the highest densities of recreational boaters in the entire Great Lakes.

V. D. 1. Vegetation Removal

Vegetation removal or "beach grooming" refers to the practice of removing vegetation from sandy beaches. This practice is utilized most frequently during low water cycles in the Great Lakes when bottomlands that are normally submerged in high water cycles are left exposed. Seed banks and root systems that have been dormant when fully submerged begin to germinate in the drier, often sandy soils[107]. However, these shoreline habitats where the vegetation re-emerges in low water cycles are actually coastal wetlands of the Great Lakes. The sandy soils, typically not associated with wetlands in the public consciousness, result from the constant wave action of the Great Lakes waters, limiting the accumulations of rich organic materials[108].

> **HIGHLIGHT**
> Beach "grooming" removes shoreline vegetation that emerges during low water levels, destroying its habitat function and value and increases shoreline erosion.

Potential environmental impacts from vegetation removal include:

- Higher beach erosion rates as vegetation is removed by discing or plowing.
- Limiting or eliminating coastal fish spawning and nursery habitat.
- Limiting or eliminating migratory waterfowl use of wetlands for habitat.

Low lake levels are a time of shoreline vegetation growth, strengthening the exposed coastal lands, when root systems grow deeper and stronger, helping to prevent shoreline erosion when levels again rise. During rain and snow melt, streams, rivers and the overland flow of water carry heavy loads of water through coastal wetland vegetation, which acts as a sponge, soaking up water and reducing flooding. Wetland vegetation also helps break down pollutants and protects clean water supplies[109].

Two species of perch, northern pike and walleye use coastal wetlands as spawning grounds and emergent wetlands[110] are made more important during lower lake level cycles. These fish can not reach the higher areas where they leave eggs during high flow regimes, so areas exposed by lower lake levels become their new nesting grounds. Migratory waterfowl utilize coastal wetlands for nesting, foraging and stopovers. Large populations of migratory waterfowl are year-round residents of Lake St. Clair.

In Michigan, vegetation removal is regulated by Michigan DEQ[111] under Part 303, Wetlands Protection, and Part 325, Great Lakes Submerged Lands, of the Michigan Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended, which describes certain "beach maintenance activities" that may be carried out between the normal high water mark of the Great Lakes and the "current" water's edge (i.e., exposed bottomlands held in public trust by the State of Michigan) without a state permit[112]. These include:

- Manual or mechanized leveling of sand in areas that are predominantly free of vegetation. Property owners may spread sand that has eroded onto upland portions of their property on bottomlands. Alteration of natural lake shore contours is not authorized.
- Mowing of vegetation to a height of not less than two inches without disturbing soil or plant roots. Mowing is limited to the width of the riparian property or 100 feet, whichever is less.
- Small scale hand pulling of vegetation, except for threatened or endangered species.
- Grooming of the soil by raking the top four inches of soil to remove debris without disturbing or destroying plant roots. Debris may include dead vegetation, trash, zebra mussel shells and dead fish.
- Construction and maintenance of a temporary pathway directly to open water. Temporary pathways may cross swales with standing waters, but may not exceed six feet in bottom width. Paths must be constructed of sand and pebbles obtained from exposed unvegetated bottomlands.

V. D. 2. Shoreline Hardening

Of the 542 miles (871 km) of Lake St. Clair's shoreline within the project area, 31 percent is identified as riprap, retaining wall, harbor structure or breakwater according to Environment Canada. Nearly the entire U.S. shoreline, except the islands of the delta, is armored.

Hardening the shoreline eliminates the migration of nearshore sediments with changing water levels. Such modifications are often motivated by the desire to eliminate such migration. Their effect, however, also reduces the amount of fish habitat available, especially in relation to what would be available during high-water years. Usually, such modifications also straighten the shoreline. Because irregularities in the shoreline cause local variations in alongshore currents, which in turn cause local variation in substrate, straightening results in a loss of habitat diversity.

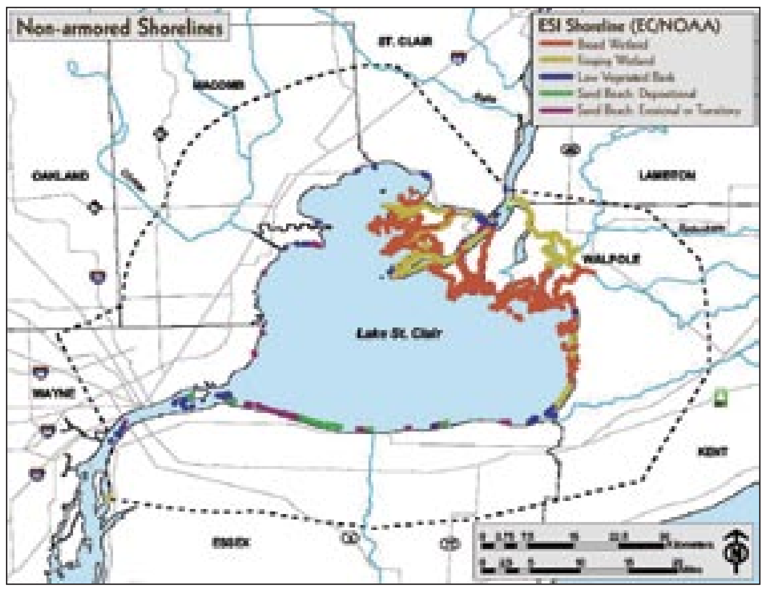


Figure V D 2 - 1
Shoreline armoring extent within the project area

Natural shores are nourished by material that has been eroded from other areas, becoming part of the littoral drift system. Attempts to reduce erosion by building shore protection structures, or armoring the shoreline in one area, have resulted in reduced littoral drift available, starving an adjacent area further down the coast.

> **HIGHLIGHT**
> Almost one third of the shoreline around Lake St. Clair is armored, including most of the U.S. shoreline, except for the delta.

Some of the physical processes linked to shoreline hardening are:

- beach area loss
- accelerated erosion of adjacent, unarmored property
- decrease in sediment supply to the beach
- increased wave energy seaward of armoring
- narrowing of dry beach area
- coarsening of existing beach material

Some of the biological processes linked to shoreline hardening are:

- burial or removal of habitat for bottom dwelling species due to shifts in beach material
- alterations in or complete loss of vegetative cover resulting in temperature fluctuations in shallow water
- loss of spawning, foraging and nursery habitat for fish due to alteration in the substrate
- loss of migratory corridor for fish caused by shifts in water elevation from existence of armoring
- decreased organic inputs due to loss of vegetation adjacent to the shoreline
- interruption of beach access to foraging wildlife

Although erosion is caused by natural shoreline processes, its rate and severity can be intensified by human activity. Wise management of shoreline construction and land uses can significantly reduce economic losses due to erosion.

Gently sloping beaches or wetlands along the water's edge are natural defenses against erosion. The slopes of the land along the edge of the water form a first line of defense called a berm, which dissipates the energy of breaking waves. During high water periods, a berm can prevent water from moving inland.

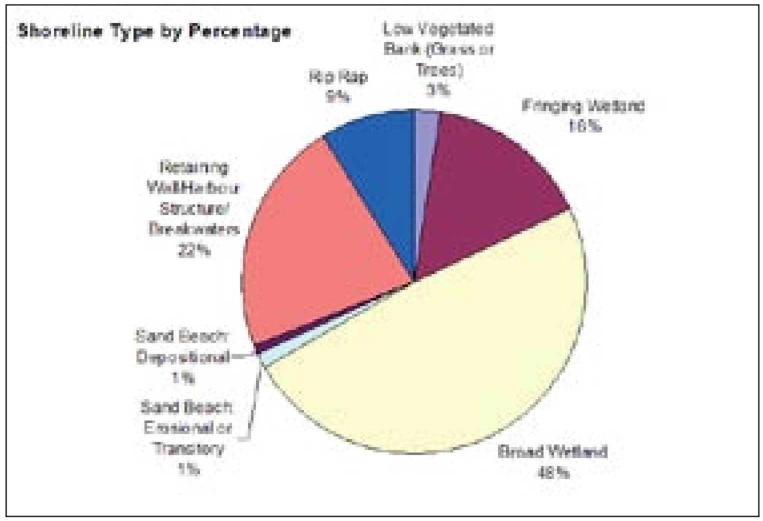


Figure V D 2 - 2
Lake St. Clair shoreline type by percentage

V. D. 3. Vessel Activity and Marina Development

Vessel activity in a confined, relatively shallow body of water such as Lake St. Clair is a known stressor of coastal habitat. Several environmental impacts result from the wakes of large or high-speed maritime vessels and anchoring. Wakes from large (e.g., Great Lakes/St. Lawrence Seaway bulk cargo carriers) or fast-moving recreational boats can cause erosion and vegetative damage in confined or shallow waters. Wakes can cause strong wave propagation that is capable of eroding shorelines or stirring up bottom sediments in shallow areas. Vegetation can be disturbed both by erosion processes and sedimentation resulting from wakes. Sedimentation reduces the amount of sunlight available for photosynthetic processes. The impacts of wakes are local in nature and likely to be more pronounced in confined, high traffic areas.

> **FACT**
> As a strategic connecting route on the Great Lakes/St. Lawrence Seaway System, Lake St. Clair's navigation channel sees from 4,000 to 5,000 vessel passages a year.

Lake St. Clair has a uniquely high combined traffic of both commercial cargo carriers and recreational craft. Commercial traffic includes U.S. and Canadian inter-lake vessels ("lakers confined to Great Lakes trades) of up to 1,000 feet long and 78,000-ton cargo carrying capacity, and oceangoing freighters of up to 740 feet in length and 36,000-ton capacity. As a strategic connecting route on the Great Lakes/St. Lawrence Seaway System, Lake St. Clair's dredged 59-foot wide, 27-foot deep commercial navigation channel sees from 4,000 to 5,000 upbound and downbound vessel passages a year.

The effect of passage of large commercial vessels on Great Lakes nearshore water habitat and biota has not been extensively studied but the areas of greatest concern are sections of the connecting channels where the vessels follow a dredged channel that occupies a large portion of the cross-sectional area of the connecting channel. In these areas, the larger vessels fill much of the channel; as they pass, they sharply disrupt the normal water level and flow conditions. The change can be easily seen by watching the movement of water at the shoreline while a vessel passes. As the vessel approaches, its propellers cause a drawdown, pulling water towards the channel and dewatering shallow shoreline areas; then as the vessel passes, it creates a shoreward surge of water that floods the shoreline. During this drawdown and surge process, the direction of water flow at the shoreline rotates 360 degrees[113]. This water movement is believed to uproot or fragment submersed aquatic plants and to erode the low-density substrates that provide attachment for these plants[114, 115, 116]. A study in the St. Clair and Detroit Rivers revealed that the density and diversity of submersed aquatic plants was lower in the channels used by large commercial vessels than in the adjacent channels that were not used by such vessels[117].

Vessel passage in the connecting channels during the period of solid ice cover creates stronger drawdown and surge effects and stronger rotation of flow direction than during the ice-free period and can substantially increase the amount of living plants, decaying plants and benthic invertebrates that are swept from the shallow nearshore portions of the river bed into the main channel and then moved rapidly downstream as "drift"[118, 119, 120]. The accelerated transport of this material through the connecting channels in winter, when natural production of aquatic plants and animals approaches the annual minimum, represents a considerable loss of materials and energy that would otherwise be recycled in summer to produce useful plants and animals in these portions of the ecosystem.

Because of its excellent sport fishery and proximity to major U.S. and Canadian population centers, among other factors, Lake St. Clair also has one of the highest resident recreational boat densities in the Great Lakes. In the three Michigan counties fronting the lake alone, a 2002 study documented a total of 129,831 registered boats or about 590 boats per mile of U.S. shoreline on the lake and delta areas[121].

Lake St. Clair, portions of the connecting channels and certain other sheltered portions of the Great Lakes nearshore waters are important resting and feeding areas for migrating waterfowl[122, 123, 124]. Recreational boaters can flush and otherwise disturb flocks of resting and feeding birds, causing them to unnecessarily expend energy needed for migration, survival and reproduction. They can also force them to seek less favorable feeding and resting habitat or to alter their migratory schedules. To help relieve this stress, recreational boating is restricted seasonally in substantial portions of Lake St. Clair, which have been declared refuges for migrating waterfowl.

FACT

Lake St. Clair has one of the highest resident recreational boat densities in the Great Lakes. Recreational boaters can disturb flocks of resting and feeding birds, causing them to expend energy needed for survival and reproduction and/or them to seek less favorable habitat.

Supporting the robust recreational boating activity on Lake St. Clair is a substantial concentration of marinas. A 1994 study identified 211 on the U.S. side and another 13 on the less populated Canadian shores.

While there is little Lake St. Clair-specific data on the impact of marina development on coastal habitat, a study on the St. Lawrence River indicated that the construction of marinas, wharves and boat launch ramps contributed to the loss of natural environments and biodiversity. The impact of these facilities on the environment varies depending on the type of structure in question, whether wharf, launch ramp or marina, with marinas generally having the biggest impact. A 1991 study identified three types of impacts of marinas: those stemming from the construction of the site, those associated with the effects of the structure and those resulting from the consequences of their operation[125].

The construction or expansion of a new marina frequently necessitates dredging. Although the issue of sediment contamination appears to be a minor consideration in the construction of a marina as compared to a commercial port, the impacts of dredging activities should not be dismissed. Indeed, these activities lead to the destruction of riparian sites that are often rich in plant communities and major spawning habitats for certain species of fish. Sediments can be swept away by the current and settle on adjacent habitats during dredging. The presence of marinas in the environment may lead to varying degrees of changes in hydrodynamics, depending on the scope of the work and in-place structures like breakwaters. These structures may also create new sediment deposition zones that are likely to modify existing habitats. Marina operations can also disturb wildlife species when boating activity is intensive and localized[126]. Moreover, the concentration of a high number of pleasure craft and support services (e.g., restaurants, maintenance) can generate solid and liquid pollutants that can affect the quality of the water and sediments near or within harbor areas, inasmuch as septic tanks are not emptied as per regulations.

V. E. Invasive Species

Recent estimates suggest that there are over 600 aquatic and terrestrial non-native species in the Great Lakes region[127]. When non-native species are introduced into an environment in which they did not evolve, there often is no natural predator available to control their population. With no natural enemies, they have the unique ability to invade and displace native species, spread foreign diseases, and alter ecosystem dynamics.

FACT

Recent estimates suggest that there are over 600 aquatic and terrestrial non-native species present in the Great Lakes region. With no natural enemies to limit their spread, they have the unique ability to invade and displace native species, spread disease and alter ecosystem dynamics.

While only small percentage of these invasives creates serious problems, the problems can be costly and can wreak havoc on natural areas. The Lake St. Clair region has many invasive species found throughout the larger Great Lakes region, including: the zebra mussel, round goby, tubenose goby, Eurasian water milfoil, *Phragmites*, Emerald ash borer and purple loosestrife. Species that are suspected of being on the verge of entering the St. Clair watershed include the spiny waterflea and the European ruffe. While there are limited studies of the impact of these invasive species specific to Lake St. Clair, experts believe that continued introduction of invasive species is one of the greatest threats to the area's biodiversity.

Invasive, Exotic, Noxious Alien or Nonidengenous?

There is no commonly accepted vocabulary for invasion terminology. Davis and Thompson argue that, "inconsistent and imprecise use of invasion terminology is one factor that is contributing to the ongoing difficulties of the field... Until a commonly accepted vocabulary is adopted by invasion ecologists, we think the field will continue to have difficulty developing reliable generalizations, partly due to misunderstandings and misinterpretations among investigators[128]."

This section provides an overview of the predominant invasive species that are known to be present in Lake St. Clair and its watershed[129]. The presence of invasive species was determined by conducting a literature and database review. In most cases, information regarding the distribution and abundance of the species is generally not known and is an important area for future research and monitoring.

V. E. 1. Aquatic and Wetland Invasives

Wetland and Aquatic Invasive Plants

Phragmites

Phragmites australis or common reed is a very aggressive, perennial wetland grass that ranges in height from 3 to 13 feet. It is a native of the Americas and Eurasia but the highly invasive form that is rapidly colonizing U.S. wetlands originated in Europe and is now found in every state of the U.S. This hearty species inhabits salt and freshwater and tolerates pH ranges and other environmental features that most marsh grasses will not. *Phragmites* produces seed but usually spreads via underground rhizomes, which is often linked to human-induced disturbances.

> **HIGHLIGHT**
> In recent years, the Lake St. Clair coastal area - has seen dramatic increases in the Phragmites population where it continues to thrive and spread.

Phragmites is a significant concern in the Lake St. Clair region as it negatively impacts both coastal and inland wetlands by out-competing and crowding out most non-woody native wetland plants that may be important foods for native wildlife and fish[131].

In recent years, the Lake St. Clair coastal area - has seen dramatic increases in the *Phragmites* population[132] where it continues to thrive and spread.

> **FACT**
> The Galerucella beetle, a natural enemy of purple loosestrife, has been credited with wiping out large stands of this invasive species in southern Michigan.

Purple Loosestrife

Purple Loosestrife is a native European plant species, which has aggressively invaded North American wetlands, lakes and rivers. It is commonly found in wetlands such as cattail marshes, sedge meadows, and open bogs and tolerates a wide range of soil types.[133] It spreads rapidly in areas where soil has been disturbed and can often be found in retention ponds and drainage ditches. Like *Phragmites*, purple loosestrife can out-compete native vegetation and displace native plants thereby reducing biodiversity, altering the hydrology of the wetland and eliminating food and shelter for fish and wildlife[134]. Purple loosestrife is a widespread and serious problem that continues to invade and thrive in wetlands throughout southeast Michigan and southern Ontario, including around Lake St. Clair.

> **FACT**
> Phragmites, purple loosestrife and Eurasian water-milfoil each have the tendency to form dense cover that shades out native vegetation, alters species composition and impairs fish spawning.

To date, few viable solutions for managing this invasive weed have emerged. Control by water level management, burning, herbicides, direct digging, cutting) has proven to be extremely difficult and is impractical on a large scale. An alternative is the biological control through the introduction of natural enemies[135]. The non-native *Galerucella* beetle has been credited with wiping out large stands of purple loosestrife in southern Michigan[136].

Eurasian Water-Milfoil

Eurasian water-milfoil is a non-native rooted aquatic plant that can grow in a variety of aquatic habitats, but grows best in alkaline systems with high concentrations of dissolved inorganic carbon. It has long stems that branch near the water's surface to create a cover of floating foliage. It

CASE STUDY

Restoration of Phragmites Dominated Wetlands In Lake St. Clair Marshes[130]

Michigan Department of Natural Resources work in the St. Clair Flats and Algonac State Park has included a multi-year study to assess methods and develop techniques for controlling *Phragmites australis* where it is invading expansive areas of Great Lakes marsh and lakeplain prairie. In 2001, the herbicides glyphosate and imazapyr were tested, alone and in combination, in test plots in St. John's Marsh and Algonac State Park, and prescribed burning during the following winter was also utilized on some plots. Vegetation was assessed prior to treatment and then again in each of the following two years. Both herbicides were effective in reducing *Phragmites* cover, but were most effective when used together. Plots treated with herbicide followed by burning showed a relatively significant 12 percent increase in recovery of native plant species, while herbicide-treated plots which were not burned showed no significant release of native species.

In 2003, surveys were conducted and samples collected for potential fungal biological control agents throughout the study area. Biological control is still in the early stages and it may not be clear if it is an effective control method for several years. Long term research is needed to study the effects of biological control agents not only on the target plant, but also on non-target species. Interestingly, no native Phragmites genotypes were found in the SE Michigan region.

Glyphosate and imazapyr were also applied to remote areas for photo analysis in 2002/2003. Future post-treatment evaluations will provide additional information on the duration of *Phragmites australis* control as well as the diversity and recovery of native wet-prairie plants. Based on the results of the initial tests, the study will provide guidance for developing a targeted and long term lakeplain prairie restoration plan for zones in the St. Clair Flats Wildlife Area that are being impacted by *Phragmites*.

FACT

The increased water clarity due to zebra mussel filtering has decreased the amount of low light habitat preferred by walleye.

is an opportunistic species that invades disturbed lake beds, recreational waterways and slow moving streams and can rapidly colonize through plant fragmentation as each fragment is able to grow roots and develop into a new plant. Native to Europe, Asia and northern Africa, this invader has been spread intentionally by fishermen who introduced it to lakes for fish habitat and accidentally by recreational boaters who inadvertently carried it to other waters. Once established, it forms dense cover that shades out native vegetation, alters species composition of aquatic invertebrates, and impairs fish spawning. Like *Phragmites* and purple loosestrife it also negatively impacts water recreation activities such as swimming, boating and fishing due to its dense growth.

Wetland and Aquatic Invasive Animals

Zebra Mussel

The zebra mussel, native to the Caspian Sea region, was first discovered in Lake St. Clair in 1988. Since then, it has spread to all five Great Lakes. Because zebra mussels attach themselves in barnacle-like colonies to water intake screens and restrict water flow, they have caused extensive problems for industries and municipalities that rely on large-scale water withdrawals. The ecology of native mussel communities changed substantially after the invasion of the zebra mussel. Unable to adequately compete with the zebra mussel, virtually all of the 18 native species have been extirpated from the open lake. Zebra mussels effectively filter water at relatively high rates and have consequently increased water transparency, particularly on the Ontario side of the lake.

Increased water clarity has changed the previously turbid system into a clear water system dominated by macrophytes, which has increased spawning and feeding habitat for many sport fishes, including muskellunge, smallmouth bass and yellow perch, while it decreased the low light habitat preferred by walleye. An additional concern with zebra mussels is that they may bioaccumulate contaminants that could then be passed to predators, many of which are popular sport and commercial fish species.

Sea Lamprey

Sea Lamprey are a primitive, jawless fish native to the Atlantic Ocean. They have a large mouth with sharp teeth designed for sucking and a well developed sense of smell, which they use to attach themselves to fish and such out their body fluids. This often kills the prey, and is one of the reasons why the lampreys have had an enormous negative impact on Great Lakes fishery[137]. Sea lamprey first appeared in Lake Ontario in the 1830's and eventually spread throughout all of the Great Lakes. Sea Lamprey were a major cause of the collapse of lake trout, white fish and chub populations in the Great Lakes during the 1940s and the 1950s[138]. The Great Lakes Fishery Commission manages a sea-lamprey control program.

Round and Tubenose Gobies

Round and tubenose gobies are bottom-dwelling fish that were discovered in the St. Clair River in 1990. Round goby are aggressive, voracious feeders that can forage in total darkness. The round goby takes over prime spawning sites traditionally used by native species, competing with native fish for habitat and changing the balance of the ecosystem[139]. Gobies can also survive in degraded water conditions, and spawn more often and over a longer period than native fish. They are found in high abundance in the St. Clair River and Lake St. Clair and are also common along the tributaries to the lake and river. In Lake St. Clair, round gobies have become an important component of the diet of muskellunge, smallmouth bass and yellow perch.

> **FACT**
> Round gobies, an aggressive species, have taken over the spawning sites of several native fish species.

V. E. 2. Terrestrial Invasives

Terrestrial Invasive Plants

Honeysuckle

A variety of introduced honeysuckle shrub species originating in Asia and Russia that have invaded native woodlands with disastrous results. Typically, they are dispersed by birds which eat their abundant berries and are most common in disturbed forest, edge and forest openings, although they can invade healthy forest interiors as well. They leaf out before native species and shade out tree seedlings and herbaceous groundcover, inhibiting forest regeneration[140].

> **HIGHLIGHT**
> Buckthorn and honeysuckle are invasive shrubs or small trees that are dispersed by the birds that eat their berries. They invade old fields, forest edge and interior, shading out the native flora.

Buckthorn

Both common buckthorn and glossy buckthorn are shrubs or small trees and were probably introduced to North America prior to 1800, but did not become naturalized until the early 1900s. Both are native to Europe and Asia, and glossy buckthorn is native to North Africa as well. Their seeds are dispersed by a variety of birds and mammals, and rapidly invade apparently stable habitat. Buckthorns have long growing seasons, rapid growth rate, and resprout vigorously following top removal. Like honeysuckle, they shade out native tree seedlings and inhibit the growth of herbaceous understory species[141].

Privet

There are about 50 species of privet that are native to Europe , Asia and North Africa, and many have been developed as hedge plants. The genus includes deciduous, semi-evergreen and evergreen forms. They can easily escape cultivation and invade adjacent areas to form dense, monospecific thickets. Common privet is widely established in the U.S. and southern Canada. Privet invades both disturbed settings, such as roadsides and old fields as well as a wide variety of undisturbed habitats: bogs, wetlands, floodplains, barrens and hardwood forest. Its dense thickets outcompete many sorts of native vegetation[142].

Autumn Olive

Autumn olive is a shrub or small tree that is native to China, Korea and Japan and was introduced to the United States for cultivation in 1830. In many areas it was widely recommended for use in habitat plantings but it invades disturbed areas adjacent to the plantings where encroachment can be rapid due to the high production of seeds, high germination rate, and hardiness of the plants. It is one of the earliest species to leaf out in spring, shading out many native plants. Autumn olive thrives in a number of settings and is capable of fixing nitrogen. Because of this, it poses a particular threat to native species that are dependant on infertile soils[143].

Garlic Mustard

Garlic mustard is an herbaceous biennial that invades forested communities and edge habitats. The plant has no known natural enemies in North America, is self-fertile, and is difficult to eradicate once established. It is one of the few herbaceous species that invade and dominate the forest understory. In its first season it develops a distinctive basal rosette and in its second year sends up one or more flowering stalks. A single plant averages 136 – 297 seeds but can produce over 7,000 seeds, effectively dominating the seedbank. Garlic mustard dominated woodlands are characterized by low native herbaceous diversity[144].

FACT
Garlic mustard is one of the few herbaceous species that invade and dominate the forest understory.

Sweetclover

Yellow and white sweetclover are herbaceous legumes that are native to the Mediterranean area and have been used extensively as forage crops, soil builders and as a nectar source for honey bees. They have escaped from cultivation and are widely distributed along roadsides and old fields throughout the U.S. and Canada. They are a threat to recovering prairies because they easily invade open areas and may compete for resources with native species or indirectly affect the prairie community by altering soil conditions[145].

Spotted Knapweed

Spotted knapweed is native to Europe and was most likely introduced to the eastern U.S. in the 1890s in alfalfa seed from Asia Minor, although it was then transported to the Pacific Northwest in soil carried as ballast. It appears to thrive in disturbed areas but then successfully invades adjacent undisturbed lands. Although the primary emphasis on controlling spotted knapweed has focused on its presence in pasture and rangelands, it poses a serious threat to restored grasslands as well[146].

FACT
Smooth brome can be particularly difficult to eradicate in fallow fields that are otherwise ideally suited for grassland restoration.

Smooth Brome

Smooth brome is a Eurasian grass species that was apparently introduced in the United States in 1884 for use as forage. It is a cool season exotic that is especially troublesome in disturbed portions of old pastures in the tallgrass and mixed prairie regions. It forms a dense sod that often appears to exclude other species, thus contributing to the reduction of species diversity in natural areas. Smooth brome has become established in overgrazed pastures and old fields but also appears to be invading native prairie from roadsides[147].

Terrestrial Invasive Animals

Emerald Ash Borer

The Emerald Ash Borer is a beetle indigenous to Asia. It was first identified in southeast Michigan in July of 2002 and was also identified in the Windsor, Ontario area that same year. It attacks and kills ash trees that are larger than 1 inch in diameter. It has no known natural enemies and native trees do not appear to have any resistance to the beetle. This beetle is a significant threat to all ash species in the Detroit and Windsor areas[148]. It has also been identified in Ohio, Indiana, Maryland[149] and Virginia[150].

HIGHLIGHT
The Emerald Ash Borer was first identified in the southeastern Michigan in July of 2002 and was identified in Windsor, Ontario later that year.

Michigan has an emerald ash borer task force, which consists of the USDA's Animal and Plant Health Inspection Service, the U.S. Forest Service, the Michigan Department of Agriculture, the Michigan Department of Natural Resources and Michigan State University. In early 2004, state officials asked local governments to declare a local state of emergency by March 15 because of damages caused by the borer. An emerald ash borer policy director has been appointed to coordinate emerald ash borer initiatives among the governor's office, the Michigan Department of Agriculture, DNR, the state police and the Michigan Department of Transportation. In March 2004, the U.S. Department of Agriculture announced that it will provide $28.2 million to help beetle control efforts.

Asian Long-horned Beetle

Asian long-horned beetles are about 1 to 1 1/2 inches in length, are black and shiny with white spots and have long distinguishable antennae that are banded with black and white. They attack many different hardwood trees, including maple, birch, horse chestnut, poplar, willow, elm, ash and black locust.

The beetle was first reported in the New York area in 1996, where it is thought to have entered via wood packing material from China. The beetle is a serious threat to hardwood trees and has no known natural predator in the United States. If the Asian long-horned beetle becomes established, it has the potential to cause more damage than Dutch elm disease, chestnut blight, and gypsy moths combined, destroying millions of acres of hardwoods. The beetle has the potential to damage such industries as lumber, maple syrup, nursery, commercial fruit, and tourism[151]. The beetle was discovered in wood packing material from China in two warehouses in Michigan – one of which falls within the Lake St. Clair watershed (Warren, Michigan)[152].

V. E. 3. Potential Invasives of the Lake St. Clair Region

Potential Invasive Animals

FACT
On the verge of invading Lake St. Clair, the Ruffe is considered a serious threat to the yellow perch commercial and sport fishing industry.

Ruffe

The Eurasian ruffe is a member of the perch family. It was first reported in western Lake Superior in 1986 from ballast water of ocean-going vessels[153]. As of spring 2002, ruffe have spread along Lake Superior to Lake Huron[154]. The ruffe has not yet been found in Lake St. Clair, but is considered to be on the verge of invading.

The Eurasian ruffe poses a serious ecological threat to the aquatic ecosystem and to sport and commercial fishing. Maturing quickly, the ruffe has a high reproductive capacity and adapts to a wide variety of environments. Explosive growth of the ruffe population reduces food and space for other fish with similar diets and feeding habits. It is considered a serious threat to the yellow perch commercial and sport fishing industry. It also has the potential to seriously disrupt the delicate predator/prey balance vital to sustaining a healthy fishery.

Spiny Water Flea

The spiny water flea is a tiny crustacean with long, sharp, barbed tail spines. The spiny water flea, a macroscopic invertebrate, was observed in high abundances in the St. Clair River by the late 1990s and has become an integral part of the zooplankton community; however its effect on native species remains essentially unknown[155]. The fishhook water flea has not yet been collected in Lake St. Clair but is considered to be on the verge of invasion.[156]

Water fleas prey on zooplankton and may be competing for food with native species. Larger fish find them unpalatable because of their spiny and fishhook tails. For these reasons, they have the potential to alter aquatic food webs of the Great Lakes. If so, this may result in further restriction on human consumption of fish, which would impact both commercial and recreational fisheries.

Asian Carp

Bighead, silver, grass and black carp all are native to Asia. Grass carp were first introduced into the United States in 1963; bighead, silver and black carp appeared in the 1970s. All four species of Asian carp escaped into the Mississippi River Basin, and all but the black carp are known to have developed self-sustaining populations there[157].

Asian carp are large, prolific, voracious feeders and have the potential to disrupt the food chain that supports native fish in the Great Lakes. They can reach over four feet in length and 100 pounds, and the climate in Asia where they originated is similar to that of the Great Lakes. If they reach the Great Lakes, they could eventually become a dominant species[158].

> **HIGHLIGHT**
> Asian carp are large, prolific, voracious feeders and have the potential to disrupt the food chain that supports native fish in the Great Lakes.

Asian carp have been found in the Illinois River, but federal and state agencies are working to prevent their movement into Lake Michigan. The U.S. Army Corps of Engineers constructed a temporary electrical fish barrier on the Chicago Sanitary and Ship Canal in April, 2002. The Illinois Natural History Survey has been monitoring the effectiveness of the temporary barrier, which is informing the design of a second, more permanent barrier, scheduled to be completed in February of 2005[159].

Northern Snakehead

The northern snakehead (*Channa argus*), a native of China, was first found in the U.S. in 1977 An established population was discovered in a pond in Maryland in 2002, which was eradicated, but in 2004, they were discovered in the Potomac River[162]. Also in 2004, a fisherman caught an adult snakehead, believed to be a released pet, in Chicago's Burnham Harbor[161].

Snakeheads have the potential to wreak havoc among native populations of fish in the Great Lakes. As juveniles, they eat microscopic zooplankton and crustaceans, and then transition to fish, insects, crustaceans as adults. Snakeheads can survive in water with very low oxygen – all are capable of obtaining oxygen from air, and some species can use either air or water for respiration. Where they have been introduced, they impact native species both by competition for food, and also by direct predation on native fish populations.

In the U.S. all species of snakeheads have recently been assigned injurious wildlife status under the Federal Lacey Act which prohibits the importation and interstate transportation of wildlife deemed by the Secretary of the Interior to be "injurious" to humans, agriculture, or other wildlife resources. This includes both live snakeheads as well as viable eggs[162].

Potential Invasive Plants

Hydrilla

Hydrilla verticillata is thought to have been introduced to the U.S. in the 1950's from the Indian subcontinent, and has been categorized as one of the world's worst weeds. Infestations of *Hydrilla* are extremely severe and can completely choke entire lakes and public water supplies[163]. *Hydrilla* is particularly threatening because of its diverse reproductive abilities (it can reproduce by seed, vegetative cuttings and tubers) and its ability to grow in dark, deep waters where other plants cannot survive, eventually forming thick mats on the surface and preventing the sunlight from penetrating to native plants such as wild celery and coontail below[164, 165].

> FACT
> Hydrilla can reproduce by seed, vegetative cuttings and tubers.

Researchers have noted reductions in size and weight of sportfish where *Hydrilla* dominates the water column, suggesting that it effectively reduces foraging efficiency[166]. *Hydrilla* seriously affects water flow and its heavy growth can obstruct boating, swimming and fishing. *Hydrilla* is now found in states bordering the Atlantic and Pacific, and approaches the Great Lakes most closely in Pennsylvania and New York[167, 168]. To date, *Hydrilla* has not been found in the Great Lakes.

V. E. 4. Key Programs

United States Federal Programs

Congress has supported aquatic nuisance species prevention and control through the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) and its reathorization through the National Invasive Species Act of 1996 (NISA). While progress has been made, a number of persistent and complex problems face ANS prevention and control. To this end, the proposed National Aquatic Invasive Species Act (NAISA) will reauthorize and strengthen regulations required under NISA. Additionally, NAISA will require all vessels equipped with ballast operating in waters of the United States to have an aquatic invasive species management plan that prescribes ways to minimize introductions and transfers of invasive species.

> FACT
> Invasive species can be introduced through a wide variety of pathways, including ballast water, aquaculture, aquarium trade, biological control, recreational boating, recreational fisheries enhancement, bait businesses and horticultural practices, among others.

The **Great Lakes Panel on Aquatic Nuisance Species** (the Panel) has been working since 1991 to prevent and control the occurrence of invasive aquatic nuisance species in the Great Lakes. Convened by the Great Lakes Commission in response to NANPCA, the panel is comprised of representatives of U.S. and Canadian federal agencies, the eight Great Lakes states and the Province of Ontario, regional agencies, user groups, local communities, tribal authorities, commercial interests and the university/research community. The Panel is charged with identifying Great Lakes priorities, making recommendations to a national Task Force on Aquatic Nuisance Species, coordinating invasive species programs and activities in the region, and advising public and private interests on control efforts.

The Great Lakes Panel on Aquatic Nuisance Species is currently working on a Rapid Response Plan for Great Lakes Aquatic Invasions and details can be found at the following website: *www.glc.org/ans/pdf/ModelRRPlan-II_04-04.pdf.*

Ballast water has been identified as a major pathway for introduction and dispersal of aquatic invasive species. Several federal agencies have regulatory authority and management programs for ballast water control. The U.S. Department of Transportation recently announced regulations for the St. Lawrence Seaway that require vessels to adopt and comply with best management practices for ballasting operations in order to minimize introduction and dispersal of aquatic invasive species. These management practices must be met before a commercial vessel can be cleared for transit in the Seaway system. U.S. Coast Guard regulations require that partially laden ships destined for the Great Lakes from abroad discharge and exchange their ballast water in mid-ocean with the intent to flush out potential invaders. However, this ballast water exchange program is only a first step to reduce future invasions. The U.S. Environmental Protection Agency has prepared a Draft Ballast Water Report (2001) that summarizes the results of a study on aquatic invasive species in ballast water discharges, which, when finalized, will include a number of regulatory and non-regulatory recommendations.

FACT
Ballast water has been identified as a major pathway for introduction and dispersal of aquatic invasive species.

A number of U.S. federal agencies have regulation, research, and management responsibilities for invasive plant species. The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) works to prevent the introduction of nonnative plants, as well as their establishment on private lands. APHIS works with state and local agencies as well as private landowners and managers to eliminate invasive plants on private lands, as well as regulating importation of biological control agents. The U.S. Department of Agriculture's Agricultural Research Service conducts basic research on agricultural weeds. Weed research and management on federal lands is conducted by a number of land management and scientific agencies, including the U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, Bureau of Reclamation, U.S. Geological Survey, and Bureau of Indian Affairs. The departments of Defense, Energy, and Transportation are also involved in weed management.

GAP
There is a paucity of programs dedicated to detecting new invasions and monitoring existing populations of invasives[169].

In response to the economic and biological threat posed by invasive plants, 16 federal agencies have formed the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW). The committee's goal is to facilitate the development of biologically sound techniques to manage invasive plants on federal and private lands. The committee promotes the invasive plants programs of individual agencies as well as interagency projects that emphasize invasive plant prevention, timely control, and restoration of degraded lands. The national program also includes research, monitoring, and public awareness elements. Another primary goal of the interagency committee is to form partnerships with state and local agencies and non-governmental organizations to identify new ways to deal with invasive plants. These partnerships help facilitate the exchange of expertise and resources and ensure a voice for private industry, landowners, and others who are directly affected by invasive plants.

Canadian Federal Programs

Canada has long-established laws and regulations to prohibit or restrict the entry of foreign animals or plants capable of causing economic damage to agricultural crops, livestock or forest trees. The introduction of quarantine pests is regulated through the Canadian Food Inspection Agency (CFIA). The Agency also performs surveillance domestically to identify, control, or eradicate regulated pests that have entered Canada. However, there is no similar program to protect ecosystems and habitats from invasive species. A 2002 audit by the Office of the Auditor General of Canada criticized

GAP

Binational coordination is needed to address transboundary and ecosystem threats from invasive species.

the federal government for not developing an effective response to protect Canada's ecosystems, habitats, and native species from invasive species.

In response, Environment Canada is coordinating the development of a national plan to address the threat of invasive alien species in partnership with the Canadian Food Inspection Agency, Fisheries and Oceans Canada, Transport Canada. The plan will outline processes for the identification and assessment of invasive species and pathways of invasion, priorities for action, and measures to be taken to address these priorities. Fisheries and Oceans Canada will take the lead role with respect to the portion of the national action plan that deals with aquatic invasive species. Fisheries and Oceans will work collaboratively with other federal departments, provincial governments and stakeholders to develop a plan to address aquatic species issues in Canada.

With respect to ballast water control, Transport Canada has primary authority and is responsible for the management of ballast water on board ships entering Canadian waters. Guidelines regarding ballast water in the Great Lakes and St. Lawrence Seaway were developed in 1989 and extended to all Canadian waters in 2000. Under Transport Canada guidelines, all ships entering Canadian waters must verify compliance and samples may be taken from their ballast water. Currently, this is a voluntary program for the purpose of reducing the risk of introducing harmful aquatic non-indigenous organisms and pathogens. Flushing and refilling a ship's ballast tanks with mid-ocean saltwater while still at sea is currently the most accepted method of control but it is not always effective.

GAP

Currently, no formal "Rapid Response" protocol exists in the U.S. or Canada to allow for the immediate implementation of appropriate eradication or control measures when a new invasive species is discovered.

Transport Canada and the U.S. Coast Guard share information on compliance with U.S. ballast water regulations under the Great Lakes Water Quality Agreement. Since 1993 the U.S. Coast Guard has inspected all ships entering the Great Lakes, enforcing U.S. laws. It provides the compliance data for the binational report to the International Joint Commission, which is prepared by Transport Canada, the Canadian Coast Guard, and the U.S. Coast Guard. While Transport Canada is responsible for regulating ballast water and preventing the introduction of aquatic invasive species by ships, it relies exclusively on U.S. inspection and enforcement in the region. The Office of the Auditor General of Canada has recommended that Transport Canada and U.S. authorities formalize arrangements for sharing current information on compliance with U.S. ballast water regulations and for coordinating efforts to regulate, monitor, and enforce ballast water regulations.

Michigan Programs

In August 2001, the Michigan Legislature passed Public Act 114 of 2001 to address the on-going invasion of aquatic invasive species. The law, which was supported by the maritime industry, requires the MDEQ to determine:

- Whether vessels operating on the Great Lakes and the St. Lawrence Seaway are complying with ballast management techniques,
- Whether ballast water management practices have been made a condition of passage on the St. Lawrence Seaway, and then
- Compile and maintain lists of vessels that comply with these management practices or treatment methods.

The Michigan Aquatic Nuisance Species Council, created by the Michigan Governor in 2002, advises the Office of the Great Lakes and the Departments of Environmental Quality, Natural Resources, Agriculture and Transportation on the implementation of Michigan's Aquatic Nuisance Species Management Plan Update as well as on the state's efforts to prevent and control invasive species introductions and spread within Michigan.

Many state and local agencies have invasive plant management responsibilities. The Michigan Department of Environmental Quality regulates the entry of invasive plants into the state by prohibiting the sale and movement of plants and by regulating high risk vectors. Its Angler's Monitoring Network was created for the purpose of reporting new sightings of invasive fish, and its website is: www.michigan.gov/deq-anglers-monitoring-network. The Michigan Department of Agriculture, Michigan Department of Natural Resources, and Michigan Department of Transportation also have invasive plant management responsibilities. Michigan also has a Michigan Invasive Plant Council that is comprised of representatives from federal, state, and local agencies, universities, and private organizations and individuals. The Council, formed in 2000, promotes the exchange of information and encourages the development of responsible solutions to control invasive plants.

Efforts at all levels of government are underway to prevent and control the spread of invasive species. Given interstate commerce protections, international trade agreements, and the geographic scope of the Great Lakes, many believe that action at the federal level in the United States and Canada may be the best approach for preventing the introduction of new invasives via the shipping industry.

Table V. E. 1
Key Invasive Species in Lake St. Clair Coastal Region

Aquatic & Wetlands Plants			
Name	**Origin**	**Introduction Date**	**Impact**
Common reed *Phragmites australis*	Circumpolar	Rapid expansion of non-native genotypes since early to mid-1990s[181]	Invades healthy and degraded wetlands, forming dense monocultures. In coastal areas, can alter natural systems by increasing the elevation of marsh surfaces and reducing the frequency of tidal inundation[171, 172].
Eurasian water-milfoil *Myriophyllum spicatum*	Europe, Asia and north Africa	Washington, D.C., in 1942	Dense growth habit shades out native vegetation, alters species composition of aquatic invertebrates, and impairs fish spawning. Impairs use of area for swimming, boating and fishing due to its dense growth[173].
European Frogbit *Hydrocharis morus-ranae*	Europe	First identified in Michigan in 2000	Forms dense floating mats that can reduce growth of native submersed aquatic plants[174].
Flowering rush *Butomus umbellatus*	Eurasia	1918 in Michigan	considered a moderate threat, but capable of aggressively displacing native vegetation
Hydrilla *Hydrilla verticillata*	Indian subcontinent	1950s	Hydrilla can reproduce by seed, vegetative fragments and tubers, forming dense mats, choking entire lakes and public water supplies.
Purple loosestrife *Lythrum salicaria*	European	1800s	Out-competes native vegetation, reduces biodiversity and degrades habitat quality. Impedes water flow in drainage[175].
Reed canary grass *Phalaris arundinacea*	circumpolar distribution	non-native strain introduced in 1880s	Reed canary grass reproduces vegetatively and by seed, quickly forming a monoculture and replacing the native vegetation

Aquatic & Wetlands Animals

Name	Origin	Introduction Date	Impact
Alewife *Alosa pseudoharengus*	Atlantic Ocean	late 1800's.	In Lake St. Clair, alewives seasonally dominate the forage fish population. Have altered species make-up within the Great Lakes, frequently out-competing lake herring, whitefish, chubs and perch for plankton and other prey.
Asian Carp *Hypophthalmichthys spp. & Ctenopharyngodon idella*	Asia	1960s	Large, prolific feeders that have the potential to out-compete native fishes, disrupting food chain.
Carp *Cyprinus Carpio*	Europe	Eastern Lake Erie in 1883	Can destroy vegetation and increase water turbidity by dislodging plants and rooting around in the substrate, causing a deterioration of habitat for species requiring vegetation and clean water[176].
Eurasian ruffe *Gymnocephalus cernuus*	Eurasia	On the verge of invasion to Lake St. Clair	The ruffe, with its high reproductive rate, may pose a serious threat to existing fish community, and sport and yellow perch commercial fishery, by out-competing fish for food and space.
Northern snakehead *Channa argus*	China	1970s	Prey on native fish for food and compete with them as well. Can tolerate low oxygen conditions
Rainbow smelt *Osmerus mordax*	Eastern coast of North America	Early 1900's	Eat a wide range of prey, making this species a threat to native fishes. Can negatively impact native species through recruitment reductions, population declines, and potentially the extirpation of native species[177].
Round goby *Neogobius melanostomus* **Tubenose goby** *Proterorhinus marmoratus*	Europe - Black and Caspian Sea region	St. Clair River in 1990.	Aggressive, voracious feeders which can forage in total darkness and take over prime spawning sites used by native fish species.
Sea lamprey *Petromyzon marinus*	Atlantic Ocean	Lake Ontario in the 1830's	Attach to fish with their sucking mouth and sharp teeth, and suck out their prey's body fluids, often killing them. Enormous negative impact on Great Lakes fishery[178].
Spiny Water Flea *Bythotrephes cederstroemi*	Great Britain and northern Europe	On the verge of invasion to Lake St. Clair	Effect on native species remains essentially unknown. May be competing for food with native species. Larger fish find them unpalatable because of their spiny tails, so they have the potential to alter the food chains of the Great Lakes.
Zebra mussel *Dreissena polymorpha*	Caspian Sea region of Asia	Lake St. Clair in 1988	Have decimated native mussel populations. Zebra mussel filtering has increased water clarity and macrophyte growth in Lake St. Clair, - increasing habitat for some species and decreasing it for others.

Terrestrial Invasive Plants

Name	Origin	Introduction Date	Impact
Autumn olive *Eleagnus umbellata*	Asia	1830	Invade old fields, forest edge. As they leaf out early, they shade out native groundcover, decreasing diversity. They produce prolific seeds, have a high germination rate and can fix nitrogen. Dispersed by birds.
Buckthorn *Rhamnus spp.*	Europe and Asia	1800s	Invade old fields, forest edge and interior. They leaf out early, shading out spring ephemerals, grow rapidly and resprout vigorously following top removal. Seeds dispersed by birds and mammals.
Cheatgrass *Bromus tectorum*	Mediterranean region	Late 1800s	Aggressive invader that can completely out-compete native grasses and shrubs and negatively impacts agricultural systems[179].
Garlic mustard *Alliaria petiolata*	Europe	1868	Garlic mustard invades forested communities and edge habitats, reducing species diversity. It has no known natural enemies in North America, is self-fertile, and is difficult to eradicate once established.

Honeysuckle *Lonicera spp.*	Asia and Russia	1800s	A number of bush honeysuckle apecies invade old fields, forest edge and interior. As they leaf out early, they shade out native groundcover, decreasing diversity. Dispersed by birds.
Japanese honeysuckle *Lonicera japonica*	Eastern Asia	Late 1800's	Blocks sunlight from getting to other plants and eventually smothers them. Can stunt the growth of native shrubs or small trees by strangling them and preventing water from moving through the plant[180].
Japanese knotweed *Polygonum cuspidatum*	Japan	Late 1800's	Forms dense thickets that can shade out other plants. Can colonize extensively in riparian areas and once established, it is difficult to remove[181].
Leafy spurge *Euphorbia esula*	Eurasia	Early 1800s	In high densities, it can reduce the cover of grasses and forbs[182] (8). Studies have shown that native plant species may be severely affected by leafy spurge[183] (9), which may also have a negative impact on wildlife populations[184] (10, 11).
Multiflora rose *Rosa multiflora*	Eastern Asia	Late 1800's	Can form extremely dense thickets that crowd out other vegetation and hinder the growth of native plants. Dense thickets can inhibit forest regeneration, and can become a dominant part of a forest understory.
Privet *Ligustrum spp.*	Eurasia and North Africa		Escapes cultivation to form dense, monospecific thickets. Can invade both disturbed areas as well as a variety of undisturbed habitats.
Smooth brome *Bromus inermis*	Eurasia	1884	Cool season grass which forms a dense sod, excluding other species and reducing diversity in natural areas.
Spotted knapweed *Centaurea maculosa*	Europe	Late 1800's	Rapidly colonizes disturbed areas, and infests adjacent habitats that are relatively undisturbed or in good condition. Crowds out native vegetation.
Sweetclover *Melilotus spp.*	Mediterranean region	1664	Herbaceous legumes that compete aggressively with natives and can indirectly affect prairie communities by altering soil conditions.
Tree-of-heaven *Ailanthus altissima*	China	Late 1800's	Rapidly colonizes due to seeds that are easily transported and high seed germination. Is fairly tolerant of shade and can spread quickly in disturbed forest areas. The roots produce a toxin that acts as a herbicide that can kill or inhibit other plant growth.

Terrestrial Invasive Animals			
Name	**Origin**	**Introduction Date**	**Impact**
Asian long-horned beetle *Anoplophora glabripennis*	China	First reported in the New York area in 1996	Is a serious threat to hardwood trees, attacking maple, birch, horse chestnut, poplar, willow, elm, ash, and black locust.
Emerald ash borer *Agrilus planipennis*	Asia	Identified in southeastern Michigan and Windsor in 2002	Attacks and kills ash trees that are larger than 1 inch in diameter. It has no known natural enemies and native trees do not appear to have any resistance to the beetle.
Mute Swan *Cygnus olor*	Eurasia	Lower Great lakes in the Mid-1960s and 1970s.	High concentrations of Mute Swans can overgraze an area, causing a functional reduction in aquatic habitat[185]

V. F. Natural Disturbances/Stressors

Natural disturbances are differ from those discussed previously in that they are primarily due to natural phenomena with a minimal level of human influence. Examples of natural habitat stressors are ice storms, wildfire, windthrow, flooding and Great Lakes water level fluctuations. However, in today's world, most, if not all, natural disturbances are at least indirectly influenced by humans. For example, global warming, which has been attributed to an increase in greenhouse gases produced by humans, has been linked to changes in the frequency and intensity of storms, melting of glaciers and changes in heating and cooling days, as well as changes in rates of precipitation and evaporation.

Natural disturbances are an integral part of healthy ecosystem dynamics. Although they may change the composition and structure of a natural community, healthy communities are able to rebound over. Some plants have developed adaptations to disturbances and actually require disturbance to proliferate. Storm events that uproot and destroy established wetland complexes can also stimulate new growth, healthy changes in community composition and habitat expansion. Extremely low water levels due to drought can eliminate wetlands but can also expose previously submerged lands that become terrestrial habitat. In both cases, when natural shorelines are present, new plants and animals are able to move in and exploit the new conditions provided by the disturbance. On the land, natural disturbances often provide new habitat, expose the seed bank, release nutrients and open up the canopy to saplings and groundcover. In short they provide opportunities for existing species to persist, other species to exploit and all species to continue along their natural evolutionary path.

HIGHLIGHT
It is important to realize that natural disturbances are an integral part of the natural world.

V. F. 1. Ice Storms

Glaze or ice storms are a significant source of disturbance in hardwood forests of North America[186, 187, 188]. Estimated return interval for severe glaze storms ranges between 20 and 100 years[189]. Glaze results in pruning of small branches, severe breakage of large branches, complete stem breakage and the creation of canopy gaps[190, 191]. Canopy trees affected but not killed by glaze are often subsequently infected by fungus and/or infested by insects and die standing or are eventually windthrown[192]. Sugar maple and beech have been reported to be moderately affected by glaze storms[193] with beech showing greater susceptibility[194]. There has been speculation that beech's tendency to root sprout following stem breakage may compensate for its greater vulnerability to ice damage[195].

FACT
Fire played a key role in maintaining the open structure of grass dominated systems or grasslands and in maintaining a shifting mosaic of natural communities across the landscape.

V. F. 2.Wildfire

Historically, fire was either initiated by lightning or by Native Americans. Fire played a key role in maintaining the open structure of grass dominated systems or grasslands and in maintaining a shifting mosaic of natural communities across the landscape. Fire-dependent systems in the study area include lakeplain oak openings and prairie. Fire also occasionally spread into adjacent systems such as wetlands and mesic forests.

Fire can serve many functions within a natural community. Fire also plays a critical role in preventing declines in species richness in many community types by creating micro-niches for small species[196]. Fire kills or stunts woody plants, converts dead plant material into nutrients, promotes seed contact with soil, warms the soil in early spring which promotes seed germination, opens resinous pine cones and stimulates herbaceous plant growth.

FACT
Flooding in the spring can lead to vernal pools in forests which provide critical breeding habitat for many amphibians.

V. F. 3. Flooding

In Michigan, flooding typically occurs in the spring and fall during long periods of precipitation and shortly after snowmelt. Some areas are more prone to seasonal flooding than others. This is usually the result of a high or perched water table, low elevations and/or close proximity to a large body of water or river system.

CASE STUDY
Michigan Prescribed Fire Council

The Michigan Prescribed Fire Council (*www.firecouncil.org*) is a coalition of individuals, private sector and governmental agencies interested in utilizing or promoting the safe use of prescribed fire as a natural resource management tool. Their mission is to protect, conserve and expand the safe use of prescribed fire on the southern Michigan landscape. They accomplish this mission by:

- Providing a framework for communications related to prescribed fire objectives, techniques and issues;
- Reviewing prescribed fire problems and suggesting courses of action;
- Promoting the safe and responsible use of prescribed fire;
- Disseminating technical information;
- Promoting the development and utilization of prescribed practices to achieve desired environmental resource management goals and
- Promoting public understanding of the benefits of prescribed fire.

The Council offers an annual two-day workshop and a list of consultants who have indicated that they provide prescribed fire service on a fee basis.

Flood waters move sediment and other debris downstream, cause bank erosion and change vegetation composition within the floodplain. Prolonged flooding can kill woody plants and turn a healthy stand of trees into standing snags providing shelter for cavity nesting birds, great blue heron rookeries, and climbing mammals such as raccoon, opossum and porcupine. Standing snags also provide foraging habitat for insectivores such as woodpeckers.

Flooding in the spring can lead to vernal pools in forests which provide critical breeding habitat for many amphibians[197]. A rich food supply of microscopic algae and tiny invertebrates plus a lack of predators contribute significantly to the survival of the egg and tadpole stages of their life cycle. Spotted salamanders, blue spotted salamander, eastern tiger salamander, red-backed salamander, four-toed salamander, eastern American toad, western chorus frog, northern spring peeper, gray treefrog and wood frog are among the amphibians that utilize vernal pools.

Flooding also provides temporary pools for waterfowl as well as fish such as northern pike that use backwater flooded areas adjacent to river systems for spawning. In addition to seasonal flooding, beaver-induced flooding may also play an important role in maintaining open communities by occasionally raising water levels and killing encroaching trees and shrubs that are not adapted to wet, low oxygen conditions. Some, such as willow and ash, are stimulated when flooded to produce new, air-filled roots to replace those that the flood has destroyed. Standing water in the spring and fall prevents shade tolerant woody plants, such as sugar maple, from establishing in the understory.

V. F. 4. Windthrow

The natural disturbance regime in mesic southern forest is characterized by frequent small-scale wind disturbance or gap phase dynamics. The Great Lakes region is one of the most active weather zones in the northern hemisphere with polar jet streams positioned overhead much of the year. More cyclones pass over this area than any other area in the continental U.S.[198]. Severe low-pressure storm systems frequently generate windthrow gaps, or openings in the canopy created by the death of a large branch or one or more trees[199, 200]. Frequent windthrow events generate a forest mosaic of different age classes and species. These small-scale disturbance events are the primary source of forest turnover. The creation of canopy gaps results in temporary increases in the availability of light, water and nutrients and decreases in root competition, which allow canopy recruitment of saplings[201, 202]. Approximately 1% of the total area of mesic forest in the project area is within recent gap (less than one year old) and the average canopy residence time ranges between 50 and 200 years[203, 204].

HIGHLIGHT

The creation of canopy gaps results in temporary increases in the availability of light, water and nutrients and decreases in root competition, which allow canopy recruitment of saplings.

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Tree species respond differently to variation in gap size, origin, orientation and age[205, 206, 207]. For example, sugar maple and beech thrive in the common small canopy gaps (20-100m2), while white ash and tulip tree require larger canopy gaps (greater than 400 m^2), which occur less frequently[208, 209]. As gap size increases, woody species diversity and the size and number of stems increase[210]. Gaps formed by wind-uprooted trees are typically larger with more exposed bare soil than gaps formed by stem breakage. Stem-breakage gaps may favor root sprouted saplings (i.e., beech and basswood) and existing advanced regeneration, while uprooted tree gaps can allow recruitment of midtolerant opportunists as well as the shade-tolerant dominants[211].

Spatial and temporal heterogeneity of treefall gaps allows for the maintenance of shade-tolerant canopy dominance and the persistence of mid-tolerant opportunists at low densities[212, 213, 214, 215]. Experts speculate that the relative abundance of beech will increase with low rates of treefall, while sugar maple will increase following periods with higher rates of gap formation[216, 217].

V. F. 5. Great Lakes Water Level Fluctuations

The Great Lakes' water levels have fluctuated dramatically since record keeping started in the early 1900's. This fluctuation is primarily attributed to annual precipitation and evaporation rates within the Great lakes watersheds. In high water years, stands of emergent plants die off or become uprooted by wave and ice action. Strong onshore winds from a storm event can produce waves strong enough to uproot thousands of plants and cause severe erosion. However, because of the flat landscape, historically, the marsh usually was able to migrate inland in shallow water areas that were once wet meadow. As the cycle continues, water levels eventually fall, allowing the rhizomes of emergent plants destroyed above ground to produce stems and recolonize shallower open water over time. This ecosystem dynamic known as "lateral displacement" (where vegetative zones expand and contract) sets back succession, accelerates nutrient cycling, increases habitat diversity and enhances coastal wetland values for wildlife.

FACT

Due to Lake St. Clair's relatively small surface area, its water levels can respond rapidly and fluctuate significantly in response to climatic factors and short-term weather events across the region.

Due to Lake St. Clair's relatively small surface area, its water levels can respond rapidly and fluctuate significantly in response to climatic factors and short-term weather events. The St. Clair River provides about 97 percent of the total water supply with drainage from the immediate watershed providing the other three percent. For this reason, the lake is particularly susceptible to even small changes in its connecting channels, the St. Clair and Detroit rivers.

Long-term changes in water levels on Lake St. Clair are usually the result of precipitation that is above or below average. Temperature and cloud cover, which drive evaporation, are also factors. Short-term changes in water levels on Lake St. Clair also occur when heavy rains fall on the Thames River watershed in Ontario and the Clinton River watershed in Michigan. Ice build-up in the St. Clair and Detroit Rivers has a major impact on Lake St. Clair water levels as it can restrict the flow in the St. Clair River by up to 50 percent, causing major changes to the Lake St. Clair inflows[218].

HIGHLIGHT

Water level fluctuations are critical to water, nutrient and energy exchange in coastal marsh wetlands.

Lake St. Clair had a record high of 175.78 meters in October, 1986, and a record low of 173.71 meters in January of 1936 - a difference of approximately 6 feet.

Between 1964 and 1998, average yearly water levels have steadily increased and the variance between the high and low peaks has decreased. In recent times however, lake levels have begun to decrease again. Lake St. Clair water levels decreased to 174.53 meters in March, 2003.

Wetland scientists have determined that water level fluctuations are critical to water, nutrient and energy exchange in coastal marsh wetlands. For example, during the breakdown of detritus (dead plant material), nutrients are released which are used for new plant growth. This process however, requires oxygen. De-watering of the marsh during low water periods allows wetland bottom soils to aerate, which increases detritus breakdown and nutrient exchange.

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65. In the United States, 50% of the lakes and 60% of rivers have impaired water quality due to excess nutrients from agricultural runoff. www.ars.usda.gov/research/programs/programs.htm?np_code=201&docid=340&page=2

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67. SEMCOG, Land Use Changes in Southeast Michigan, 1990-2000

68. An animal feeding operation is a facility where farm animals are in a confined or concentrated situation for at least 45 days out of any 12-month period and where vegetation is not sustained.

69. The MDEQ is taking steps to implement the new federal NPDES regulations for CAFOs. A stakeholder committee consisting of environmental interest groups, local government associations, agricultural industrial commodity groups, and state and federal agencies developed proposed changes to Michigan's Wastewater Discharge Permit targeted for the fall of 2004.

70. Research by Edsall 1996 as well as by Wilcox & French 1996 revealed that plant nutrients in the water column and in the sediments were high enough to produce the growth of the plant material. Other research by Fox (1995) indicated that storms during the early summer could have caused the detachment of the submersed plants, and using a drift model, showed the possibility of rafting on the western shorelines. Another potential cause for the 1994 accumulation of floating plant mats were the discharges of the combined sewer overflows (CSOs) along the Red Run and near the mouth of the Clinton River.

71. Macomb County was utilizing five CSO basins that discharged a mixture of stormwater and sewage water into Lake St. Clair. These CSO facilities include the Chapatron, Martin, Milk River, St. Clair Shores, and Twelve Towns Basins.

72. www.epa.gov/waterscience/criteria/nutrient/strategy.html

73. From: www.ars.usda.gov/research/programs/programs.htm?np_code=201&docid=340&page=2

74. The U.S. EPA's ECOTOX (ECOTOXicology) database provides single chemical toxicity information for aquatic and terrestrial life and is a useful tool for examining impacts of chemicals on the environment. It is online at: www.epa.gov/ecotox/

75. Bioaccumulation is the accretion of chemicals in animal tissue at levels greater than those in the water or soil to which they were applied.

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91. U.S. industrial permittees in the study area are in compliance with the discharge permits issued to them by the Michigan Department of Environmental Quality (MDEQ) There are minor exceedances of permit conditions at facilities within the watershed but these exceedances are not formally actionable under the enforcement guidance used by the department (MDEQ staff, LSC Management Plan).

92. In the past, spills have had a large impact on environmental quality of Lake St. Clair. The number and size of spills or releases has reduced dramatically over the last several years due to measures implemented by both U.S. and Canadian industries. Between 1990 and 2001, spills on the U.S. side decreased from 28 to 18 annually. Canadian records indicate an even greater reduction, from between 70 and 135 spills annually between 1986 and 1989, to between seven and 12 spills between 1998 and 2002.

    Two plans mandate the procedures and mechanisms for a joint binational notification and response to spills of oil or hazardous substances in the Lake St. Clair region. The first is Annex I of the Canada-United States Joint Marine Pollution Contingency Plan (CANUSLAK) which was mandated under Annex 9 of the Great Lakes Water Quality Agreement. The second is Annex III of the Canada-United States Joint Inland Pollution Contingency Plan (CANUSCENT). Each of these plans establishes fundamental procedures for timely notification and coordinated and integrated response at the federal level of each government.

    Formal cross-border notification procedures have also been adopted and are implemented through the U.S. National Response Center and the Canadian National Environmental Emergencies Centre, as well as the Ontario Ministry of the Environment Spills Action Centre and the Emergency Management Division of the Michigan State Police. The United States Coast Guard and the Canadian Coast Guard have a similar working arrangement and share information with the provincial and state agencies. Water treatment operators also use an informal reporting system. A water intake operator who hears about a spill, or is impacted by an unknown spill, immediately calls the next facility on the "notification list" who in turn calls the next facility, and so on.

    Individually, both the United States and Canada have existing mechanisms in place to respond to and manage the actions required during an oil and hazardous substance spill at the federal, state/provincial, and local level.

93. The MDEQ has regulatory oversight for all municipal wastewater treatment plants on the U.S. side of Lake St. Clair. All plants in watershed are in compliance with their discharge permit requirements although many are on specified compliance schedules to correct problems with their local sanitary sewers. The MDEQ has reported that there are minor exceedances of permit conditions at facilities within the watershed but that none of these exceedances are formally actionable under the enforcement guidance used by the department. When minor exceedances occur, MDEQ staff contact the facilities to determine the cause and assure that corrective actions have been taken.

The Ontario Ministry of the Environment (OMOE) has regulatory oversight for treatment plants in the Canadian portion of the watershed. Over thirty municipal water pollution control plants (WPCPs) are located along the tributaries entering Lake St. Clair on the Ontario side. Another two municipal wastewater treatment plants discharge directly into the lake. The OMOE Environmental Compliance Report reports noncompliance for municipal plant discharging in the region.

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