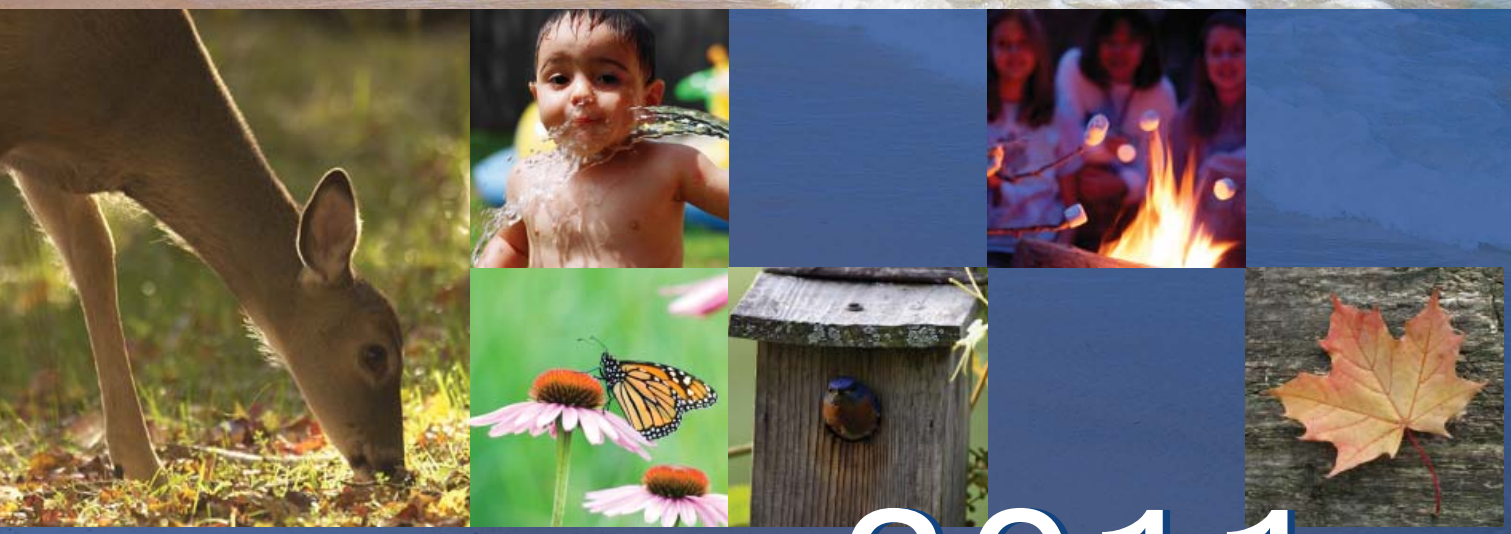
2011 2011 2011

State of Michigan's Environment 2011

Second Triennial Report



State of Michigan's Environment 2011

Triennial Report

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Message from the Governor

As a lifelong Michigander, I have always been deeply proud of what our state represents. We are known throughout the nation for a rich history of innovation as well as our bountiful natural resources. Michigan's expansive forests, coastline beaches, plentiful inland lakes and myriad outdoor recreation opportunities draw visitors from around the country and the world.

We prize our natural resources. The state works endlessly to protect and manage them through the work of several state agencies, most notably the Michigan Departments of Environmental Quality and Natural Resources.

In 1999, the Michigan Legislature mandated that the two departments develop a program to track and report changes in the environment. Program specialists assembled the appropriate scientific tools to monitor biological, chemical and physical attributes of the state's land and water in ways that can show how we are changing over time.

The idea is that by documenting changes in environmental indicators like animal and fish populations, state forests, land cover, air quality and surface water, we can identify trends and craft policies to ensure that our natural treasures remain intact for our kids, their kids and beyond.

This report was conceived as a biennial document, issued in 2001, 2003 and 2005. The Legislature in 2005 directed that it be changed to a triennial report.

I am proud to present "The State of Michigan's Environment 2011." This comprehensive look at where we've been and where we are, in terms of our environment, will help guide our focus in the years to come.

State leaders will find in these pages a useful tool for guiding policy discussions. I welcome that dialogue because every Michigander has a stake in ensuring that the Michigan we leave for future generations is the one we have been blessed to enjoy in our lifetimes.

Rick Snyder,
Governor

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Introduction

The Environmental Indicators Act of 1999 requires that the Michigan Department of Environmental Quality (MDEQ) work with the Michigan Department of Natural Resources (MDNR) to produce reports on the quality of Michigan's environment, based on scientifically supportable environmental indicators using sound scientific methodologies.

In July 2001, the Michigan Environmental Science Board developed a set of criteria from recommendations made by MDEQ and MDNR for evaluating the state's environmental quality. The first biennial report – State of Michigan's Environment – was published in November 2001. Subsequent reports were issued in December 2003 and January 2006.

In 2008, the first of what is now a triennial report was published after the Environmental Indicators Act was amended in 2005.

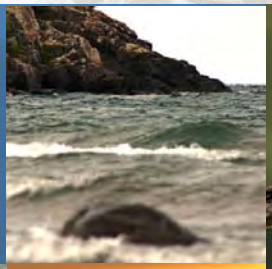
The second triennial report – State of Michigan's Environment 2011 – follows a pattern developed for the 2008 report. It is divided into three sections: Environmental Measures, Programmatic Measures, and Emerging Contaminants of Concern in Michigan.

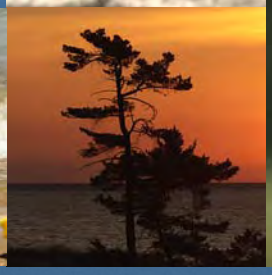
The first section presents the ecological, physical, and chemical measures used to track environmental quality. The second section discusses state agency measures used to fulfill state and federal environmental programmatic requirements. The final section discusses recognized contaminants that may have potential for environmental and public health impacts that experts do not as yet fully understand.

The material contained in this report reflects assessments of highly complex issues; any change noted from the previous report should be understood as a simple snapshot in time. Three years is an extremely short time frame to evaluate natural influences or corrective actions within an ecosystem and any changes could easily be short-term anomalies rather than long-term changes. It may take many, many years to determine actual trends.

Also note that simple value judgments – good, bad, or moderate; healthy or unhealthy – are not scientifically definable and may lead to incorrect conclusions. Additional information may be necessary to accurately identify the trends that various environmental measures may seem to indicate.

These reports provide the State of Michigan with a tool to track and evaluate its ever-changing environment. It is hoped that the Triennial Reports will serve to promote environmental stewardship activities which will ultimately improve the state's overall environmental quality.





Environmental Measures

ECOLOGICAL INDICATORS

Trends in Land Use/Cover

Monitoring change in land use/cover types provides a useful indirect measure of trends in ecosystem health. High rates of land conversion places stress on natural ecosystems. Human population growth and/or dispersal usually cause a conversion of land use/cover types from natural vegetation or agricultural types to more intensive use. While often economically beneficial in the short-term, these changes often have long-term negative impacts on ecosystem health through the loss of wildlife habitat and incremental increased water and air pollution.

Change is the only constant with Michigan's environment. Change occurs through natural processes such as ecological succession and fire, and through human activities such as agricultural, residential, urban, and industrial development. Since European settlement, Michigan's land cover has changed dramatically. At times, this change has occurred quite rapidly over relatively short periods of time. The original land surveyors of Michigan recorded a landscape dominated by forest in the north and a mix of forest and savanna in the south. Early settlers cleared land for agriculture while logging companies provided wood to a growing nation. The logging era of the late 19th and early 20th Centuries changed Michigan's landscape dramatically. The 20th Century was marked by a return of forest to the northern Michigan landscape and intensive agriculture and urban development in southern Michigan. **Exhibits 1 and 2** provide a graphic representation of the loss of wetlands in Michigan between 1800 and 1980 and the percent change in natural vegetation, respectively, that

Exhibit 1. Changes in Michigan's Wetlands 1800 - 1980

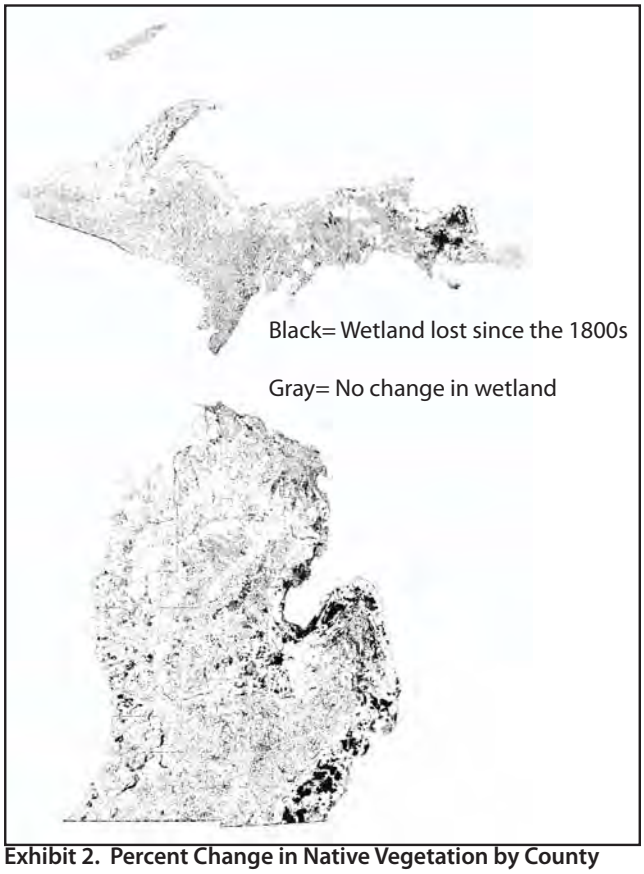
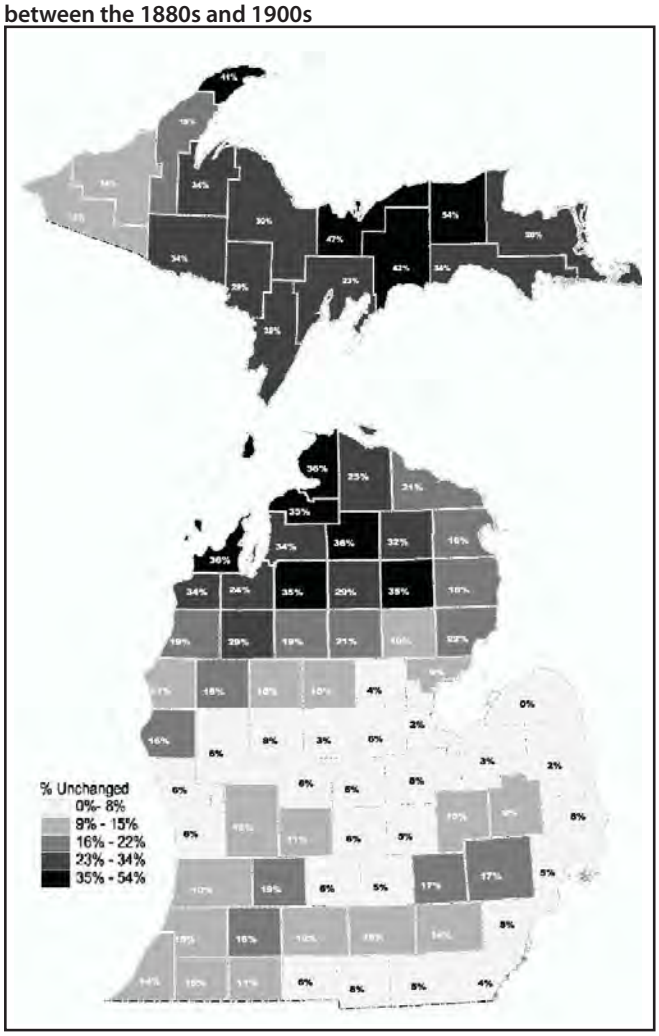


Exhibit 2. Percent Change in Native Vegetation by County between the 1880s and 1900s



have taken place due to competing uses of land resources in Michigan between the 1880s and the 1990s.

Michigan's land cover was mapped in 1978 by the MDNR. At that time, Michigan was composed of 37 percent forest, 29 percent agricultural, 18 percent wetland, 8 percent open field, 6 percent urban, and 2 percent inland water. The United States Department of Agriculture (USDA) also tracks changes in Michigan's land cover through its National Resources Inventory program. According to the USDA, between 1982 and 2007 there was a 50 percent increase in developed land. Most of this development occurred on former agricultural land. During this same time period, there was a loss of approximately 2.3 million acres of crop and pasture land. Other noticeable recent trends include an increase in forests and a decrease in wetlands. Between 1982 and 2007, there was an increase of 721 thousand acres of forest on non-federal rural land in Michigan. The increase in forest was the result of natural succession of open fields and abandoned agricultural land. In 1978, Michigan had approximately 6.2 million acres of wetlands. The United States Fish and Wildlife Service (USFWS) reports that the rate of wetlands loss has declined dramatically across the nation compared to previous decades; however, loss of wetlands is still occurring with conversions to urban and agricultural uses.

Urbanization

As previously indicated, the percentage of Michigan land in urban use in 1978 was six percent. Numerous studies have documented the changes in Michigan's land cover since 1978, most notably the spreading of urbanization along with a population out-migration from many cities. According to one such study, if current land use patterns continue, between 1.5 and 2 million more acres of land area will be urbanized by 2020.

In 2001, the Michigan Land Resource Project looked at the future of Michigan's land-based industries if current development trends continue. The Michigan Land Resource Project projected that by 2040 the amount of developed land in Michigan will have increased by 178 percent, nearly three times that which currently is developed. At the same time, it was predicted that the amount of acres in agriculture, private forests, wetlands, and other vegetated lands, would decrease by 17 percent, 8 percent, 10 percent, and 24 percent, respectively. The recent economic recession potentially impacted the pace and spread of urbanization in Michigan. In addition, Michigan was the only state in the nation which lost population, losing .6% of its population. Most of the loss occurring in Wayne

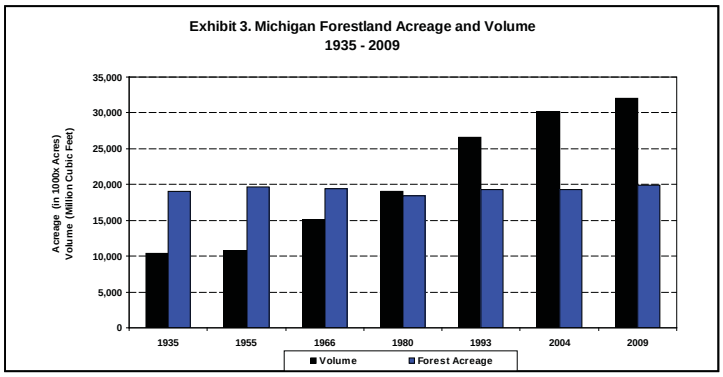
County (10% of its population) and counties in the Upper Peninsula (Iron County-10%, Ontonagon County-13%). The implications of the state's recession and loss of population have not been studied to understand their impact on the spread of urbanization. Information from the 2010 census reveals, however, that those rural counties closest to population centers continue to grow faster than the urban core counties, e.g. Clinton and Livingston counties. Also counties in northwest Michigan also experienced large population growth (Grand Traverse County-12%).

Trends in Forest Acreage, Mortality, Growth, and Removals

The Forest Acreage, Mortality, Growth, and Removals indicators address several dimensions

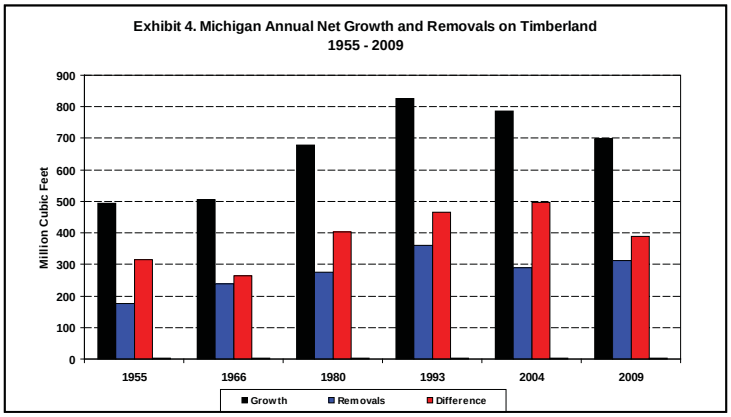
relating to the health of Michigan's forests. As previously indicated, Michigan's forests have been recovering following over-exploitation and fire devastation that took place towards the end of the 19th Century and the beginning of the 20th Century. The state will never again see the vast forest acreages or the old growth forests that once were present; however, recent inventory data indicate the state's forests have been steadily recovering over the past century.

Six statewide forest inventories have been conducted by the U.S. Forest Service, Forest Inventory and Analysis (FIA) program during the past 80 years. These inventories indicate that forest acreage has remained relatively stable since the 1950s. The only exceptions to this are a slight decrease between 1966 and 1980, which was followed by an expansion between 1980 and 1993 and a second modest expansion between 2004 and 2009 **(Exhibit 3)**. Losses (or conversions out) of forested land between 1980 and 1993 were made up for by other lands being converted into forest. The predominant land type converting into forest was agricultural.



In contrast to the stable forest acreage, total standing timber volumes have more than tripled since the middle of the last century and continue to increase through the 2009 inventory, reflecting a maturing forest **(Exhibit 3)**. This expanding volume also indicates that more growth has been continuously added to the forest than what has been removed or died through natural causes. However, increases in annual net growth peaked in the 1990s and are now decreasing, as natural mortality has been increasing **(Exhibit 4)**. This is also reflective of a maturing forest resource.

The proportion of growth to removals decreased between 2004 and 2009 and is approaching 2:1. This effect is mostly due to decreased growth over the same period.



Trends in Vegetation Diversity and Structure

Michigan's forests are some of the most diverse in the United States. The FIA statewide forest inventories identify over 75 different tree species with substantial mixtures of species within each of the major forest cover types. This diverse forest provides habitat for a wide variety of plant and animal species.

In addition to maturing, Michigan's forests have been gradually transitioning towards more shade-tolerant, late successional tree species. For example, aspen and paper birch (species particularly adapted to full sunlight) has declined in both acreage and volume since 1980, while the more shade tolerant species such as maple, spruce, and oak-hickory types have increased. The acreage and volume of jack pine have also been declining since 1980, but the loss has been more than offset by gains in red and white pine. The broad increase in volume across most cover types has been accompanied by a trend toward more sawtimber-sized trees. Recent data indicate the trend towards more shade tolerant, older trees may be diminishing or stabilizing as timber harvesting of more mature trees perpetuates shade intolerant, early successional species. Ash species are an exception to this trend, as extensive mortality is occurring from the continued spread of the exotic Emerald Ash Borer throughout the state.

Similarly, animals that depend on pioneer tree species for habitat also have declined over the past several decades. For instance, ruffed grouse,

American woodcock, golden-winged warbler, and other songbirds dependent upon early successional tree species have suffered from this change in habitat while other bird species dependent on the shade-tolerant tree species have benefited.

The MDNR, in conjunction with the University of Michigan, participates in a national program that conducts annual evaluation of the condition, changes, and trends in the health of forest ecosystems in Michigan. The USDA Forest Service manages this national program, referred to as the Forest Health Monitoring Program (FHM Program). The vegetation diversity and structure indicator is composed of a suite of measurements of forest understory diversity, vegetation structure, down woody debris, and forest fire fuel loading. Variables collected for this indicator can provide information to help evaluate wildlife habitat, plant diversity, vitality, soil conservation, and carbon cycling. As part of the FHM Program, botanists field identify nearly all the plant species on site, including locally rare species and exotic species from overseas. An immediate return from this evaluation is to detect areas of exotic plant invasion and spread. Multi-scale data on plant diversity can be used to evaluate species richness patterns over time. This information will help to evaluate the effect of exotic plants relative to their native counterparts. However, no data or formal reporting on vegetation diversity and structure are available at this time nor anticipated due to federal funding being eliminated for the further development or evaluation of this indicator.

Trends in Lichen Communities

Lichens are unique organisms, made up of cooperating algae and fungi. Individual species in this very diverse group are useful as environmental indicators. Epiphytic lichens, or lichens that live on other plants, are very sensitive to changes in air quality since they rely totally on the atmosphere as a source of nutrition. A large body of scientific literature has documented the close relationship between lichen communities and air pollution, especially acidifying nitrogen, fertilizing nitrogen, sulfur dioxide, and other sulfur-based pollutants.

The composition of a lichen community is one of the best indicators of air pollution in forests. Long-term observations of the abundance of a particular group or species of lichen can provide early indication of changes in air quality or changes in forest composition. A decline or increase in the abundance of a particular species of lichen can be a bellwether of declining or improving environmental conditions.

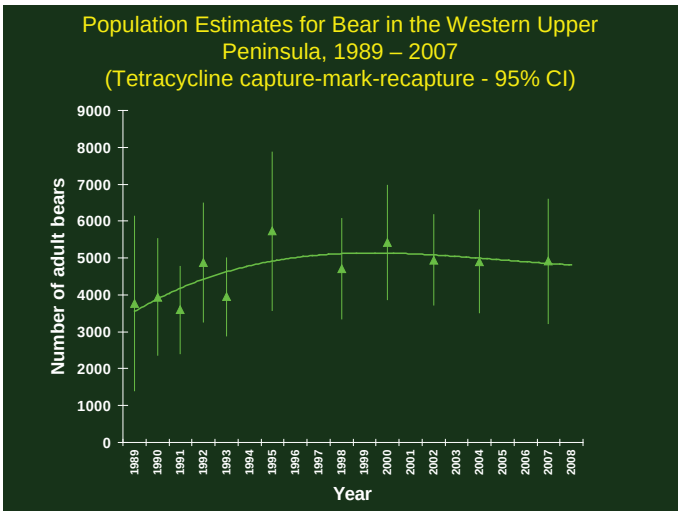
The USDA Forest Service's FHM Program developed the lichen community indicator. Lack of funding for this facet of the FHM Program has prevented collection of lichen indicator data since 1998, and its not anticipated that this funding will be restored in the immediate future.

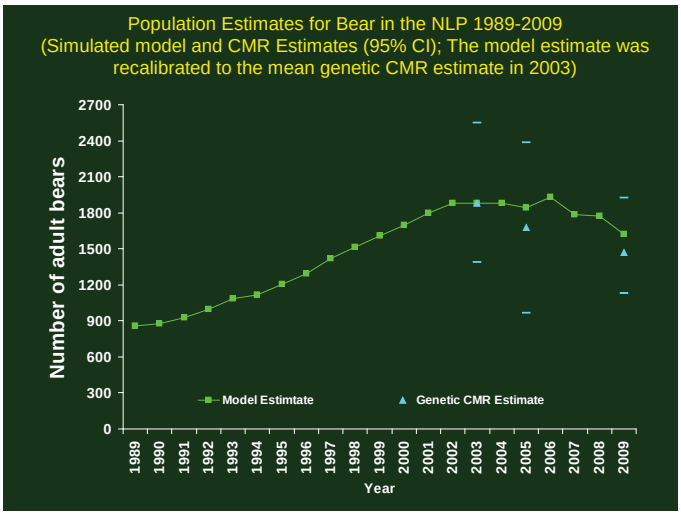
Trends in Mammal Populations

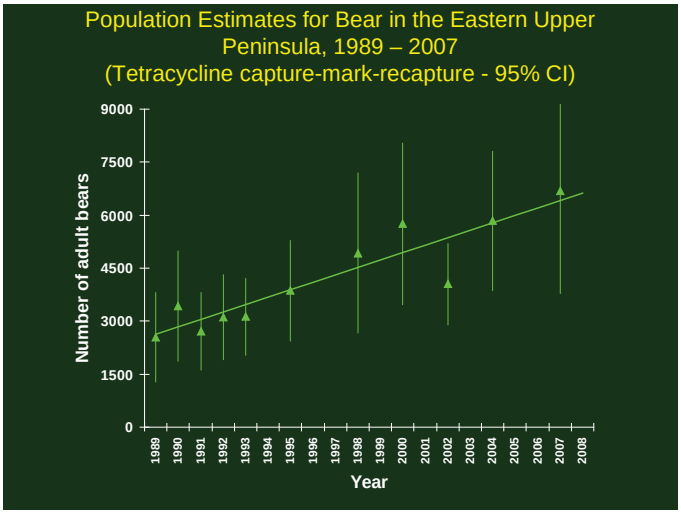
Many mammal populations in the state have remained stable or are increasing. For many of us in Michigan, large mammals like bear, wolf, and moose, are important to the natural heritage of our

beautiful state. Mammals can tell us about the health of our environment in a variety of ways. Much of our information on population trends in mammals are gained through indices such as, the winter track surveys for wolves, aerial surveys for moose, and annual harvest surveys for most other mammals that are hunted or trapped.

Exhibit 5,6,7 Bear







For some more common mammals, like raccoons and coyotes, there is a perception that their populations have increased greatly. Yet looking at their populations statewide, they are likely stable or only slightly increased due to people-animal interactions because these species have become adapted to urban and suburban habitats and more people have moved into once rural areas, rather than dramatic increases in populations. The primary tools for managing these species are trapping and hunting.

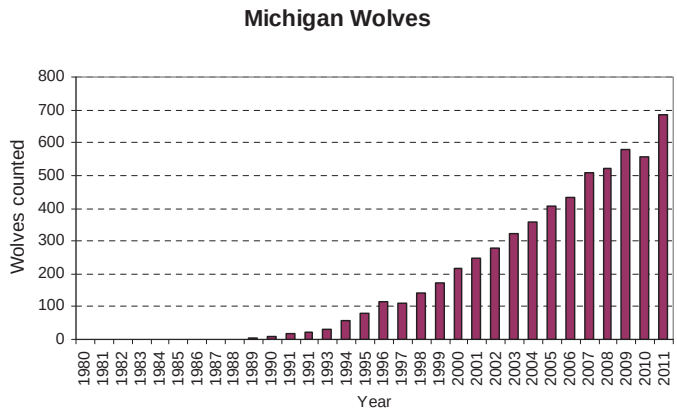
Bear

Bear populations have remained relatively stable or are slightly increasing **(Exhibit 5,6,7).** Bears are naturally shy omnivores that do feed opportunistically, which can create conflicts with people. They have been expanding their range into the southern Lower Peninsula, and it has become clear that bears can also inhabit areas with people, provided some forested habitats exist, especially along riparian zones. The MDNR manages bear populations sustainably to provide recreational opportunities through hunting and wildlife viewing, while balancing local communities tolerance for bears. Hunting is the primary management tool to help limit negative people-bear interactions by keeping bear populations under biological and social carrying capacity. In 2008, a bear management plan was developed to guide thoughtful management for multiple values of bears. For more information about bears go to: **www.michigan.gov/bear**.

Wolf

The gray wolf population in the Upper Peninsula has continued to grow at about a 10% increase per year **(Exhibit 8)**. As a result of successful management on the part of various agencies, wolves have met

Exhibit 8 Wolves



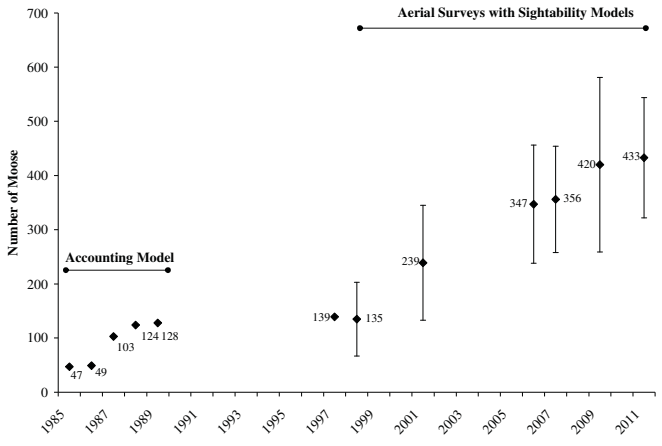
and exceeded recovery goals. Steps are now being taken by the US Fish and Wildlife Service, at the urging of the State, to remove the gray wolf in the Western Great Lakes region from the federal endangered and threatened species list because they no longer require the protection of the Endangered Species Act. With concerted effort, we can do great things for wildlife.

Moose

Moose were reintroduced to the Upper Peninsula of Michigan in the mid-1980's to produce a self-sustaining population, with an optimistic goal of 1,000 moose by the year 2000. Unfortunately, the population of this majestic animal grew slower than the predicted rate, and as a result the herd did not meet those initial expectations **(Exhibit 9)**. Legislation passed in 2010 established a Moose Hunting Advisory Council that is charged with considering a moose hunting season in Michigan. Their report is due in December 2011.

Michigan is at the southern edge of the range of moose in North America due to temperature restrictions. Projections of climate change suggest that temperatures in Michigan will rise by 6-10˚ F in the winter by the end of the 21st century, which likely will be too warm for moose in the Upper Peninsula. As such, moose are likely to be an early indicator of climate change here in Michigan.

Exhibit 9 Moose



Winter population estimates and 95% confidence intervals (for 1999-2011) of moose in the western Upper Peninsula, 1985-2011. Estimates from 1985-1989 were based on an accounting model and estimates from 1997-2011 were based on aerial surveys corrected with sightability models (see text for details).

Bats

Although bats have not been discussed in previous years of this report, they warrant mentioning. Bats make up one-fourth of the world's mammal species. They consume large amounts of insects and are one of the primary nighttime predators of insects. Unfortunately they are currently at great risk. White-nose syndrome appears to be an exotic disease in North America that has been killing bats. The syndrome was named for the white fungus that sometimes develops on the muzzle of the bat, giving the appearance of a white nose. Infected bats prematurely awaken from hibernation, rapidly depleting their fat reserves, and are unable to survive the winter. The disease is thought to be spread through bat-to-bat contact or by humans visiting caves and mines. To date over one million bats have died from white-nose syndrome. The disease has yet to reach Michigan, but it seems likely it will appear here in the near future. The public can help with surveillance efforts by reporting large numbers of bats dead, dying, or exhibiting unusual behavior to **www.michigan.gov/emergingdiseases**.

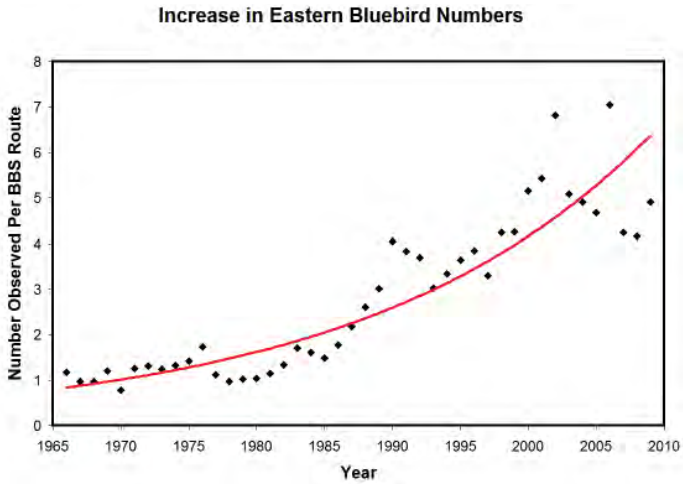
Trends in Breeding Bird Populations

Bluebirds

The numbers of cavity-nesting birds, like bluebirds, are frequently limited by a shortage of nest sites. The introduction of two exotic cavity-nesters (house sparrows in 1851, and European starlings in 1890) increased the amount of competition bluebirds experienced for nest sites. As the populations of house sparrows and starlings increased, the beautiful bluebird began to decline due to a loss of a critical piece of their habitat through

competition. In the late 1970s, two books were published on the plight of the bluebird and the public became more aware of the problem. There

Exhibit 10 Bluebird

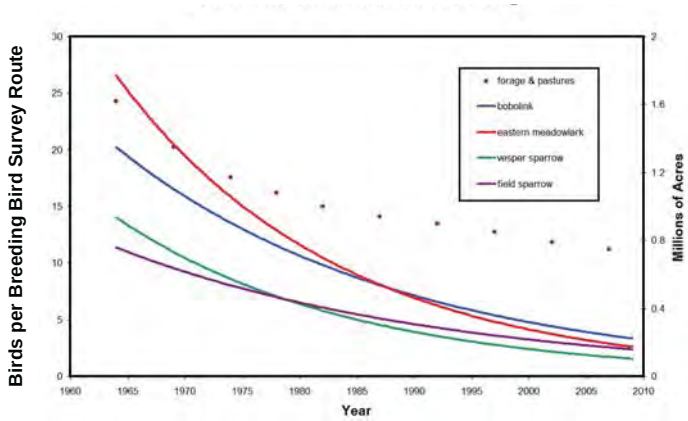


was a groundswell of interest in bluebirds and it became common for individuals to erect nest boxes. Breeding Bird Survey data **(Exhibit 10)** shows an increase in bluebird numbers that corresponds to the increased interest in the birds. The story of the bluebird not only demonstrates the negative impacts that many exotic species have on our native wildlife, but it also demonstrates the positive impact the average citizen can have on threatened wildlife. This is a great success story.

Grassland Birds

As a group, grasslands birds are the most at-risk of all North American birds. **Exhibit 11** Grassland Birds and Livestock Forage, shows four representative grassland birds that have been declining at an annual rate of about four percent per year over the past 43 years. Most of these declines have been attributed to changes in land use and agricultural

Exhibit 11 Grassland Birds & Livestock Forage



practices. Michigan livestock production has been gradually shifting from being forage-based, where feed is dependent upon hay and pasture, to production, more dependent on grain and silage **(Exhibit 11),** resulting in a loss of grassland habitat. In addition to acreage declines, the average size of grassed parcels has shrunk, making them less attractive to grassland birds that require large areas. Those lands still maintained in hay or pasture are often being managed more intensively, harvested earlier, more frequently, and at higher rates, which disturb or destroy nests. In addition, many grasslands have been converted to other land use types. All of these changes are reducing the quantity and quality of habitat available for grassland birds, and hence major declines continue to be seen in their populations.

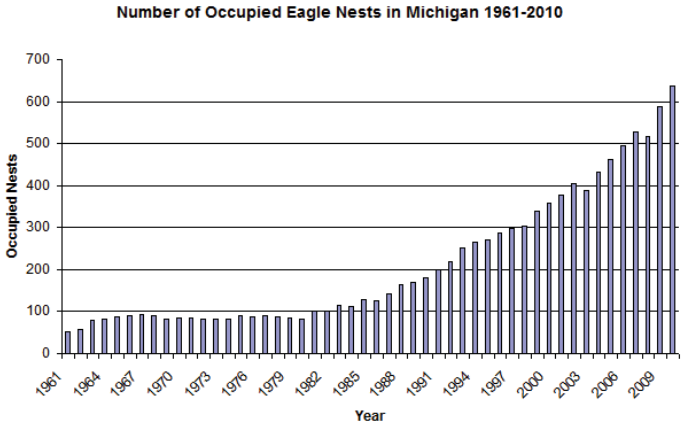
Trends in Bald Eagle Populations

The bald eagle is a top-level predator of the aquatic ecosystems. The bald eagle's position at the top of the food chain makes it highly vulnerable to impacts that result from contaminants that accumulate in the food chain. During the late 1950s and early 1960s, the bald eagle and many other predator and colonial species of birds declined significantly due to years of widespread pesticide and other chemicals hazardous to reproduction. With the advent of strict environmental laws on the production and use of pesticides, the bald eagle and other bird populations began to recover.

As one measure of population change, the National Audubon Society began the National Bald Eagle

Census in 1961. The MDNR began conducting annual censuses of bald eagle nests in Michigan in 1963. From a low of 50 nests recorded in 1961, the bald eagle population has continued to increase to a known high of 636 occupied nests in 2010 **(Exhibit 12)**. In addition to an increasing

Exhibit 12 Bald Eagle



population; nest success, measured as number of nests producing fledged young, also has increased. Combined, these measures suggest that not only are bald eagles increasing in number, but that they also are successfully raising more young per breeding pair than in the past.

Trends in Frog and Toad Populations

Frogs and toads can be effective indicators of environmental quality. They breathe through their permeable skin and may absorb toxins and other gases directly into their system. Also, their reliance on both aquatic and terrestrial habitats during their life cycle makes them particularly vulnerable to a variety of threats. Frogs and toads are sensitive to changes in water quality and adjacent land use practices. They are easily recognized by their vocal calls, making them great indicator species. In 1996, the MDNR established a statewide volunteer survey to monitor frog and toad population trends. Volunteers, following a national protocol as part of the North American Amphibian Monitoring Program, visit survey routes three times during the breeding season. Data collected include species heard and an abundance index for each species.

Most of Michigan's 13 native species of frogs and toads appear to have stable population trends. Overall, this is great news for our frogs and toads, their habitats and the environment.

Exhibit 13 and Exhibit 14 illustrate abundance trends of three of the less common frogs and toads (northern leopard frog, bullfrog, and American toad) and three of the more common frogs and toads (spring peeper, eastern gray treefrog, green frog), respectively, that have statewide distribution and relatively stable populations. Fowler's toads have been rarely reported, however over the last two years they have not been reported at all. This has raised concerns over Fowler's toads and research to understand what is happening is needed. Mink frogs continue to raise concerns with local herpetologists because they too are rarely reported in the survey.

This type of long-term trend data provides insight into the natural fluctuations of frog and toad populations, which can then be distinguished from threat-related factors. The MDNR plans to continue the statewide surveys indefinitely. This monitoring program is a great example of a state agency and volunteers working together to conserve and manage wildlife.

Exhibit 13 Frog 1

Frog 1: Average Number of Sites per Survey Route that Northern Leopard Frog, Bullfrog, and American Toad were Heard, 1996-2010.

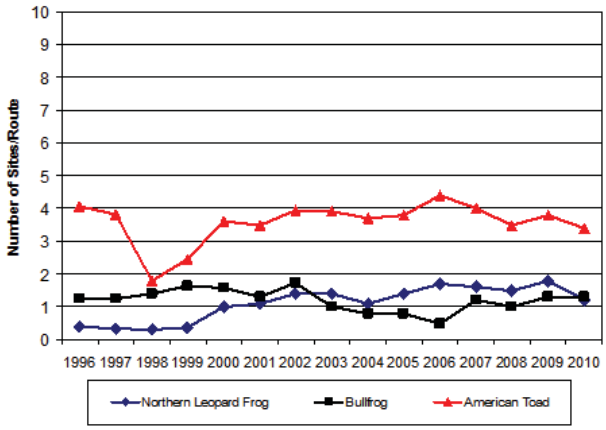
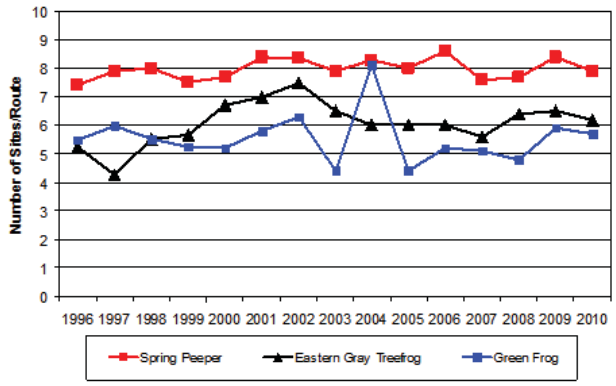


Exhibit 14 Frog 2

Frog 2: Average Number of Sites per Survey Route that Spring Peeper, Eastern Gray Treefrog, and Green Frog were Heard, 1996-2010.

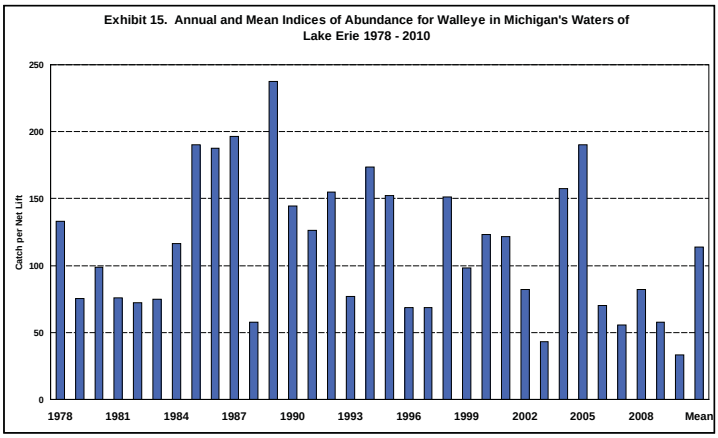


Trends in Fish Populations, Benthic Macroinvertebrates, and Contaminant Levels

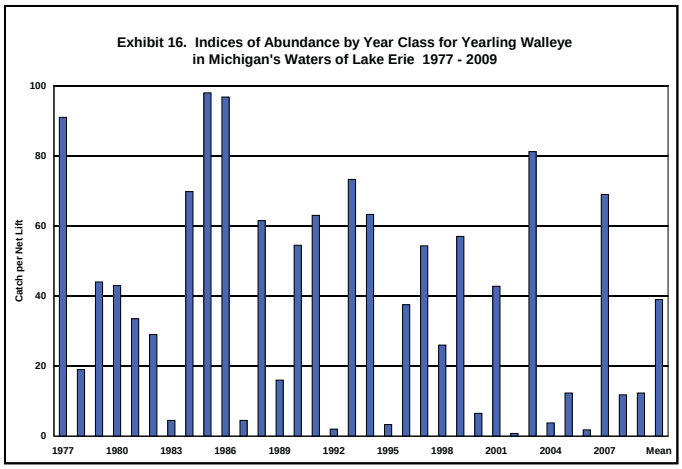
Walleye in Lake Erie

The MDNR has employed an experimental gill net fish sampling protocol at two stations in western Lake Erie since the fall of 1978 as part of a cooperative interagency Walleye Assessment Program. This protocol, referred to as the Index Gill Net Survey, typically includes two 1,300-foot sets of variable-mesh multi-filament gill nets at each sampling station. The gill nets are suspended six feet below the surface of the water. The Index Gill Net Survey is conducted during early October each year.

Gill net catch rates reflect trends in walleye abundance. The trend in the total walleye catch rate for each year of the MDNR Lake Erie Index Gill Net Survey provides an index of abundance **(Exhibit 15)**. In general, walleye abundance was relatively low in the late 1970s and early 1980s, increased in the 1980s, and peaked in 1989. From 2000 to 2003, walleye abundance declined to the lowest level observed since 1978. In 2004 and 2005, abundance rebounded to levels well above the mean on the strength of the 2003 year class. Since 2006, a general downward trend has been apparent, with the 2010 abundance level the lowest recorded since the survey began in 1978. Annual walleye abundance is strongly related to annual variation in reproductive success. This is reflected in yearling catch rates each year **(Exhibit 16)**. The impact of poor reproduction for Lake Erie walleye is well illustrated in the low catch rates observed for yearlings from the 2000, 2002, 2004, 2006, 2008, and 2009 year classes. In contrast, the yearling catch for the 2003 year class indicates reproductive success



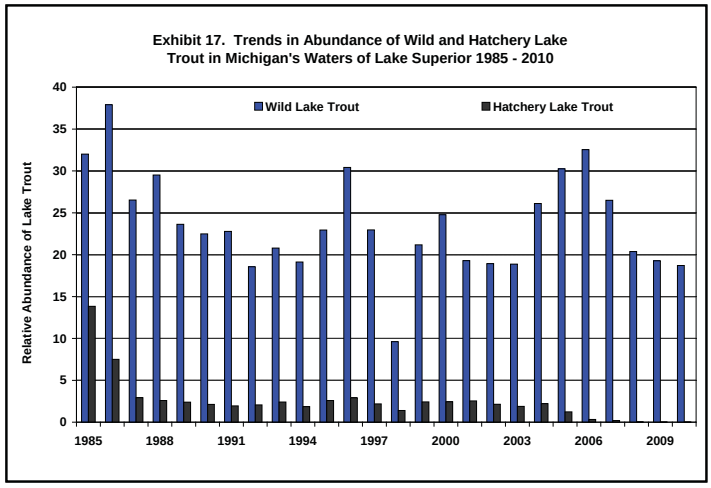
was the highest achieved since the mid-1980s. While less abundant than the 2003 year class, the yearling catch for the 2007 cohort is also well above the mean.



Lake Trout in Lake Superior

The lake trout is the dominant native predator fish in the cold-water fish communities of the upper Great Lakes. Lake trout numbers are a good indicator of aquatic ecosystem health. Lake trout are long-lived and accumulate toxins in their bodies. The concentrations of these toxins are monitored by the MDEQ to evaluate potential health risks to the public. Imbalance in fish community dynamics also is reflected in shifts in lake trout population dynamics. During the 1940s and 1950s, lake trout populations significantly declined due to high levels of commercial exploitation and parasitism by the non-native sea lamprey. Subsequently, an extensive lake trout rehabilitation program was implemented to re-establish self-sustaining populations. Lake trout populations increased during the 1970s and early 1980s due to sea lamprey control, restrictions on commercial fisheries, and stocking of hatchery-raised lake trout. During the mid-1980s, wild lake trout populations (sustained by natural reproduction) were increasing in most areas of Michigan's waters of Lake Superior. By the mid-1990s, wild lake trout abundance increased to a point where stocking of hatchery-produced fish was discontinued in all areas of Michigan's waters of Lake Superior, except in Keweenaw Bay and Whitefish Bay. During the period of increasing wild lake trout abundance, hatchery lake trout abundance and survival declined. Currently, lake trout populations are nearly rehabilitated in all areas of Michigan's waters of Lake Superior, except in Whitefish Bay.

(Exhibit 17). In recent years, hatchery lake trout comprise less than five percent of lake trout abundance in Michigan's waters of Lake Superior, except in Whitefish Bay where most fish are of hatchery origin. High levels of commercial exploitation and lack of significant natural reproduction have been inhibiting lake trout abundance in Whitefish Bay. In addition, moderate levels of fishery exploitation on the west side of the



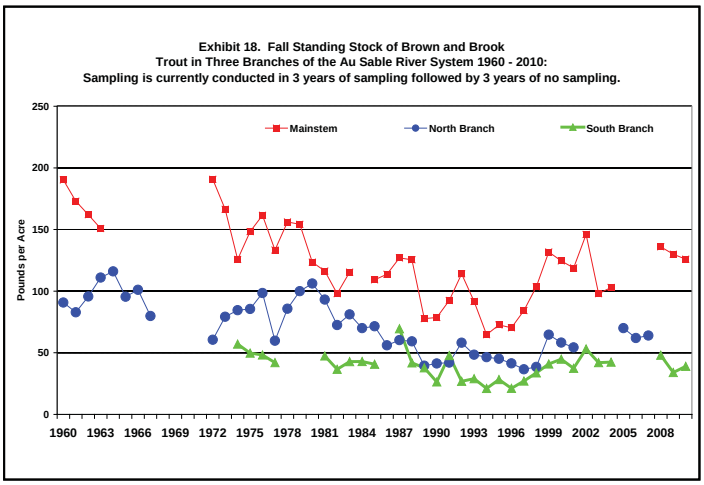
Keweenaw Peninsula may be affecting recovery of lake trout and is being monitored closely. Further, lake trout growth rates have declined to the lowest levels since the 1970s due to the higher abundance of lake trout and lower abundance of prey fishes.

Brown and Brook Trout in the Au Sable River System

Trends in stream fish populations can be useful environmental indicators because the quality of their habitat is shaped by conditions in the watershed upstream. Stream trout may be a particularly good indicator because healthy, self-reproducing trout populations require specialized environmental conditions. Trout need relatively cold and well-oxygenated water. They also require clean gravel for spawning, shelter from predators, high velocity water, a diverse and abundant food supply, and free access to different habitats at different stages of their lives.

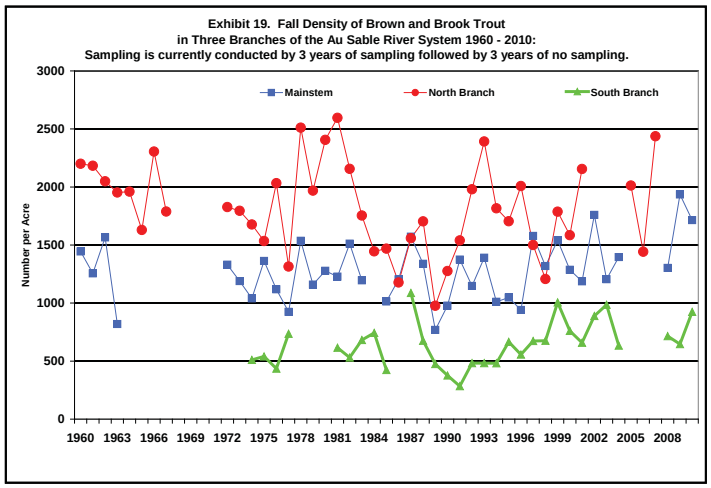
Human activities in a watershed have the potential to either enhance or degrade trout habitat quality. Activities that reduce ground water yield to streams can result in a warming of the water body, which reduces the area available for trout to survive. Cutting or clearing trees from land adjacent to streams reduces shading, reduces the potential for trees to fall into the stream to provide shelter and nutrients, and may increase erosion of sediment into the channel. Any construction in a watershed that increases soil erosion to streams degrades trout habitat. Activities in a watershed that change the magnitude or timing of flood flows also diminish habitat quality. Examples of such activities include construction of drains and storm sewers, increases in water-impermeable surfaces such as parking lots, and operation of lake level control structures.

The MDNR has sampled trout populations for many years at fixed sites in portions of the upper Au Sable River system in Crawford County. Fall standing stock of brook and brown trout (expressed in pounds per acre) in the mainstem and north branch of the Au Sable River were generally higher during the 1960s and 1970s than in subsequent decades **(Exhibit 18).** Trout standing stock was substantially lower than average in all three branches from about 1985 to 1995, but have increased since that time. The decline in total trout standing stock was primarily due to declines in growth, survival, and reproductive



rates for brown trout. Extensive additions of large woody material intended to increase availability of protective cover may be partially responsible for the recent increases in trout standing stock. In addition, privately- and publicly-funded habitat restoration efforts have been directed toward reducing erosion of sediment into the river system. Relatively stable spring flow conditions during most years over the past decade also likely contributed to the increase in stocks because stable spring flows promote better survival of young trout.

Long-term trends in total numbers of brook and brown trout combined are not as obvious since the range of trout densities observed was quite large **(Exhibit 19)**. Average total brook and brown trout density during each decade (1960s through 1990s) has been very similar. Total density of trout since 2000 is higher than the long-term average for the period of record in all three branches. Current trout abundance in the upper Au Sable River is indicative of good overall habitat quality.



Benthic Macroinvertebrates

The MDEQ collects data on the relative abundance of benthic macroinvertebrates in streams and rivers throughout Michigan. These surveys, which are a major component of the state's watershed assessments, are conducted on a five-year rotating basin schedule to support the National Pollutant Discharge Elimination System and nonpoint source protection programs. The sampling method, known as Procedure 51, is a rapid assessment protocol designed to quickly assess stream aquatic life conditions. Biologists sample streams to identify the benthic macroinvertebrate species present and to use this information to determine whether waterbodies are attaining Michigan Water Quality Standards (WQS).

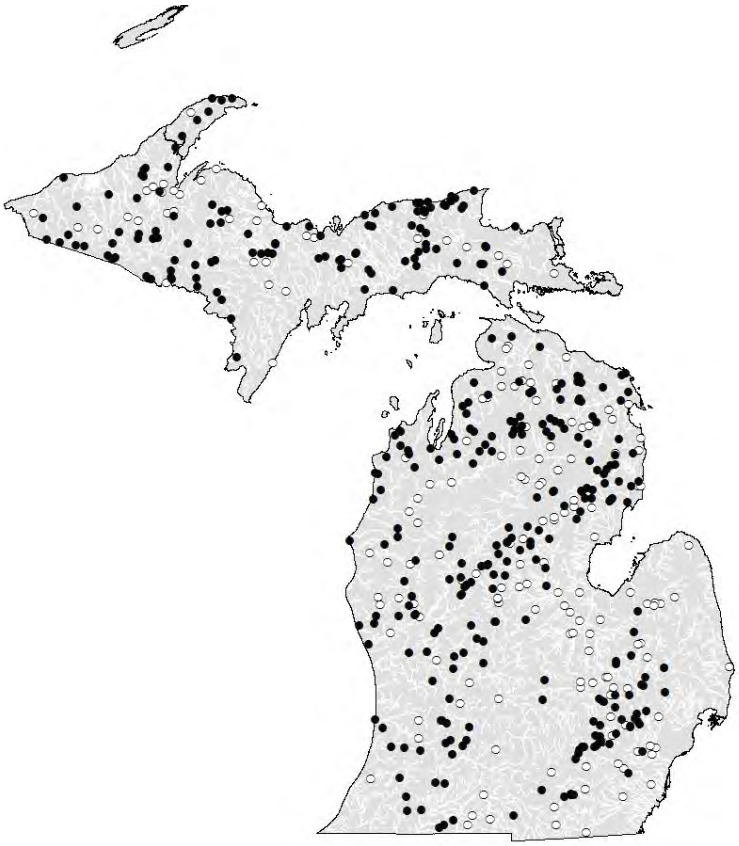
The MDEQ recently developed a statistically-based network design and sampling procedure to assess statewide WQS attainment, and to measure long-term trends in benthic macroinvertebrates at a mix of fixed and randomly selected stations. This design has been in place since 2006, and we recently completed one statewide five-year cycle (2006-2010). During this cycle, a total of 1,224 sites representing approximately 20,600 stream/river miles were assessed. Our preliminary indication is that the overall statewide attainment for the Other Indigenous Aquatic Life Designated Use (OIAL) was 95% +/- 2%, although additional statistical analysis is ongoing. The attainment percentages by watershed ranged from 30% in the Detroit River watershed to 100% in several watersheds. These numbers apply only to the OIAL Designated Use based on benthic macroinvertebrates; many other waterbodies are listed as non-attaining for other Designated Uses based on other sources of data, such as chemical contaminants, temperature, dissolved oxygen, *E. coli*, etc.

During the next 5-year cycle, the attainment status in each watershed will be reassessed using a new set of randomly selected sites. In addition, up to ten sites visited in the first cycle in each watershed will be re-sampled in future cycles to monitor for trends over time. These results will be provided in future reports.

Status and Trends Program

Assessing the status of over 10,000 inland lakes and 36,000 miles of stream habitat in Michigan is a daunting task. Over the past several decades, the MDNR has conducted numerous surveys of fish populations in lakes and streams across the state. Although a few assessments have been conducted with consistent methods over a long period of time, most surveys have been short-term, with the intention of addressing immediate site-specific issues. While this strategy has proven useful for providing information to support fisheries management on individual water bodies, it does not provide an adequate statistical framework

Exhibit 20 - Ramdomly selected lakes and streams sampled from 2002-2010



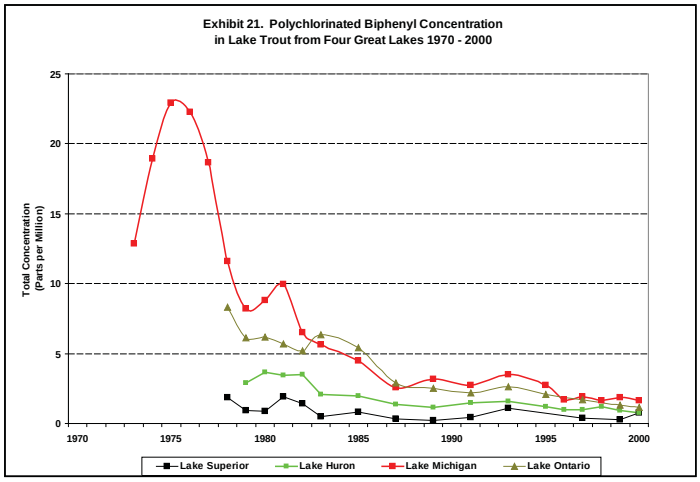
Lake (closed circle) and stream (open circle) locations sampled by Fisheries Division's Status and Trends Program.

for inferences regarding status and trends in fish populations and communities across broader spatial or temporal scales. Consequently, this historical data strategy does not allow fishery managers to put the results of individual lake surveys in the context of larger scale trends that may need to be addressed.

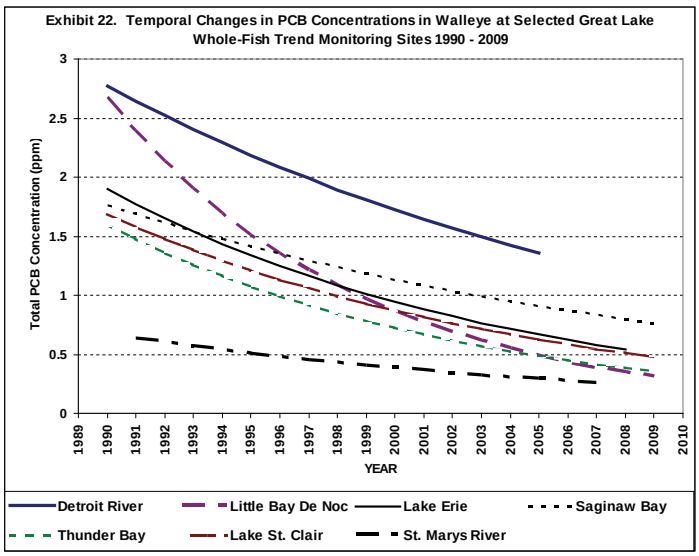
Recognizing the limitations of this approach to provide regional or statewide trends in fish populations, the MDNR began its Status and Trends sampling program in 2002. This program annually evaluates the status and trends of habitat conditions and fish communities at randomly selected streams and lakes throughout the state; further detail in the trends of high-quality trout and smallmouth bass streams is recorded from a network of 48 fixed sites throughout the Upper and Lower Peninsulas. In addition to the fixed stream sites, 356 randomly selected lakes and 169 randomly selected streams were sampled from 2002 – 2010 **(Exhibit 20)**. Data analysis for the first six-year reporting period of the Status and Trends Program was completed in 2010. The results (expected to be published during 2011) will give biologists and stakeholders statistically sound estimates of the status and trends of game fishes, non-game fishes, and aquatic habitat while still providing information essential for effective fisheries management.

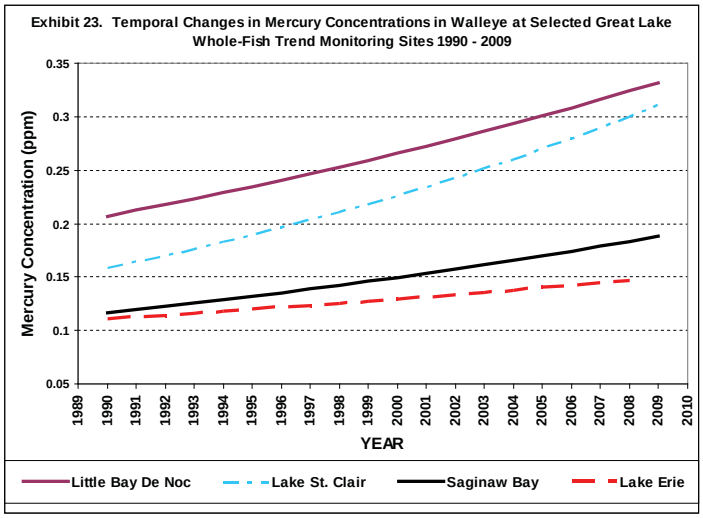
Contaminants in Fish

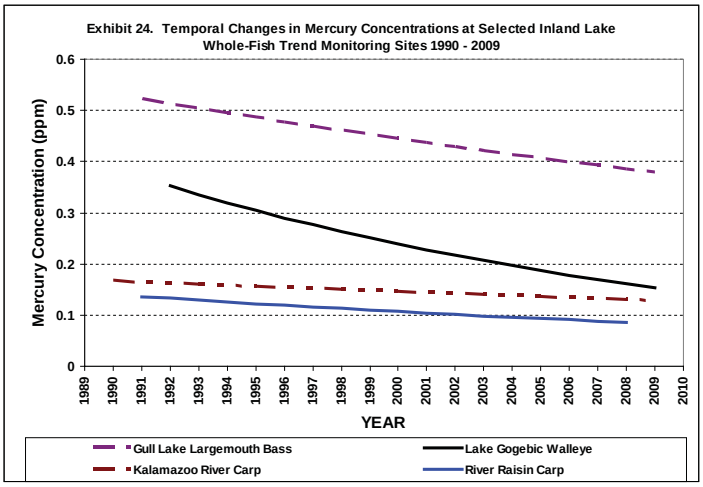
The MDEQ monitors persistent, toxic pollutants in fish from waters of the state. Extremely low concentrations of some of these pollutants in water can bioaccumulate to relatively high concentrations in fish tissue. In some cases, contaminant concentrations in fish tissue may reach levels that pose a wildlife or human health risk. Currently, Michigan collects and analyzes over 700 fish tissue samples from approximately 50 locations annually. Since 1980, Michigan has collected and analyzed over 17,000 fish tissue samples from more than 800 locations. Edible portion (fillet) samples are used to develop sport fish consumption advisories. Fish from 22 fixed Great Lake, connecting channel, and inland lake sites are collected every 2 to 5 years and analyzed as whole fish as a means to measure temporal trends in contaminant concentrations.



Since the 1970s, pollution control efforts have resulted in significant reductions of many contaminants. Data collected by the EPA indicate that PCBs in whole lake trout from the Great Lakes have declined dramatically **(Exhibit 21)**. In addition, temporal trend data collected by the MDEQ indicate that PCB levels in walleye from the Great Lakes and connecting channels have declined since 1990 **(Exhibit 22)**. Similar trends for PCBs and the pesticides DDT and chlordane have been measured in other species, both in the Great Lakes and in inland waters.







The MDEQ trend data indicate that mercury concentrations have increased in at least one species of fish from 6 of 10 Great Lake or connecting channel trend sites, including walleye from Lake Michigan, Lake Huron, Lake Erie, and Lake St. Clair **(Exhibit 23).** In contrast, significant declines in mercury concentrations have been measured at 4 of 12 inland lakes **(Exhibit 24)**; no significant changes in mercury concentration have been measured at the other 8 inland lakes.

Trends in Endangered, Threatened, and Special Concern Species

Conservation, protection, and restoration of Michigan's endangered, threatened, and special concern species takes multiple approaches. Monitoring populations provides critical data to determine the need for listing a species on the state list. A state endangered species is one that is in danger of extinction throughout all or a significant part of its range in Michigan. A state threatened species is one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range in Michigan. These species have legal protection under the Michigan Endangered Species Act. Special concern species are species thought to be declining and if they continue to decline may warrant legal protection under the Act. Monitoring and conservation efforts directed towards these species now may help to secure their populations and prevent the need to list them as endangered or threatened in the future. **Exhibit 25** presents the number of plants and

Exhibit **25**: Number of plants and animals in Michigan, and the number considered endangered, threatened, special concern, or extirpated in Michigan (2011).

Category	Total Number	Endangered	Threatened	Special Concern	Presumed Extirpated
Plants	2,833	79	198	91	52
Mussels and Clams	77	13	6	16	0
Snails	180	13	10	38	0
Insects	15,000-20,000	7	14	81	1
Fish	152	9	9	8	9
Amphibians	23	2	1	3	0
Reptiles	29	2	3	6	0
Birds	414+	9	14	18	1
Mammals	66	4	4	4	0
Totals:		138	259	265	63

animals in Michigan and how many are considered state endangered, threatened, special concern, and presumed extirpated.

This monitoring and survey data is included in the State's natural heritage database, which tracks known information on rare species. This database provides critical information to help managers make well informed decisions. Many threats continue to impact Michigan's wildlife; one of these is poorly planned development. The MDNR uses the Environmental Review process to protect and conserve Michigan's rarest species. During an Environmental Review, proposed projects are reviewed for impacts to endangered and threatened species. If negative impacts are likely, the MDNR works with the landowner or project manager to provide recommendations to minimize those impacts.

On-the-ground management efforts are also used to help conserve these special wildlife. The endangered Kirtland's warbler is one of the rarest warblers in North America. It nests in just a few counties in Michigan's northern Lower and Upper Peninsula, in Wisconsin, and Ontario and currently no where else in the world. This songbird is dependent on dense, young jack pine habitats for breeding. The recovery efforts for this species have been a true success. While maintaining commercial harvest of jack pine, the recovery goals for Kirtland's warbler have been met and the land managing agencies are working to remove the species from the endangered species list while ensuring suitable breeding habitat is maintained. This effort has been a model for recovering a species and delisting it.

The Mitchell's satyr is one of the world's rarest butterflies, found only in Michigan and Indiana. This butterfly is endangered in Michigan and the biggest threat to their continued survival is habitat loss and alteration. This species is dependent on a special kind of wetland habitat called a fen where the main source of water is groundwater. Conservation of groundwater will be the key to the continued existence of Mitchell's satyr and many other rare species that rely on fen habitats. Fen hydrology includes recharge areas, which are often miles from the fen itself. The recent interest in large groundwater withdrawals may have a significant negative impact on the Mitchell's satyr butterfly. Further work is needed to develop tools to help managers make well-informed decisions.

Michigan's endangered and threatened list is based on known habitat requirements and population trend information of species, and as such can serve over time as a measure of the state's biological diversity and provide an indirect measure of a changing environment. When targeted efforts and resources are put towards the needs of endangered and threatened species, we have achieved success and recovery. Great examples of this are the wolf, eagle, and Kirtland's warbler. However, threats to Michigan's wildlife and their habitats continue to increase. Between 2000 and 2009, the endangered and threatened list increased by 20%, evidence that rare species continue to decline. More work is still needed to conserve Michigan's wildlife for the future.

Trends in Exotic Species

Exotic species are plants and animals that have been introduced by human activity into an ecosystem in which they are not native. Once introduced, many of these species spread naturally, producing a significant change in the composition, structure, or processes of the invaded ecosystems.

Introductions of exotic species, whether intentionally or unintentionally, play a major role in modifying terrestrial and aquatic ecosystems of the Great Lakes Basin. Freed from competitors, predators, parasites, and pathogens that naturally regulate populations in their native environments, some exotic species can become a nuisance by growing at or near their potential exponential growth rate and out-competing native species for food and other habitat resources. Invasions of terrestrial and aquatic ecosystems by exotic nuisance species now rank second only to habitat loss as the major threat to biodiversity in the Great Lakes Basin. **Exhibit 26** presents the number of exotic terrestrial and aquatic plants and animals that are known to have been introduced into the Great Lakes Basin since the 1800s. The exact number is not known, but is thought to be much larger.

Exotic Terrestrial Species

Currently, 47 exotic terrestrial plant and animal species are known to have successfully invaded the Great Lakes Basin **(Exhibit 26)**. Additional information on this and other exotic terrestrial species may be found at the Internet sites for the Michigan Department of Agriculture and Rural Development (MDARD) **(www.michigan.gov/eab)**, Michigan Technological University's Center for Exotic Species **(www.forest.mtu.edu/research/ces)**, and the National Invasive Species Council's Internet sites **(www.invasivespecies.gov)**.

Exhibit 26. Numbers of Known Exotic Terrestrial and Aquatic Plant, Animal, and Virus Species Introduced into the Great Lakes Basin 2008

Ecosystem Type	Plant Species		Animal Species				Virus	Total
	Phytoplankton	Vascular	Invertebrates	Insects	Fish	Birds		
Terrestrial	_	37	_	7	_	3	_	47
Aquatic	27	60	68	2	26	_	3	186
Total Species	27	97	68	9	26	3	3	233

Source: National Oceanic and Atmospheric Administration's national Center for Research on Aquatic invasive Species, Great Lakes Environmental Research Laboratory: Great Lakes Aquatic Nonindigenous Species List, March 2008. Center for Exotic Species, Michigan Technological University, April 2003. National Invasive Species Council, July 2007

Aquatic (bacteria and virus)	27	55	64	2	28	--	6	182

Source: National Oceanic and Atmospheric Administration's national Center for Research on Aquatic invasive Species, Great Lakes Environmental Research Laboratory: Great Lakes Aquatic Nonindigenous Species Information System, May 2011.

Emerald Ash Borer

One of the more recent species that has had a major environmental and economic impact on Michigan is the emerald ash borer (EAB). The EAB is native to eastern Russia, northern China, Japan, and Korea and affects ash trees. The insect was first detected in the summer of 2002 in six southeast Michigan counties and in Windsor, Ontario, Canada. Data from the most recent surveys indicate that Michigan's Lower Peninsula is generally infested, and EAB outliers exist in several areas in the Upper Peninsula.

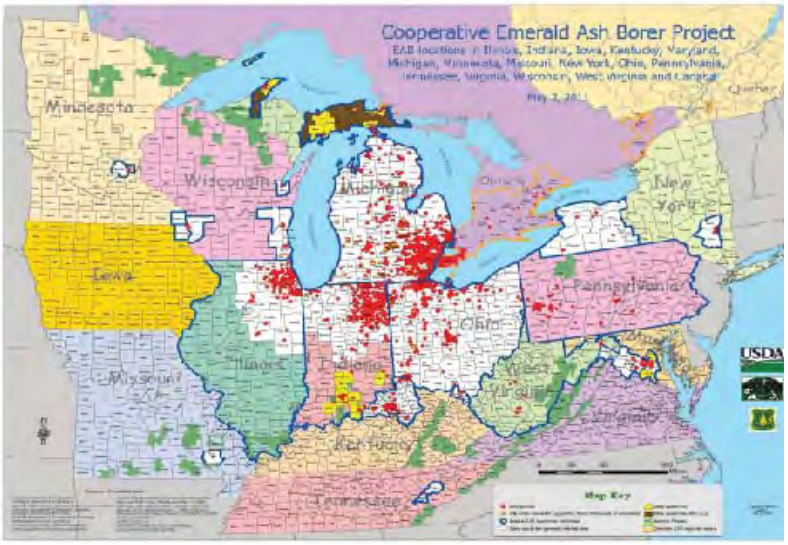


Exhibit 27. Locations of Emerald Ash Borer Infestations in Michigan

EAB has also been confirmed in 14 Northeastern and Midwestern states and in Canada **(Exhibit 27).**

To date, the EAB has destroyed or damaged millions of ash trees across the Lower Peninsula. Michigan's efforts to contain the EAB have entailed quarantining counties to limit the movement of hardwood firewood, ash trees, branches, lumber and other ash tree materials that may be harboring the insect. A permanent inspection station at the Mackinac Bridge also has limited the movement of hardwood firewood and ash logs into Michigan's Upper Peninsula.

Addressing outlying infestations of EAB continues to be a priority in Michigan and nationally. A project to Slow Ash Mortality (SLAM) in two EAB outliers in the Upper Peninsula is receiving national and international attention.

The overall goal of SLAM is to evaluate the effectiveness, practicality, and challenges associated with an integrated, multi-year strategy designed to slow the expansion of ash mortality in a localized EAB outlier. The information, experience, and results acquired from this pilot project will serve as a model for an approach that could be incorporated into the national EAB program. The Moran/St. Ignace outlier in Mackinaw County and the Larium site in Keweenaw County are ideal sites for this pilot project. They are both geographically distinct and separated from EAB infestations in Lower Michigan. Delimiting surveys at both sites suggest that EAB densities are relatively low. Specific objectives of the Michigan SLAM Project include:

I. Development of an integrated, multi-year strategy to suppress EAB population growth and slow the progression of ash mortality;

II. Implementation of the integrated strategy beginning in 2008;

III. Evaluation of the success of the integrated SLAM approach;

IV. Evolution and expansion of the SLAM approach for implementation at additional pilot sites.

Efforts also are underway by the Emerald Ash Borer Task Force to learn more about the emerald ash borer's biology and to develop additional control and detection options through research projects spearheaded by Michigan State University (MSU). Members of the Emerald Ash Borer Task Force include representatives from the Governor's Office, MDARD, MDNR, MSU, and the USDA's Animal and Plant Health Inspection Service and Forest Service,

in cooperation with local units of government and various industry groups, associations, and universities.

Recently a new insecticide, Tree-age® (active ingredient emamectin benzoate) was registered for use in Michigan against EAB. This systemic insecticide is applied by trained and certified arborist or landscaper and is injected through the bark at the base of ash trees. Bioassays by researchers with MSU and the U.S. Forest Service to assess survival of EAB beetles revealed that 100% of the beetles that fed on leaves from emamectin benzoate-treated ash trees died. This material shows a great deal of promise for protecting street and landscape ash trees.

Beech Bark Disease (American Beech)(BBD)
The BBD advancing front (e.g. areas infested with scale before fungal infection) continues to spread east and west in the Upper Peninsula and to new areas in the North Lower Peninsula **(Exhibit 28).** Isolated, satellite populations of beech scale occur well ahead of the advancing front in both the Western UP and NLP.

The USDA Forest Service Research Facility in Delaware, Ohio, continues to collect scions from Michigan's resistant trees to study resistance to BBD. These trees resist scale establishment. Without the scale, beech is not susceptible to infection by

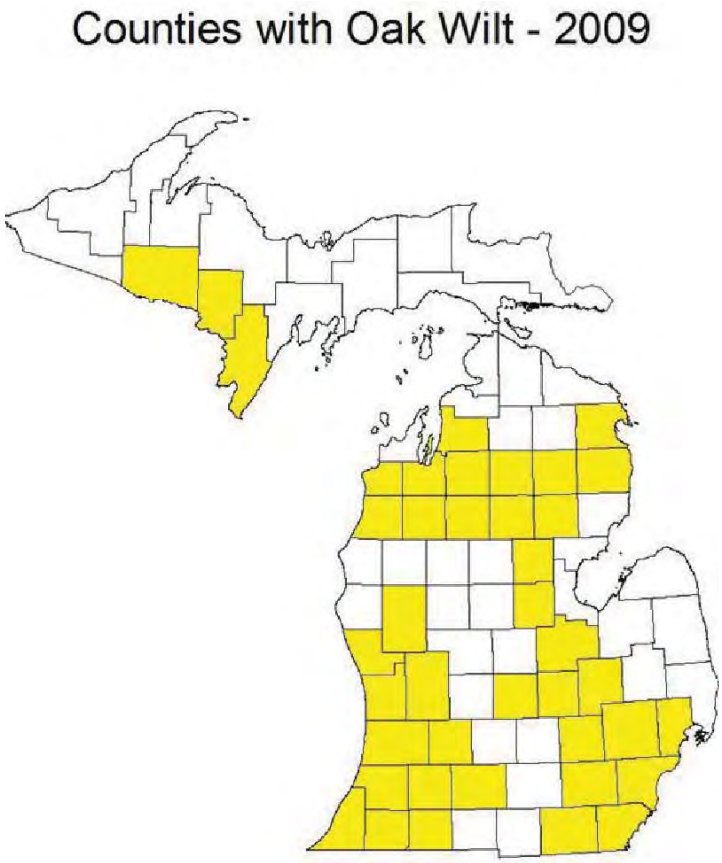
Exhibit 28

Neonectria species which cause BBD. The MDNR, Forest Management Division, has been collecting scions from reported resistant American beech in areas heavily BBD impacted forests since 2004. Each year, the scions are harvested in January. To date, scions from 24 different resistant trees from Michigan have been used for grafting. In the fall of 2010, Michigan began planting its first American beech seed orchard with BBD resistant stock. The seed from these orchards will be used to restore an American beech component in BBD impacted hardwood forests. The MDNR continues efforts to detect and protect BBD resistant trees.

Michigan Technological University received a USDA Forest Service Evaluation Monitoring Grant in 2009, which includes a systematic survey effort for resistant American Beech in Michigan's BBD advancing and killing front areas. The evaluation monitoring plot network established in the early 2000s by University of Michigan is being resampled. In 2010 most of the sites in the Upper Peninsula were revisited, and efforts will be expanded in 2011 to the Lower Peninsula.

Oak Wilt (Red Oak Group)
Oak wilt (Ceratocystis fagacearum) is one of the most serious tree diseases in the eastern United States, killing thousands of oaks each year in forests, woodlots, and home landscapes. Oak wilt was first identified in 1944. The extent of its impact wasn't realized until the 1980's. Only in the last few years

Exhibit 29



has oak wilt been reclassified as an exotic disease. Oak wilt is established widely in the southern Lower Peninsula with spotty distribution in the Northern Lower and Upper Peninsulas **(Exhibit 29)**.

Although oak wilt attacks all oak species, the red oak group (northern red oak, pin oak, black oak, scarlet oak, and red oak hybrids) is most susceptible. Inventory of Michigan forests reports 264 million oak trees in the oak wilt susceptible red oak group, with 111 million oak trees greater than 5 inches in diameter at breast height and 41 million oak with a diameter greater that 11 inches. Infected red oaks die within days or weeks. Members of the white oak group are much less susceptible and live much longer after infected. The disease spreads from tree to tree through connected (e.g. grafted) root systems. Untreated infection centers spread slowly eventually killing all contiguous, root-grafted oaks.

As the public moves northward into forested areas, the risk of spreading this disease grows. People often harvest dead oaks for firewood. This wood is often taken to camps or on camping trips where it will serve as a source of inoculum the following year if oaks are wounded in the spring or early summer.

Property values are often significantly reduced due to the loss of many trees on oak landscapes when a single tree is infected.

Acorns from oak trees are a valuable though inconsistent source of wildlife food. More than 180 different kinds of birds and mammals use oak acorns as food; among them are squirrels, blue jays, crows, red-headed woodpeckers, deer, turkey, quail, mice, chipmunks, ducks, and raccoons.

Drought effects on short-lived oak species on light soils

Droughts can trigger significant declines in tree health. Hardest hit are trees that grow in light, sandy soils or on lowlands exposed to significant water table fluctuations. Drought stressed trees are susceptible to a host of insect pests and diseases. As a result of a series of droughts in the last decade and dry conditions in 2010, tree mortality on these drought prone sites increased. Oak was especially affected by the two-lined chestnut borer (Agrilus bilineatus) and Armellaria root rot. Some areas were also impacted by multi-year defoliation by the forest tent caterpillar (Malacosoma disstria) and the gypsy moth (Lymantria dispar). It will take a few years of normal or higher amounts of precipitation for trees to return to normal growth patterns.

Feral hogs

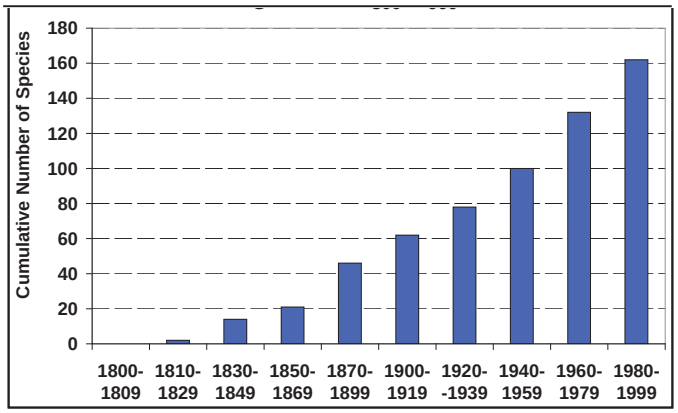
The MDNR is becoming increasingly concerned with the threat posed to Michigan's wildlife by feral swine. This invasive species is a voracious and opportunistic predator that has the capacity to significantly impact a variety of wildlife including wild turkeys, pheasants, ruffed grouse, a host of other ground nesting birds, and white-tailed deer. Through their rooting behavior they can destroy river banks causing soil erosion and affecting water quality through the introduction of bacteria. In addition they pose risks to humans, livestock, and animal health since there has been seven documented pseudorabies cases in the Michigan feral swine population so far.

Feral swine have been introduced into other states and the impacts have been severe to wildlife populations and their habitat, as well as water quality. Michigan has the opportunity to eradicate feral swine if we take swift action.

Exotic Aquatic Species

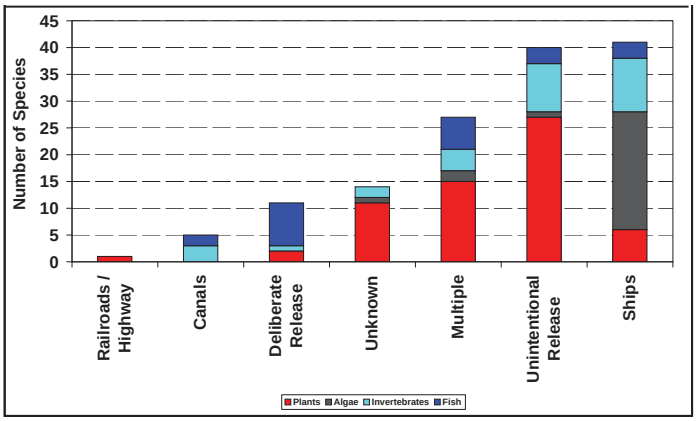
Currently, 182 exotic aquatic plant and animal species are known to have been successfully introduced into the Great Lakes Basin since the 1800s **(Exhibit 30)**. The list of exotic aquatic species, which is continually updated, is maintained by the National Oceanic and Atmospheric Administration's (NOAA) National Center for Research on Aquatic Invasive Species and can be accessed on the NOAA Internet site **(www.glerl.noaa.gov/res/Programs/glansis/glansis.html)**. A watchlist of potential exotic aquatic species that have a high probability of invading the Great Lakes is also maintained on the NOAA internet site. The largest number of exotic aquatic species introduced into the Great Lakes Basin coincides with the expansion of the St. Lawrence Seaway in 1959, which allowed greater transoceanic shipping traffic. More than one-third of the known exotic aquatic species were introduced into the Great Lakes during the last half of the 20th Century **(Exhibit 31)**.

Exhibit 30. Introduction of Exotic Aquatic Species into the Great Lakes 1800 -1999



The four primary routes of entry for aquatic exotic species into the Great Lakes include ballast water from ocean-going ships, unintentional releases, multiple sources, and unknown sources **(Exhibit 31)**. Not all non-native species become invasive and cause economic or environmental harm, but a few cause major damages. Some of the more problematic introductions in recent decades have been the sea lamprey, Eurasian watermilfoil, and zebra/quagga mussel. Eurasian watermilfoil and zebra mussels have propagated not only throughout the Great Lakes, but also throughout many of the state's inland lakes at an alarming rate. Limited progress has been made in terms of control of the Eurasian watermilfoil and research has yet to discover an effective control for the zebra mussel.

Exhibit 31. Sources of Entry of Exotic Species into the Great Lakes



While some progress has been made to decrease the number of new exotic aquatic species being introduced into the Great Lakes, much remains to be accomplished. Pursuant to federal law, ships entering the Great Lakes are now required to exchange their ballast water at sea, flushing out organisms, and raising the salinity of the ballast water to kill freshwater organisms that might remain alive in the ballast tank. Although open water exchange helps to reduce the risk of finding exotic aquatic species in ballast tanks and sediments, it does not ensure protection of the Great Lakes since even with ballast pumping, many aquatic species remain in the unpumpable residual ballast water and sediments and can gain entrance into the Great Lakes. A ship under this condition is referred to as No Ballast on Board (NOBOB). Over 90 percent of vessels entering the Great Lakes are NOBOB and contain viable forms of life, including potential aquatic invasive species. Many NOBOB vessels contain fresh or low-salinity water from other countries that can pose an especially serious risk of new exotic aquatic species introductions. Michigan supports the adoption of strict, mandatory regulations for NOBOB vessels that are the same as for ships in ballast.

State, Federal, and International Ballast Water Action

In 2001 Michigan legislation was passed (adding Section 3103a to Part 31, Water Resources Protection, of the Natural Resources Environmental Protection Act, 1994 PA 451, as amended [NREPA]) requiring the MDEQ to determine annually whether ballast water management practices are being complied with by all vessels operating on the Great Lakes and the St. Lawrence Seaway. Oceangoing vessels are required to report compliance with the

Code of Best Management Practices for Ballast Water Management developed by the Shipping Federation of Canada. Nonoceangoing vessels are required to report compliance with a set of voluntary best management practices developed by the Lake Carriers Association and the Canadian Shipowners Association to reduce the number of introductions of exotic aquatic species into the Great Lakes. A list of the ships reporting compliance with the voluntary bestmanagement practices is maintained on the MDEQ's Internet site **(www.michigan.gov/deqballastwaterprogram)**. In 2010 over 246 vessels complied with the MDEQ reporting requirements.

In June 2005 Michigan legislation (amending Section 3112 of the NREPA) was signed establishing the requirement for a ballast water discharge permit for ocean-going ships in Michigan ports. The permit requires ocean-going vessels to either not discharge ballast water or to treat ballast water before discharge to prevent introductions of exotic aquatic species to the Great Lakes. The general permit was issued in October 2006, and became effective January 1, 2007. By the end of 2010, 174 Certificates of Coverage were issued to vessels under the general permit by the MDEQ.

Ballast water discharges in the United States (U.S.) are regulated by both the United States Coast Guard (USCG) and the USEPA. In August 2009, under the authority of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, which was revised as the National Invasive Species Act of 1996, the USCG proposed regulations that would establish performance standards for living organisms in ships' ballast water discharged in U.S. waters. Final regulations are expected in winter of 2011-2012.

In March 2005 a decision by the Northern District Court in California ordered the USEPA to rescind a rule to exempt the discharge of ships' ballast water from regulation under the 1972 Clean Water Act. Implementation of a USEPA permit for discharges incidental to the normal operation of vessels (including ballast water discharge) began in February 2009. In 2009 Michigan, along with several environmental organizations, challenged the USEPA permit arguing that the USEPA failed to regulate ballast water discharges in a manner that satisfies Michigan Water Quality Standards and protects the Great Lakes from aquatic invasive species. Through negotiations with the USEPA, a settlement agreement was reached in 2011 that outlines a process for the USEPA to establish common protective standards for ballast water discharges to United States waters. The next draft permit is expected in November 2011, with a final permit expected in November 2012.

Internationally, a Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention) was adopted by the International Maritime Organization (IMO) in 2004. The Convention sets a ballast water discharge standard and timetable for compliance, pending ratification by at least 30 member countries of the IMO representing 35% of the world's commercial shipping tonnage. Standards apply to all vessels beginning in 2016. As of May 2010, 25 countries representing nearly 25% of the world's shipping tonnage signed the convention. At this time, the U.S. has not signed on to the convention.

Aquatic Nuisance Species Management Plan

In 2002 Michigan released an update to its 1996 Nonindigenous Aquatic Nuisance Species State Management Plan, which was approved as Michigan's plan under the auspices of the federal National Nuisance Species Act. The 2002 document entitled, Michigan's Aquatic Nuisance Species State Management Plan Update: Prevention and Control in Michigan Waters (2002 Plan), provides a framework for action and outlines critical steps necessary to help prevent and control aquatic nuisance species (exotic aquatic species) in the state. Most key recommendations of the 2002 Plan have been implemented.

A collaborative process to update the Plan was initiated in 2010 with the formation of a team of experts from the Michigan Departments of Environmental Quality, Natural Resources, Agriculture and Rural Development, and Transportation. The updated Plan will focus on the identification of pathways for Aquatic Invasive Species (AIS) introduction and spread, development of strategic activities to block pathways, early detection of and rapid response to new AIS occurrences, and abatement of harmful effects of AIS. Development of the updated plan will include incorporation of input from stakeholders. The final updated plan is expected in 2012.

PHYSICAL AND CHEMICAL INDICATORS

Ambient Levels of Criteria Air Pollutants

Pollutants, both man-made and naturally-occurring, affect the quality of Michigan's air. Air quality can vary depending upon location, time, and weather conditions. The air quality in Michigan has shown marked improvement over the past 40 years (1970-2010) as sources of air pollution have been identified and corrective solutions implemented. However, with new scientific information leading to more stringent national health standards, challenges remain.

National Ambient Air Quality Standards (NAAQS) have been established for six pollutants referred to as criteria pollutants. The criteria pollutants include carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. The MDEQ operates an air monitoring network in 26 counties, which represents the overall air quality in the state. Currently (2010), all areas in Michigan are reporting well below the USEPA criteria pollutant standards for carbon monoxide, nitrogen dioxide, ozone, and particulate matter.

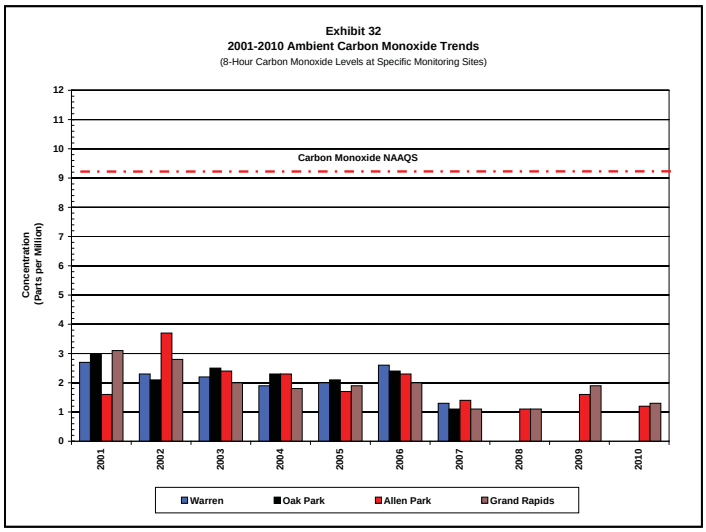
However, with the USEPA implementing new standards for lead and sulfur dioxide in 2008 and 2010, parts of Michigan are not attaining these new standards. Additional information on Michigan's air quality is available on the MDEQ's Air Quality Web site at **http://www.deqmiair.org/**. A brief summary for each of the six criteria pollutants is presented below.

Carbon Monoxide

Carbon monoxide is produced primarily from transportation, fuel burning for space heating, and electrical generation. Industrial processes, as well as wood, agricultural, and refuse burning, also contribute to carbon monoxide emissions. Carbon monoxide can exert toxic effects on humans by limiting oxygen distribution to organs and tissues. People with impaired circulatory systems are vulnerable at lower levels than healthy individuals. Exposure to carbon monoxide can impair visual perception, work capacity, manual dexterity, learning ability, and the performance of complex tasks.

Michigan's on-road motor vehicles account for 60 percent of the state's carbon monoxide emissions. Michigan's non-road transportation sources contribute 29 percent of the state's carbon monoxide emissions. These sources include aircraft, marine vessels, non-road two- and four-stroke engines, and railroads. Carbon monoxide emissions from Michigan's industries (point sources) account for only 3 percent.

The USEPA first established health standards for carbon monoxide in 1971, and in 2011 proposed to retain these standards. Since 1984 there have been no exceedances of the carbon monoxide standard in Michigan. **Exhibit 32** indicates a clear downward trend, representing a 50 percent decrease in average carbon monoxide levels over 10 years. The decline of carbon monoxide follows a national trend. Starting with the Clean Air Act of 1970, catalytic converters, fuel economy standards, national standards for tailpipe emissions, new vehicle



technologies, clean fuels programs, and state and local emissions reduction measures are credited with the decrease in emissions of carbon monoxide.

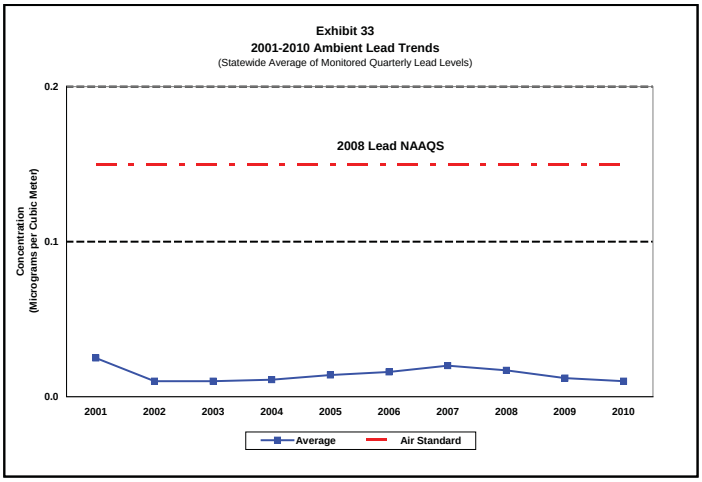
When the MDEQ's funding for air monitoring was cut in April 2007, all but two carbon monoxide monitors were shut down. These are operated in Grand Rapids and Allen Park as part of the National Core Monitoring (NCORE) Program.

Lead

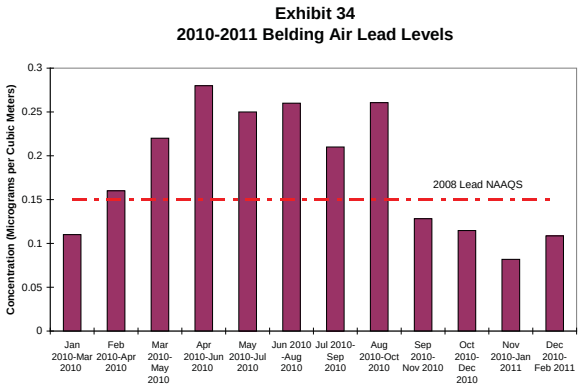
The most common sources of lead emissions are gasoline additives, non-ferrous smelting plants, and battery manufacturing. Historically, lead was added to gasoline to prevent engine knocking. The lead content of gasoline began to be controlled in the 1970s when legislation was passed to gradually reduce lead levels. Currently, smelters, foundries, boilers, waste incinerators, glass manufacturers, cement producers and piston-driven aircraft engines using leaded fuel are the major sources of lead.

Human exposure to lead can occur through ingestion or inhalation. The nervous system is most sensitive to the effects of lead and high exposures to lead can result in behavioral and learning disorders. Lead also may be a contributing factor in high blood pressure and heart disease.

Concentrations of lead in the air decreased steadily in the 1980s after the removal of lead from gasoline, and have remained low over the past ten years **(Exhibit 33)**. The MDEQ has routinely monitored lead in Dearborn plus, since 2010, in Grand Rapids and Allen Park.



In 2008 based on updated scientific data, the USEPA revamped the lead NAAQS. The new standard is 10 times more stringent than the previous standard. As part of the new standard, the MDEQ was required to monitor near stationary lead sources emitting greater than 1 ton per year. As a result of this effort, the MDEQ recorded a violation of the new health standard in Belding in 2010 **(Exhibit 34)**.

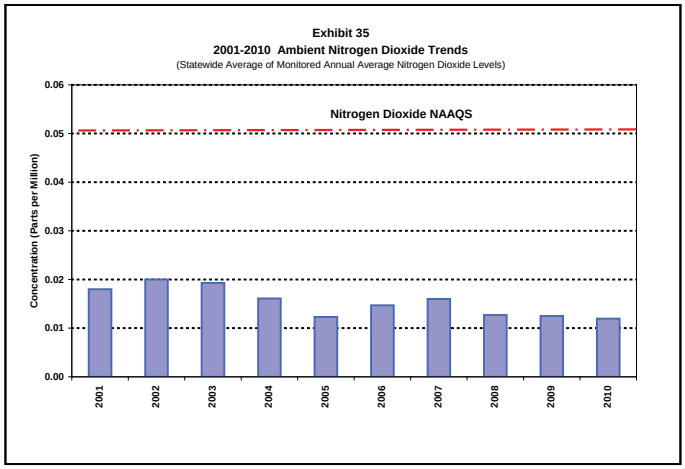


Nitrogen Dioxide

Nitrogen dioxide is formed during high temperature combustion processes, such as those from power plants burning fossil fuels and from burning fuels in motor vehicle engines. In Michigan, 57 percent of nitrogen dioxide producing compounds are emitted from motor vehicles and 36 percent come from point sources such as industrial, commercial, institutional, and residential fossil fuel combustion.

The human respiratory system is susceptible to effects caused by exposure to nitrogen dioxide. Asthmatics are particularly sensitive to these effects. Nitrogen oxides contribute to the formation of ground level ozone and can contribute to acid rain. It sometimes can be seen as a reddish-brown layer.

Statewide monitoring results show that annual average nitrogen dioxide levels have remained less than 40 percent of the NAAQS **(Exhibit 35)**. Regulations on vehicle emissions over the past few decades and reductions in emissions from power plants due to stricter regulations and new technologies have contributed to a decreasing trend. In 2010 the USEPA changed the form of the nitrogen dioxide standard from an annual to a 1-hour standard and the MDEQ is investigating how its monitoring data compare to this standard.



The MDEQ operates nitrogen dioxide monitors in Detroit, Lansing, and near Houghton Lake. In addition, the MDEQ has operated nitrogen oxide monitors at its NCORE sites in Grand Rapids and Allen Park since December 2007.

Ozone

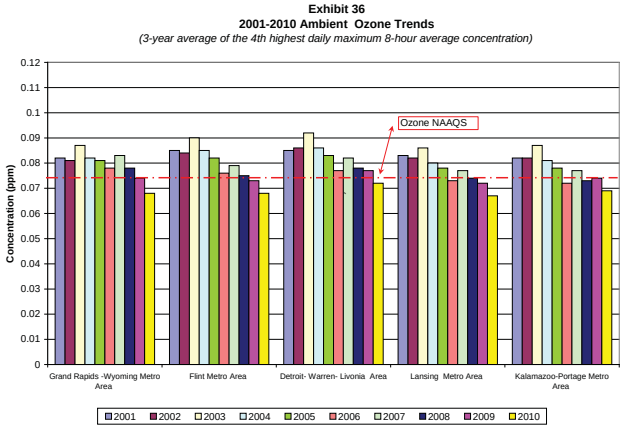
Ground-level ozone is created by photochemical reactions involving nitrogen oxides and volatile organic compounds (VOCs) in the presence of sunlight. These reactions usually occur during the hot summer months when ultraviolet radiation from the sun initiates a sequence of photochemical reactions. Ozone is a key component of urban smog. This ground-level ozone can be transported hundreds of miles under favorable meteorological conditions and so ozone levels are often higher in downwind rural areas than in urban areas. This is why shoreline monitors in western Michigan often measure high ozone levels due to transport from upwind areas such as Gary, Chicago, and Milwaukee.

Major sources of nitrogen oxides and VOCs include engine exhaust, gasoline vapors, chemical solvents, industrial facilities, power plants, and biogenic emissions from natural sources.

Elevated, long-term ozone exposure irritates the respiratory system, reducing lung function and aggravating asthma, emphysema and bronchitis-like chronic conditions. Ozone also impacts vegetation and the surrounding ecosystem, resulting in reduced crop yields and diminished resistance to diseases.

Within Michigan, 58 percent of the ozone-producing VOCs are emitted by vehicles. The remaining 42 percent are emitted from the combustion of fuels; chemical and petroleum product manufacturing, storage, and distribution loss; solvent utilization in coatings and adhesives; and waste disposal and recycling.

Exhibit 36 shows a comparison between the 8-hour standard and trends in urban areas. The MDEQ measures ozone at 25 different locations throughout Michigan. In 2010 all sites in Michigan were in attainment with the 8-hour ozone NAAQS.



Particulate Matter

Particulate matter is a broad classification of material that consists of solid particles, fine liquid droplets, or condensed liquids adsorbed onto solid particles. Large particles with diameters of less than 50 micrometers (µm) are classified as total suspended particulates (TSP). PM10 are "coarse particles" less than 10 µm in diameter (about one-seventh the diameter of a human hair) and PM2.5 are much smaller "fine particles" equal to or less than 2.5 µm in diameter.

Particulate can be emitted directly (primary) or may form in the atmosphere (secondary). Most man-made particulate emissions are classified as TSP. PM10 consists of primary particles that can originate from power plants, various manu-facturing processes, wood stoves and fireplaces, agriculture and forestry practices, fugitive dust sources (road dust and wind blown soil), and forest fires. PM2.5 can come directly from primary particle emissions or through secondary reactions that include VOCs, SO2, and NOX emissions originating from power plants, motor vehicles (especially diesel trucks and buses), industrial facilities, and other types of combustion sources.

Human exposure to particulate matter can affect breathing and aggravate existing respiratory and cardiovascular disease. More serious effects may occur depending on the length of exposure, the concentration, and the chemical nature of the particulate matter. Asthmatics and individuals with chronic lung and/or cardiovascular disease, people with influenza, the elderly, and children are most susceptible. Particle size is the major factor that determines which particles will enter the lungs and how deeply the particles will penetrate. It is the major cause of reduced visibility in many parts of the U.S. PM2.5 is considered a primary visibility reducing component of urban and regional haze. Airborne particles impact vegetation ecosystems and damage paints, building materials and surfaces. Deposition of acid aerosols and salts increases corrosion of metals and impacts plant tissue.

The USEPA has set particulate air quality standards for PM10 (24-hr average) and PM2.5 (24-hr and annual averages). Michigan is attaining the PM10 standard but is designated as exceeding the 24-hour and annual PM2.5 standards in southeast Michigan. The MDEQ is seeking redesignation as data now shows compliance. The MDEQ runs 27 filter-based and 13 continuous PM2.5 monitors statewide. **Exhibit 37** shows the PM2.5 levels monitored in 8 urban areas relative to the annual PM2.5 standard.

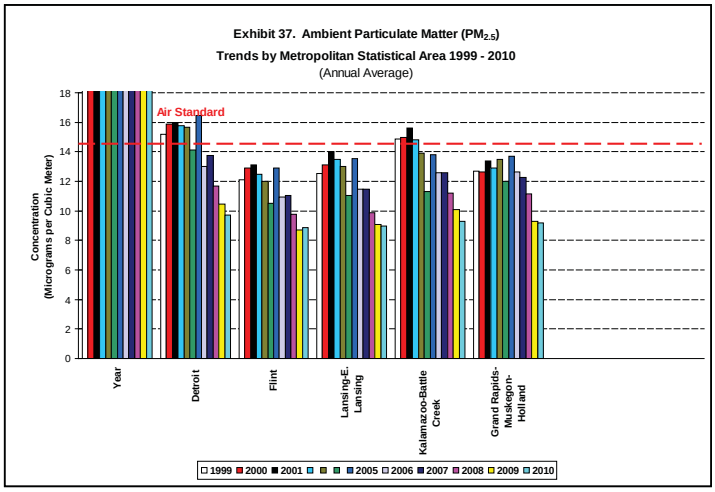
Sulfur Dioxide

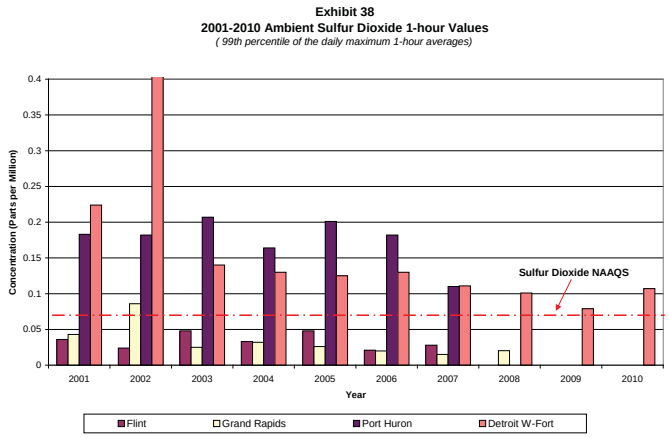
Nationwide, the largest source of sulfur dioxide is coal-burning power plants. State regulations require that most of the coal burned in Michigan contain low amounts of sulfur. Sulfur dioxide also is emitted from smelters, petroleum refineries, pulp and paper mills, transportation sources, and steel mills. Other sources include residential, commercial, and industrial space heating. Sulfur dioxide and particulate are often emitted together.

Human exposure to sulfur dioxide aggravates existing respiratory and cardiovascular diseases. Asthmatics and individuals with chronic lung and/or cardiovascular disease, children, and the elderly are most susceptible. Sulfur dioxide and nitrogen oxide together are the major precursors to acid rain, which can potentially acidify lakes, streams, and soils and corrode building surfaces.

Levels of sulfur dioxide have fallen dramatically. This is due to tougher state and federal emission limits on power plants.

On June 22, 2010, the USEPA changed the sulfur dioxide NAAQS to a 1-hour standard. While the MDEQ is still analyzing the data from its Detroit-Fort Street sulfur dioxide monitor, it appears that this site will not meet the new standard **(Exhibit 38)**. The MDEQ also operates SO2 monitors as part of its NCORE network in Allen Park and Grand Rapids.



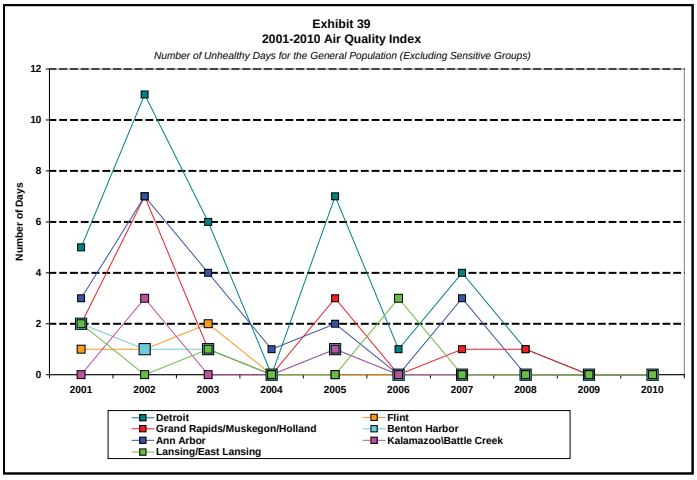


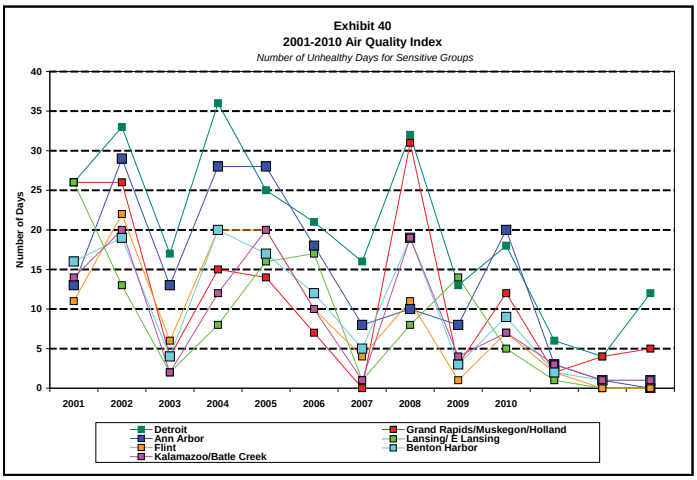
Air Quality Index

The Air Quality Index (AQI) was developed by the USEPA to provide a simple and uniform way to report daily air quality. The AQI provides advice to the public about the health effects associated with various levels of air pollution, including recommended precautionary steps if conditions warrant.

The AQI values are available to the public and news media on the Internet on a near real-time basis for a number of metropolitan areas in Michigan. Over the last several years, AQI values have been mostly good and moderate air quality levels. However, some metropolitan areas in Michigan have experienced days that were categorized as unhealthy for the general population or unhealthy for sensitive groups. **Exhibits 39 and 40** reflect the current AQI categories and unhealthy days for the years 2001-2010.

While based on actual measurements, caution should be exercised with the use of the AQI, since the health classification labels are quite general and are therefore subject to interpretation. Additional





information on the AQI, including the daily AQI values for Michigan monitoring sites, is available on the DEQ's Air Quality Internet site **http://www.deqmiair.org/**. MIair also displays air quality forecasts, continuous air monitoring data, and animated O3 and PM2.5 maps.

Ambient Levels of Air Toxics Contaminants

There are many more air contaminants than just the six criteria pollutants. The additional air pollutants are referred to as air toxics. While there are no NAAQS for air toxics, many do have health reference levels. The available air toxics emissions and monitoring data are relatively limited in comparison to the criteria pollutants data.

The MDEQ's air toxics monitoring program was established in January 1990. Since the program's inception, approximately 50 toxic organic compounds and 13 trace metals have been monitored at various urban locations throughout the state. Detailed information on which air toxics are currently being monitored is available at the MDEQ's Internet site **(http://www.michigan.gov/deqair)**.

The USEPA has developed a nationwide air toxics monitoring network: **(http://www.epa.gov/ttn/amtic/natts.html)**. This network is measuring ambient concentrations of air toxics at monitoring sites throughout the U.S. that can be used in the estimation of human and environmental exposures

Exhibit 41
National Air Toxics Trend Site (NATTS) Dearborn, Michigan

to air toxics. Dearborn, Michigan is one of those sites **(Exhibit 41)**. In December 2010, a unique air toxics assessment study was completed, funded by the USEPA. This study was called the "Detroit Air toxics Initiative (DATI-2) Risk Assessment Update" and provided a risk characterization for air toxics based on air concentrations monitored in the Detroit area. (**http://www.michigan.gov/deq/0,1607,7-135-3310_4105-139044--,00.html)**

This study evaluated monitoring data from February 2006 to February 2007, including VOCs, carbonyls, and metals monitored at six sites in the Detroit area. Air concentrations during DATI-2 were also compared to other published studies in the U.S., indicating that similar levels occur in other large cities. The report provides estimates of health risks that may be associated with breathing the measured levels over time.

The DATI-2 study found that air concentrations and associated cancer and non-cancer risk estimates had declined since the first DATI project, including compounds producing the greatest potential health risks. Three reasons are suggested for the decline in air concentrations and subsequent health risks: improved regulatory compliance by industries, decreased vehicle emissions, and reduced industrial emissions due to the economic downturn. However, manganese continues to exceed the health benchmark and is a concern due to the potential to cause neurological health effects. Two cancer causing compounds, formaldehyde and benzene, also continue to show elevated health concerns even though concentrations have decreased since DATI-1.

The DATI-2 Risk Assessment Report provides useful information, however, it should be noted that the risk estimate in this type of study represents a "snapshot" in time and does not reflect individual risks from past or future exposures to air toxics. Furthermore, there are uncertainties in the estimation of exposure levels and there is limited information available on potential health effects of air toxics alone and in combination with other air pollutants. However, this study helps identify the air toxics of greatest concern in the Detroit area and is useful for characterizing the air quality for the public and regulatory agencies.

Deposition of Persistent and Bioaccumulative Air Toxics

Some air toxics can persist and bioaccumulate in the environment. For these substances, deposition to the ground and water is a concern because of potential ecological impacts and human exposure. Limited deposition studies of persistent, bioaccumulative, toxic air pollutants have been conducted. Many of these have focused on mercury deposition. A 2007 mercury deposition study conducted by the University of Michigan's Air Quality Laboratory included monitoring for mercury in both Chicago, Illinois, and Holland, Michigan to better characterize the impact of Chicago/Gary on southwest Michigan: **(http://www.glc.org/glad/projects/keeler07/)**. The mercury concentrations were significantly different between the two sites, with concentrations in Chicago approximately twice those found in Holland. The study demonstrated that sources in the Chicago/Gary urban area have a measureable impact levels in Holland, Michigan.

Another longer term study, also conducted by the University of Michigan's Air Quality Laboratory, assessed spatial and temporal trends of mercury in both rural and urban areas at six monitoring sites in Michigan: **(http://www.glc.org/glad/projects/keeler06/**, **http://www.glc.org/glad/projects/keeler04/)**. Data collected from 1994 to 2003 demonstrates a clear decreasing gradient from south to north in the amount of mercury deposition in precipitation. Also, deposition in urban areas was twice that of rural sites. Michigan mercury emissions (2005) mostly originated from coal combustion (48%), volatilization during solid waste processing (11%), metals manufacturing and shredding (10%), cement manufacturing (9%), incineration (5%), product use/breakage (4%), and burn barrels (2%).

Additionally, the USEPA continues to monitor for metals, polychlorinated biphenyls, pesticides, and polycyclic aromatic hydrocarbons (PAHs) at Eagle Harbor, Sleeping Bear Dunes, and other locations around the Great Lakes basin: **(http://www.epa.gov/greatlakes/monitoring/air2/index.html)**.

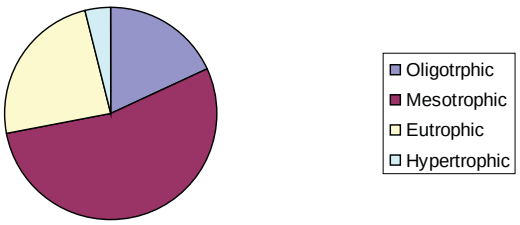
The USEPA has observed, based on the data collected at the Integrated Atmospheric Deposition

Network sites, a decreasing temporal trend for PAHs and PCBs and at most sites for pesticides. **http://www.epa.gov/greatlakes/monitoring/air2/iadn/Tech_sum_2002_2008.pdf**.

Inland Lake Water Quality

The federal Clean Water Act requires states to assess lake water quality and to categorize lakes according to their trophic status, an indicator of biological productivity. Lake trophic status is commonly inferred as the level of growth of algae and higher plants, or primary productivity, as measured by phosphorus content, algae abundance based on chlorophyll content, and depth of light penetration in the lake. Low productive lakes are generally deep and clear with little aquatic plant growth. These lakes are generally very desirable for boating and swimming and may support coldwater fish, such as trout and whitefish. By contrast, highly productive lakes are generally shallow, turbid, and support abundant aquatic plant growth. These lakes commonly support warm water fish, such as bass and pike. Historically, over 700 public lakes in Michigan have been assessed and classified. The majority (67%) were categorized as moderately productive lakes or low productive lakes. Only five percent of the lakes evaluated were categorized as excessively productive lakes **(Exhibit 42)**.

Exhibit 42. Trophic Status of the 732 Lake Water Quality Assessment Lakes 2001-2010



Currently, the Cooperative Lakes Monitoring Program, a Michigan Clean Water Corps (MiCorps) program **(www.micorps.net)**, provides for long-term water quality measurement and continues the lake classification process. The MiCorps program enlists citizen volunteers from the public and limited access lakes across the state to monitor lake primary productivity indicators, including water clarity, total phosphorus, and chlorophyll a, from which the lakes can be categorized in terms of trophic status. During 2008 - 2010, volunteers monitored these primary lake productivity indicators on 277 lakes. For these lakes, the majority exhibited moderate (68%) to low (27%) productivity. Five percent of the monitored lakes were categorized as having high productivity and two lakes exhibited excessive productivity **(Exhibit 43)**.

Exhibit 43. Trophic Status of the 277 Cooperative Lakes Monitoring Program Lakes 2008-2010

The Cooperative Lakes Monitoring Program is a cost-effective volunteer program for increasing baseline water quality data and lake productivity classifications for Michigan's inland lakes. The long-term monitoring program can provide information to evaluate water quality variability and trends in these lakes. However, results from the volunteer program alone only provide information on lakes where volunteers choose to participate in the program and may not be representative of lakes statewide. Consequently, the MDEQ is using money from the Clean Michigan Initiative (CMI) to expand the program and to re-establish monitoring of public access lakes across the state. This effort will build upon the historical lake data that exist and supplement the information generated from the volunteer monitoring program.

The MDEQ, in partnership with the USGS, has re-established a Lake Water Quality Assessment Monitoring Program for public access lakes in Michigan **(http://mi.water.usgs.gov/splan1/sp00301/cmiinland.php**). Baseline data for conventional water quality parameters such as plant nutrients (i.e., total phosphorus and nitrogen), chlorophyll a, dissolved oxygen, temperature, water clarity, and dissolved ions (i.e., chloride, sulfate, sodium, potassium, and calcium) were collected and the trophic status classification updated for 732

public access lakes through 2010. Of the 732 lakes sampled, 18% were characterized as low productive (oligotrophic) lakes, 54% as moderately productive (mesotrophic) lakes, 24% as highly productive (eutrophic) lakes, and 4% as excessively productive (hypereutrophic) lakes. This project was completed in 2010.

CMI funds also continue to support work by the USGS to explore the feasibility and practicality of using remote sensing satellite imagery for lake water quality assessments that will enable the MDEQ to estimate productivity in inland lakes statewide. Statistical models for predicting lake water clarity and chlorophyll content have been developed and tested with data collected from the Cooperative Lakes Monitoring and Lake Water Quality Assessment Monitoring Programs. An on-line statewide application tool for predicting lake water clarity and chlorophyll content was launched in 2008 **(http://mi.water.usgs.gov/splan1/sp00301/remotesensing.php)**. The statistical models and on-line application tool will continue to be enhanced and refined during the next several years along with the inland lakes data collection effort.

In 2007, Michigan participated in the USEPA supported National Lakes Assessment Survey **(http://www.epa.gov/owow/lakes/lakessurvey/)**. The MDEQ coordinated Michigan's involvement in the Survey in which 50 Michigan inland lakes were monitored. The Survey was designed to help the USEPA to provide regional and national estimates of the condition of lakes, as well as statewide assessments for those states who participated in the Survey. A final report was issued in 2010 (see above link).

Surface Water Chemistry

Consistent with a Water Chemistry Trend Monitoring Plan developed by the MDEQ and the USGS, water samples have been collected from 31 major Michigan rivers since 2000. Water samples also are collected from Saginaw Bay, Grand Traverse Bay, and the Great Lakes connecting channels. Samples are analyzed for nutrients, heavy metals, and other selected parameters. These data are used to measure spatial and temporal trends in inland rivers, connecting channels, and bays.

Exhibit 44 compares mean total phosphorus concentrations from downstream stations of 20 tributaries from 2007 to 2009. Phosphorus is a key nutrient that affects algal growth and regulates productivity in surface waters. Phosphorus concentrations tend to be generally higher in rivers that drain urban or heavily agricultural areas, and lower in relatively undeveloped, heavily forested watersheds.

Exhibit 44

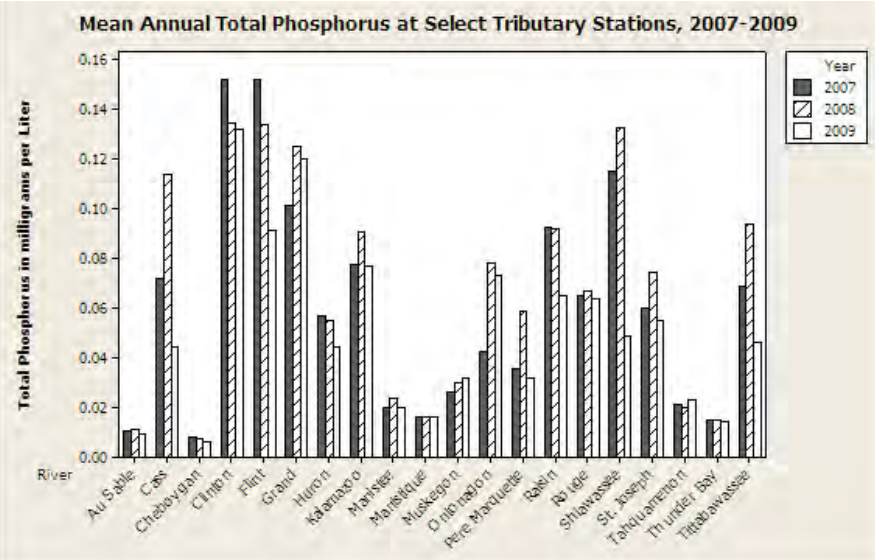


Exhibit 45 presents the mean annual total phosphorus concentrations from seven locations throughout the inner Saginaw Bay. Between 1993 and 2009, average phosphorus levels were lowest in 1996 and 2005 (0.15 mg/L) and highest in 1998 (0.36 mg/L). Mean total phosphorus appears to be decreasing over time; however, variation in the data precludes detecting a significant trend at this time. The MDEQ has taken a number of actions to reduce phosphorus levels in the Saginaw Bay watershed and will continue to monitor Saginaw Bay to evaluate the effectiveness of these actions.

Exhibit 46 shows mean total mercury concentrations from downstream stations of 20 tributaries from 2007 to 2009. The highest average annual mercury concentration occurred in the Ontonagon River in 2009 (5.9 ng/L). The lowest concentration was found in the Cheboygan River in

2008 (0.33 ng/L). Interestingly, the Ontonagon and Cheboygan Rivers had the highest and lowest mean mercury levels, respectively, in the previous Triennial Report as well. Mean mercury levels exceeded the Michigan water quality standard (1.3 ng/L) in 17 (2007 and 2008) and 18 (2009) of these 20 tributary stations. Similar to the phosphorus river data, no clear trend in water quality can be discerned from the mercury river data at this time.

Exhibit 45

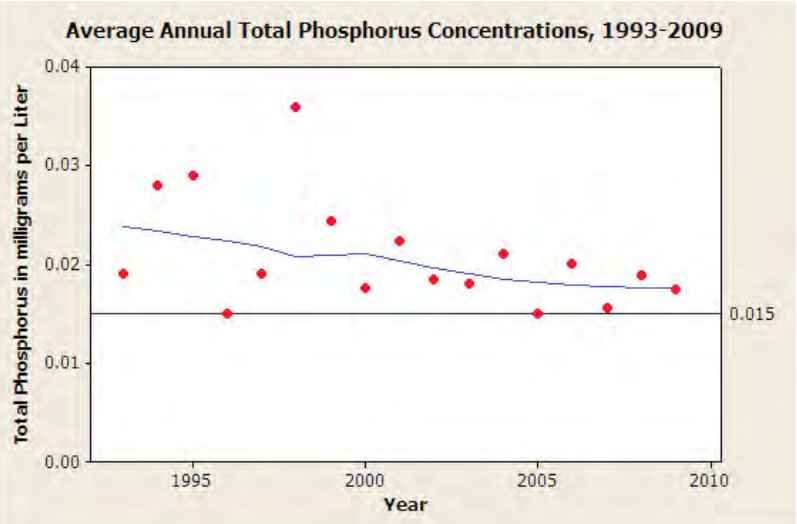
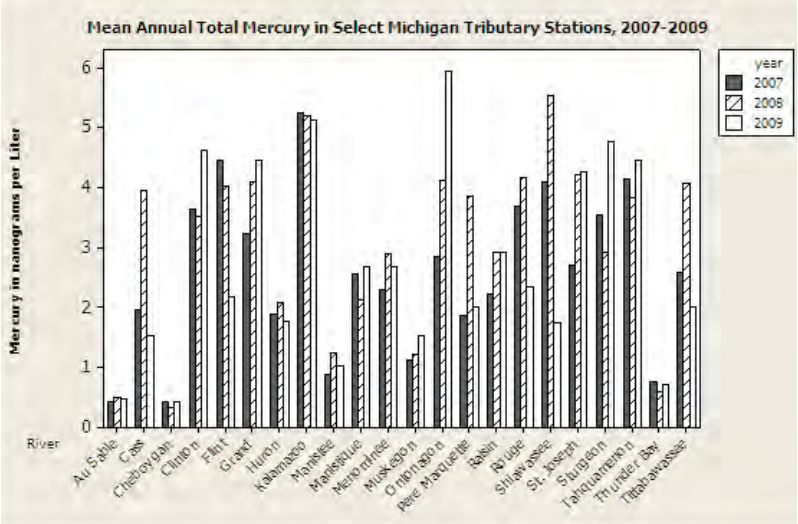


Exhibit 46

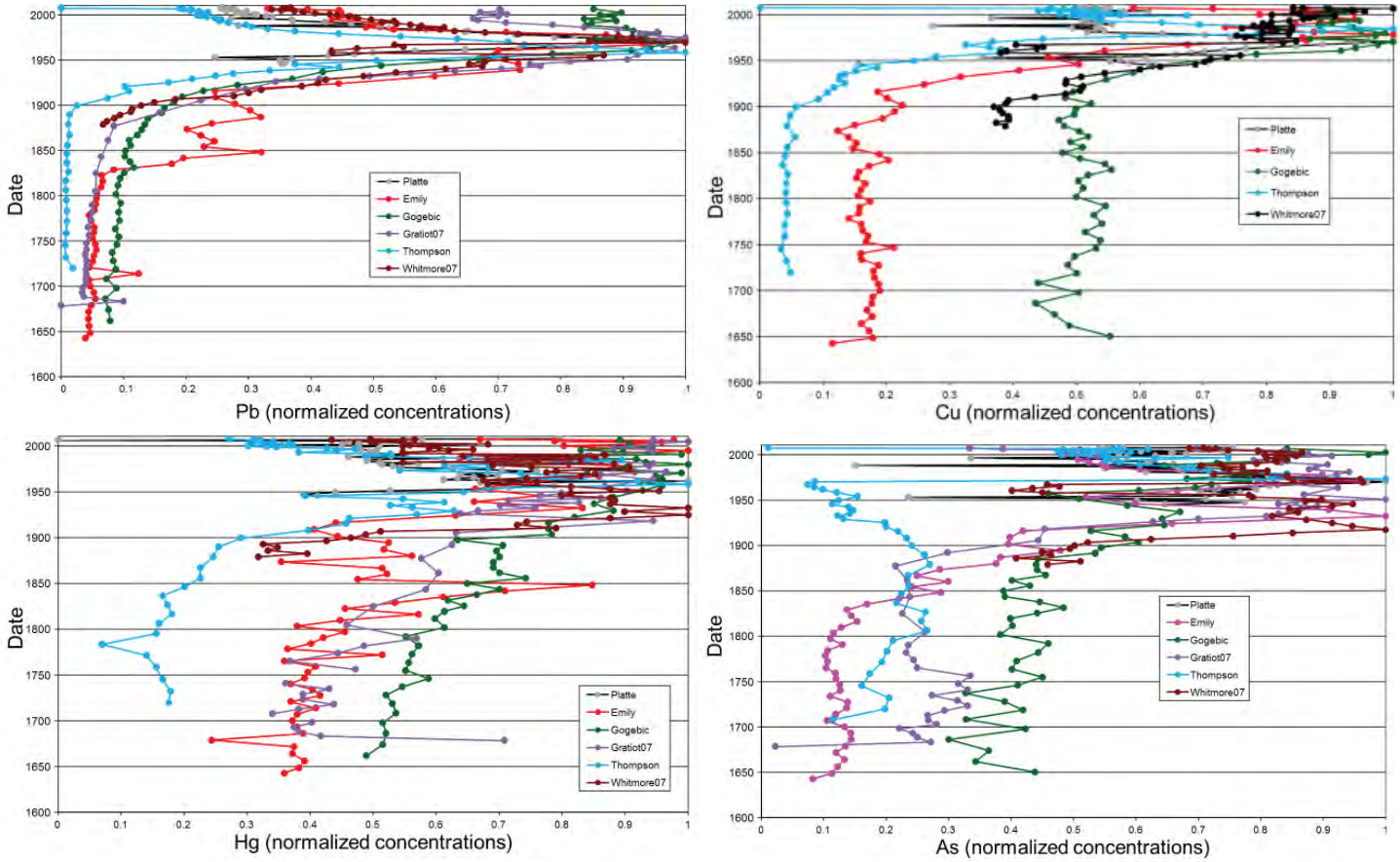


Inland Lakes Sediment

A joint initiative between the MDEQ and MSU to assess chemical trends in inland lake sediments was initiated in 1999. The objectives of the project are to (1) use sediment records in selected inland lakes across the State of Michigan to understand current exposure to toxic chemicals; and (2) identify historical trends that can be used to anticipate future changes in exposure including new threats. Since 1999, vertical sediment core samples have been collected from 47 lakes; 11 of these lakes have been sampled twice. Sediment slices are analyzed for mercury, other selected metals (e.g., lead, arsenic, cadmium, copper, and nickel), and selected persistent organic pollutants (POPs) (e.g., PCBs, PAHs, and pesticides). 210Pb (a naturally occurring unstable isotope) and 137Cs (peak activities from the Chernobyl incident) are used to establish sediment rates and consequently the ages of each of the sediment slice. The following exhibits build on those presented in the 2008 Triennial Report. Graphs that indicate "normalized" concentrations on the x-axis mean that instead of absolute concentrations, concentrations of chemicals in each core are normalized to the highest concentrations. Thus, the highest value will be one. Normalization does not change the shape of the data, but does allow for easy comparisons of patterns among lakes.

Exhibit 47 includes example data used to address the goals of the project. The data also exemplify the complexities of understanding contaminant loadings in the environment. Graph A shows changes in lead concentration over time. All of the lakes across the state show a similar pattern (caused by a regional atmospheric source) with peak concentrations around 1974, the time when lead was banned in gasoline. Prior to this time the pattern of the increase in lead concentrations was similar among lakes. After banning, the patterns differ and many lakes have not returned to concentrations reflective on uncontaminated systems, some lakes remain elevated, and some have increasing concentrations. Graph B shows that copper does not peak at the same time in all lake sediments, indicating individual watershed influences. Similar to lead, some lakes remain elevated and some have increasing concentrations. Graph C shows that although the record for arsenic indicates

Exhibit 47. Graphs A,B,C,D



human influences (elevated concentrations), it is very complicated. The record is highly influenced by processes that make arsenic mobile in the sediments after burial, which might have implications to the benthic communities. Graph D shows mercury concentrations are highly influenced by human activities and vary widely among lakes, suggesting the possible influence of local watershed sources. Similarities in some episodic high concentrations indicate the influence of regional and perhaps global sources. Some of the events can be attributed to historical increases in mercury deposition (e.g., World War II).

Exhibits 48 and 49 summarize some aspects of the PCB and PAH analyses. For each, Figure A is the inventory analysis. Uncorrected inventory is the total mass of POPs in the sediments. Focusing corrected inventory adjust the values to account for sediment washed into the depositional basin from the lake and watershed. If atmospheric deposition of the POPs were equal across Michigan, then the corrected inventories for each lake should be the same. The results show that for many lakes (and the Great Lakes), the PCB values are similar and

Exhibit 48. Trends in Polychlorinated Biphenyls

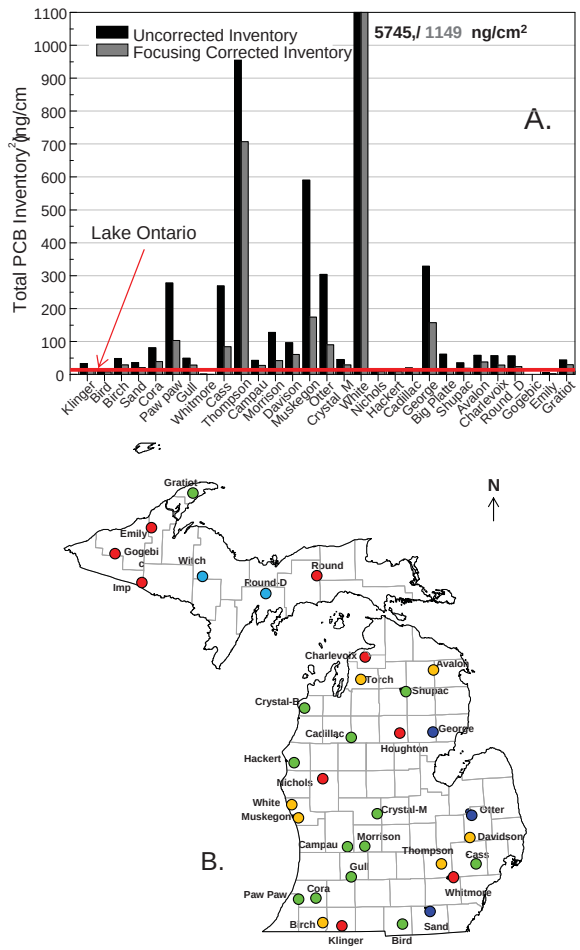
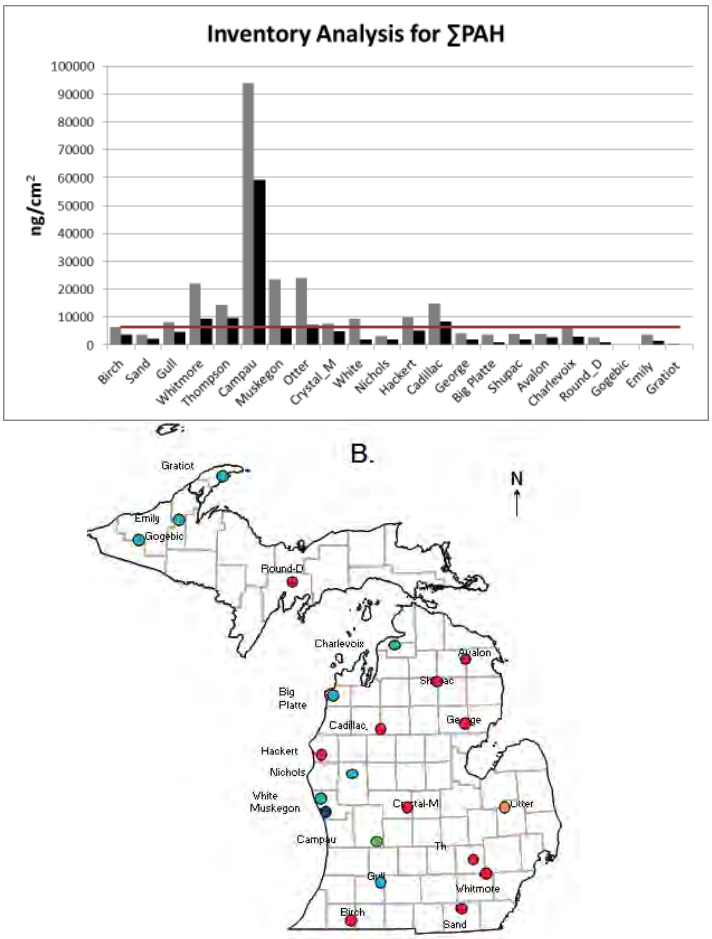


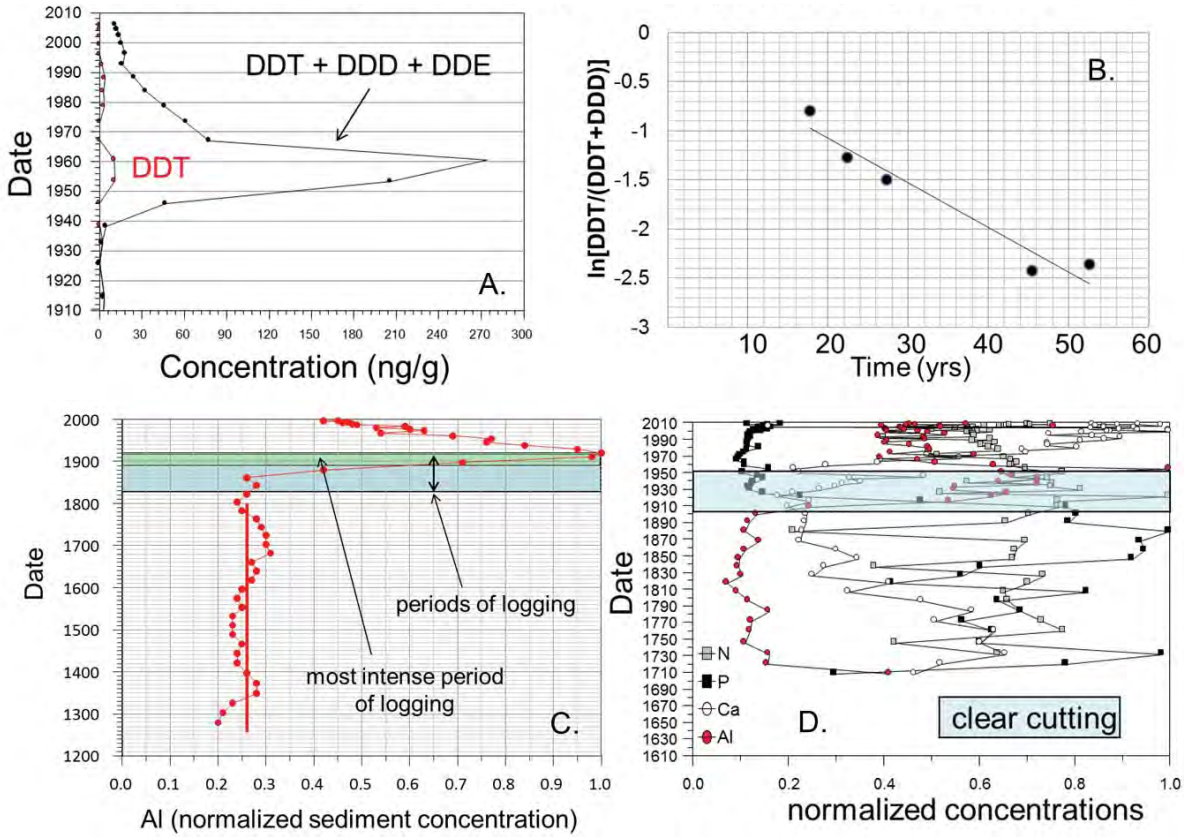
Exhibit 49. Trends in Polycyclic Aromatic Hydrocarbons



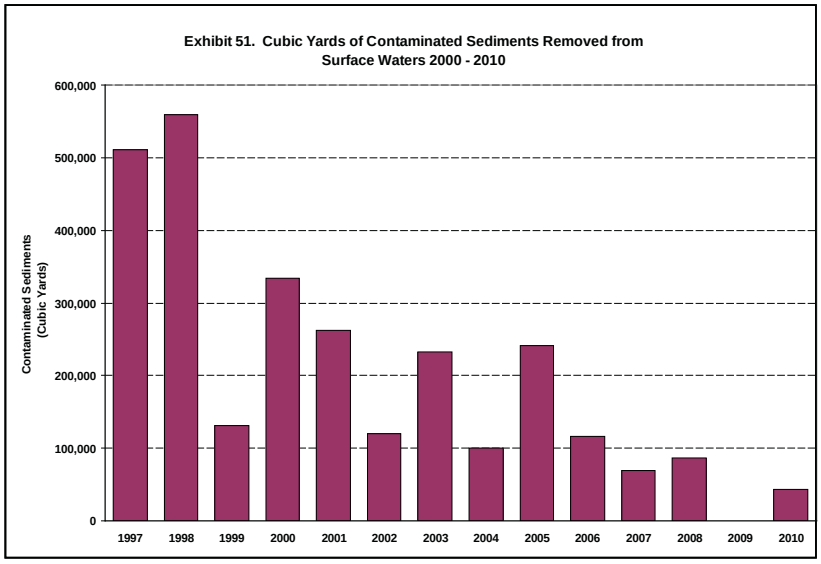
there is no apparent north-south trend. Some lakes (e.g.,Thompson, White) have high inventories suggesting sources within the watersheds. Results for PAHs are similar, but only Lake Campau has unusually high values. A cluster analysis of the congeners at a particular time horizon was conducted, indicating which lakes are similar in the relative abundance or fingerprint of the congeners and which congeners are similar. Examining these relationships might help to identify common sources. The results of the lake clusters are shown on Figure B in each exhibit where similar colors mean similar fingerprints. Preliminary results are beginning to show areas across Michigan in which lakes have similar fingerprints that might be related to source.

Exhibit 50 shows examples for two new types of knowledge gained; understanding the fate of DDT in the environment and the influence of land-use change on ecosystems. DDT can be a mixture of the breakdown products DDE and DDD. Total DDT (DDT + DDD + DDE) peaks in Thompson Lake (Howell, Michigan) around 1960, which is the peak in DDT consumption. Total DDT concentrations have not reached zero and thus DDT is still flushing off of the

Exhibit 50. Trends in DDT's, Al, N, P, and Ca



landscape. Figure B shows how we can use the data to determine the rate (slope of the line) of DDT breakdown, which in Thompson Lake DDT has a 15 year half-life. Figure C shows that aluminum concentrations (Elk Lake) increase dramatically as a result of logging. Concentrations reflect the increase in landscape erosion, and indicate that the watershed has not recovered from this activity after 100 years. Figure D shows the influence of logging (Thompson Lake) on calcium and nitrogen concentrations. Higher productivity is related to higher calcium levels in the sediment. As is the case for Elk Lake, aluminum concentrations increase during clear cutting. Phosphorous concentrations dramatically decrease and calcium concentrations increase after logging. Prior to logging, decreasing calcium levels possibly indicated oligotrophication. Such trends in calcium and phosphorous concentrations are not necessarily similar among lakes. On the other hand, nitrogen concentrations show a decline after logging, followed by an increase, a pattern observed in many lakes. Logging and recent human activities have clearly changed lake productivities from historic conditions.
In addition to the lake sediment assessment program, the MDEQ also participates in the removal of contaminated sediments from lakes and streams. **Exhibit 51** shows the cubic yards of sediment removed from Michigan waters since 1997. Approximately 87,000 cubic yards of contaminated sediment was removed in 2008 from the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Project. In 2010, nearly 6,500 cubic yards of material was removed from the St. Mary's River at a former manufactured gas plant site in Sault Ste Marie. This is phase one of the project, with additional worked planned for this year. This project was completed with Great Lakes Legacy Act funds. In addition, approximately 37,000 cubic yards of sediment were removed from the Kalamazoo River Superfund site.



Stream Flow

Natural flow regimes play a significant role in maintaining stream channel configuration, wetland and riparian vegetation, and stream-dependent biological communities. Stream flow is an indicator of the amount and type of habitat available for fish and other aquatic organisms. It also is an indirect measure of water quality in streams, lakes, and reservoirs occurring in stream systems.

Changes in flow patterns reflect changes in runoff from land, ground water level, water extraction, discharge from upstream reservoirs (if present), and climatic variability. Several common stream flow measures are used to monitor and assess status of flow patterns. These include measures of high (10% exceedance frequency), median (50% exceedance frequency), and low (90% exceedance frequency) flows. High and low flow measures can be standardized by the median flow to facilitate comparisons among different rivers. An additional measure of runoff (mean annual discharge/mean annual precipitation) also is evaluated.

The status of flow is determined by comparing recent flow patterns to a benchmark. This benchmark can be based on presettlement flows or from the earliest period of record. Models have been developed that predict stream flow as a function of geology, stream size, and current land cover characteristics. These models can be used to estimate baseline flow patterns by substituting current land cover data with presettlement land cover data.

The primary source of flow data comes from USGS gauging stations. At present, the USGS maintains approximately 150 stations statewide.

Great Lakes Water Level Trends

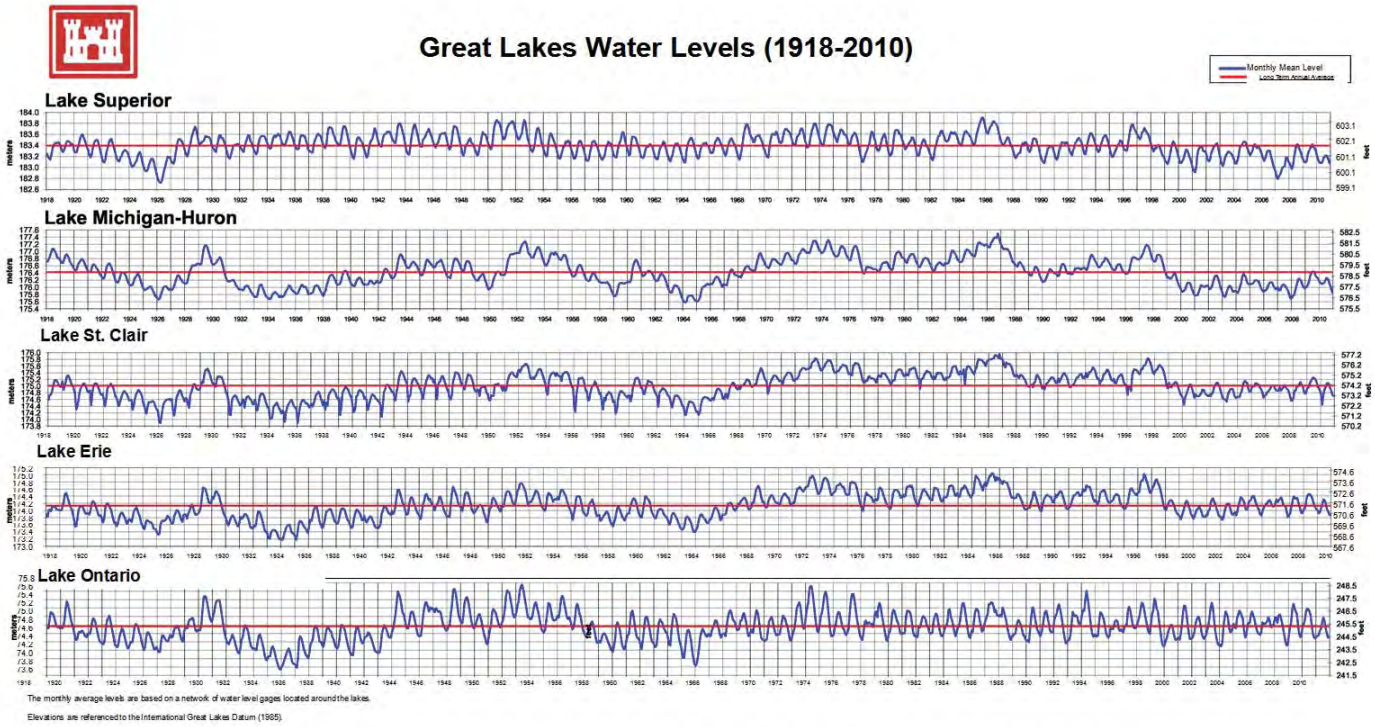
The Great Lakes Basin lies within eight U. S. states and two Canadian provinces and comprises the lakes, connecting channels, tributaries, and ground water that drain through the international section of the St. Lawrence River. Lake levels are determined by the combined influence of precipitation (the primary source of natural water supply to the Great Lakes), upstream inflows, ground water, surface water runoff, evaporation, diversions into and out of the system, consumptive uses, dredging, and water level regulation.

Climatic conditions control precipitation ground water recharge, runoff, and direct supply to the lakes, as well as the rate of evaporation. During dry, hot weather periods, inflow decreases and evaporation increases, resulting in lower lake levels and reduced flows. During wet colder periods, higher levels and increased flows occur. **Exhibit 52** shows the monthly mean and long-term annual average water levels of the Great Lakes for the period 1918 - 2010.

Between 1918 and 2010, there have been several periods of extremely high and extremely low water levels and flows. Exceptionally low levels were experienced in the mid-1920s, mid-1930s, and early 1960s. High levels occurred in 1929 - 1930, 1952, 1973 - 1974, 1985 - 1986, and 1997 - 1998. Great Lakes levels are highly sensitive to weather fluctuations, as illustrated by the impact of high water levels in the early 1950s and mid-1980s and of low water levels in the 1930s and mid-1960s. An example of how quickly water levels can change in response to climatic conditions occurred during 1998 - 1999, when the water levels of Lakes Michigan and Huron dropped 22 inches in 12 months.

The hydraulic characteristics of the Great Lakes are the result of both natural fluctuation and, to a lesser extent, human intervention. Despite this, human activities, such as control works, dredging, and

Exhibit 52



diversions, still can have an impact on lake levels. Out-of-basin diversions or other large removals and large consumptive uses can reduce water levels both above and below the actual point of withdrawal and also reduce flows in the system. A 5-year International Upper Great Lakes Study was instituted by the International Joint Commission in March 2007 to evaluate options for improvements to the existing St. Mary's River regulation plans and to investigate potential hydraulic changes in the St. Clair River that may be impacting water levels in the upper Great Lakes. The results of the study are available at: **http://www.iugls.org/**.

Conclusions are that the difference in water levels between Lake Michigan-Huron and Lake Erie has declined by 23 centimetres (cm) (9 inches) between 1962 (the time of the last major dredging in the St. Clair River) and 2006.

Three key factors have contributed to this decline:

- A change in the conveyance of the St. Clair River accounts for 10 to 12 cm (3.9 to 4.7 inches); a relatively dramatic and rapid change in conveyance appears to have occurred in the mid-1980s, possibly resulting from a single event, such as a major ice jam.
- Changes in climatic patterns account for 9 to 27 cm (3.5 to 10.6 inches); this factor has become even more important in recent years, accounting or an estimated 75 percent of the decline between 1996 and 2005.
- Glacial isostatic adjustment (the rebounding of the earth's crust after the melting of the glaciers about 10,000 years ago) accounts in general for 4cm (about 1.6 inches), but varies greatly throughout the basin.

Great Lakes Ice Cover Trends

The State of the Lakes Ecosystem Conference (SOLEC) currently has developed over 80 indicators designed to assess the overall quality of and track the changing conditions of the Great Lakes over time. The indicator that is currently used by the SOLEC to assess extent of Great Lakes ice during the winter months is Indicator #4858: Ice Duration on the Great Lakes Indicator. **(http://binational.net/solec/sogl2009/SOGL_2009_en.pdf)**

According to the 2009 assessment of the SOLEC Ice Duration on the Great Lakes Indicator and based on current data, it is anticipated that ice formation on the Great Lakes may continue to decrease in total cover if current predictions of milder winters hold true. Data collected from ice charts suggest there has been a decrease in the maximum ice cover per season over the last 30 years. The trends on each of the five Great Lakes show that during this time span the maximum amount of ice forming each year has been decreasing, which correlated to the average ice cover per season observed for the same time duration. Between the 1970s and the 1990s there was at least a 10 percent decline in the maximum ice cover on each lake, nearly 18 percent in some cases, with the greatest decline occurring during the 1990's **(Exhibit 53)**.

Changes in water and air temperatures will influence ice development on the Great Lakes and, in turn, affect coastal wetlands, near shore aquatic environments, and inland environments. Air temperatures over a lake are one of the few factors that control the formation of ice on that surface. Colder winter temperatures increase the rate of heat released by the lake, thereby increasing the freezing

Exhibit 53. Great Lakes Mean Ice Coverage 1970 – 1999

Lake	1970 - 1979	1980 - 1989	1990 - 1999	Change from 1970s to 1990s
Erie	94.5%	90.8%	77.3%	-17.2%
Huron	71.3%	71.7%	61.3%	-10.0%
Michigan	50.2%	45.6%	32.4%	-17.8%
Ontario	39.8%	29.7%	28.1%	-11.7%
Superior	74.5%	73.9%	62.0%	-12.6%

Source: Ferris, G. 2003. Ice duration on the Great Lakes indicator #4858, pp 71-72. In *State of the Great Lakes 2003*. State of the Lakes Ecosystem Conference, Environment Canada and U.S. Environmental Protection Agency. 102p.

rate of the water. Milder winter temperatures have a similar controlling effect, only the rate of heat released is slowed and the ice forms more slowly. Globally, some inland lakes appear to be freezing up later and breaking up earlier, than the historical average, based on a study of 150 years of data.

The freezing and thawing of lakes is an important aspect to many aquatic and terrestrial ecosystems. Many fish species rely on the ice to give their eggs protection against predators during the late part of the ice season. Near shore ice has the ability to change the shoreline as it can encroach upon the land during winter freeze-up times. Even inland systems are affected by the amount of ice that forms, especially within the Great Lakes Basin. Less ice on the Great Lakes allows more water to evaporate and be spread across the basin in the form of snow. This can have an effect on the foraging animals that need to dig through snow during the winter in order to obtain food.

Climate and Weather Trends

Michigan's current climate may be broadly characterized as being dominated by three general weather patterns. The two most dominant patterns originate from west to north and from west to south, influencing weather in northern Michigan and southern Michigan, respectively. The approximate boundary or tension line between these areas runs along an east-west line at about the latitude of Bay City. In general, the southern Lower Peninsula is warmer with a long frost-free season, has more rain in the springtime, less rain in the fall, and more thunderstorms, tornadoes, hail, and freezing rain than the north. The climate of the northern Lower Peninsula and eastern Upper Peninsula tends to be cooler with a shorter frost-free period, greater snowfall and influenced more by the presence of the bordering Great Lakes.

A third weather pattern occurs in the western portion of the Upper Peninsula. Due in part to the generally higher elevations and more northerly location, cooler temperatures, severe thunderstorms, and high winds are common.

Knowledge of the state's climate and weather is important to help interpret observed changes in air and water quality environmental indicators, but also in many of the programmatic measures. Michigan's climate has fluctuated for thousands of years and will continue to fluctuate with time. The change from glacial conditions occurred about 11,300 years ago when warm dry Pacific air masses became more frequent. Warm air masses dominated from 9,500 to 4,700 years ago. The tendency since then has been toward cooler and wetter conditions with a brief warming period from 1200 to 1400. Cooler temperatures and greater precipitation dominated again from around 1550 to 1850.

While annual variation exists, Michigan's mean temperature trend between the mid-1890s to the period of record through the mid- to late 2000s is similar to global patterns - cooling from approximately 1940 through the 1970s, followed by warming from the early 1980s that continues to the present **(Exhibit 54A)**. Across the period of record, the overall change is about +0.6°C. This compares favorably to overall global trends and temporal patterns which include an increase in mean temperature of approximately +0.8°C since 1850 (IPCC, 2007).

Much of Michigan's increase in average temperature over the past 30-40 years is attributed primarily to increasing minimum temperatures. For example, mean winter minimum temperatures from the mid-1980s through the present have increased approximately 4°C **(Exhibit 55)**. Similarly, both Michigan and regional warming correlates well with warmer nighttime temperatures (i.e. minimum temperatures), especially during the winter months. It may be surprising to note that relatively little

Exhibit 54A and 54B: Mean statewide temperature and precipitation data, for the period 1895–2006. Source: Michigan State Climatologist's Office, East Lansing.

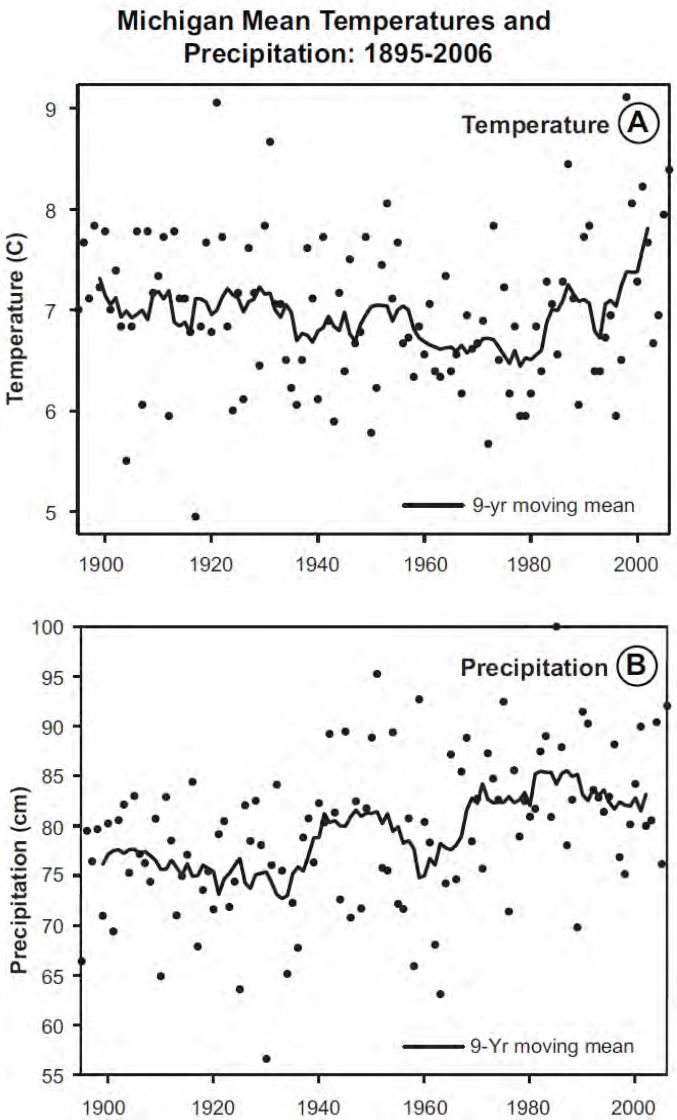
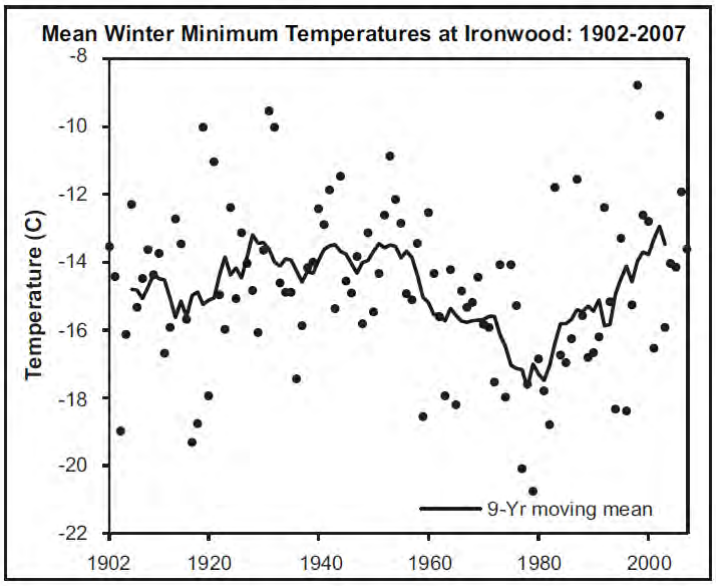


Exhibit 55: Mean winter minimum temperature, 1961–2004, at Ironwood. Source: Michigan State Climatologist's Office, East Lansing.



temperature change seems evident based on the records during the summer and fall seasons.

Other climate trends are apparent! Michigan's mean precipitation has demonstrated an upward trend over the period of record **(Exhibit 54B)** and in the number of days with quantifiable precipitation. But the most readily observable changes resulting from the recorded increase in winter temperatures is the reduction in the amount and duration of ice cover on the Great Lakes **(Exhibit 56B)**. Records show that the the number of days with greater than 20 percent ice cover has dramatically declined since 1972 (Assel 2003). One well documented example

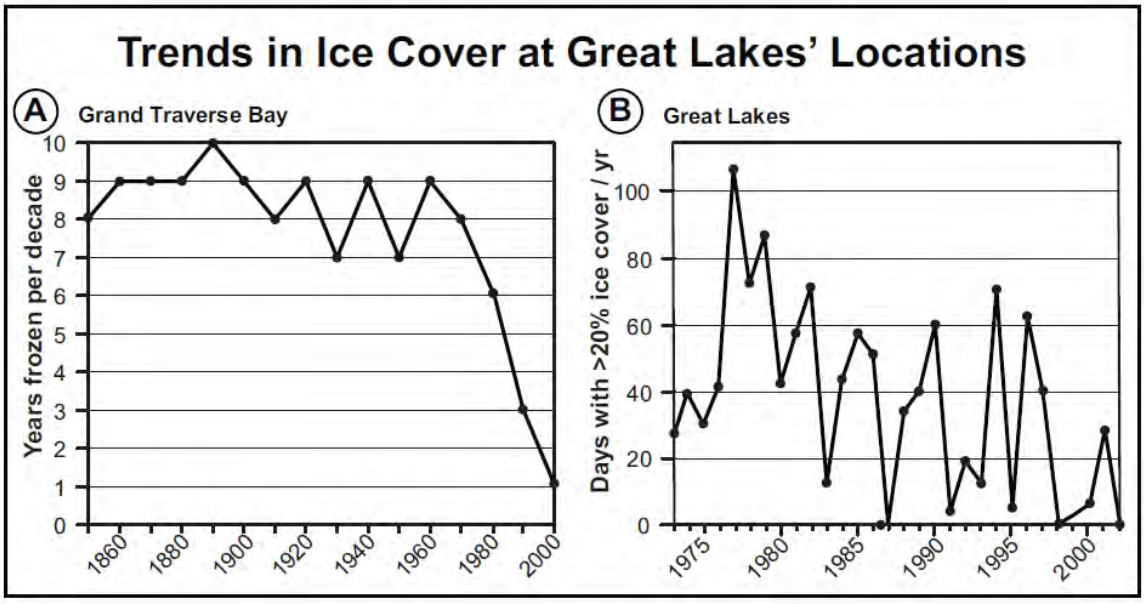


Exhibit 56A and 56B: Ice cover changes at two different Great Lakes' locations.
A. Number of years per decade that Grand Traverse Bay froze completely over. Source: Traverse City Record-Eagle.
B. Percentage of days per year from 1973–2003 with >20% ice cover on the Great Lakes. Source: Assel (2003).

shows that the number of years per decade that Grand Traverse Bay has been frozen over has rapidly decreased since the early 1970s **(Exhibit 56A)**. This is supported by additional studies of data collected in western Lake Superior where the most dramatic changes in ice cover have occurred since 1975. During this period the ice season has begun an average of 11.7 days later and ended 3.0 days earlier every decade.

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Andresen, J.A. 2007. Historical Climate Trends in Michigan and the Great Lakes Region. Prepared for the International Symposium on Climate Change in the Great Lakes Region: Decision Making Under Uncertainty. Michigan State University, East Lansing, MI 15-16 March, 2007

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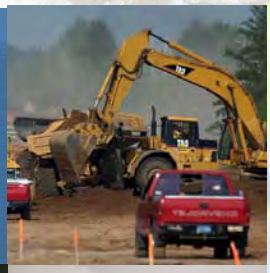
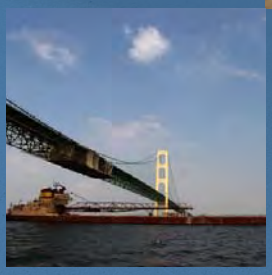
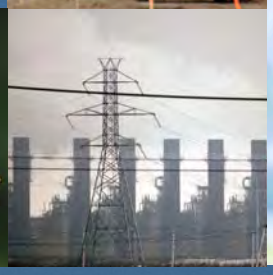






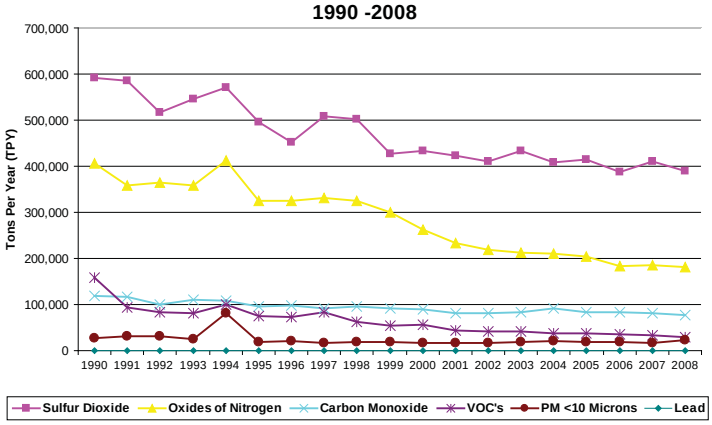
Programmatic Measures

AIR QUALITY

Air Emissions Estimates

The federal Clean Air Act requires states to prepare and maintain inventories of emissions from large stationary sources. Emissions from large "point" sources are calculated for particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic chemicals (VOCs), and lead. The MDEQ compiles information from over 1,700 facilities. **Exhibit 57** presents a summary of point source emissions for six contaminants; emissions of these contaminants have decreased substantially over the past twenty years.

Exhibit 57. Air Point Source Emissions 1990 -2008



Air pollutant emission sources are categorized as point sources, area sources, mobile on-road sources, and mobile non-road sources. Point sources are the primary contributors to sulfur dioxide and lead,

Exhibit 58
2008 Estimated Levels of Volatile Organic Compounds Emissions by Source Category

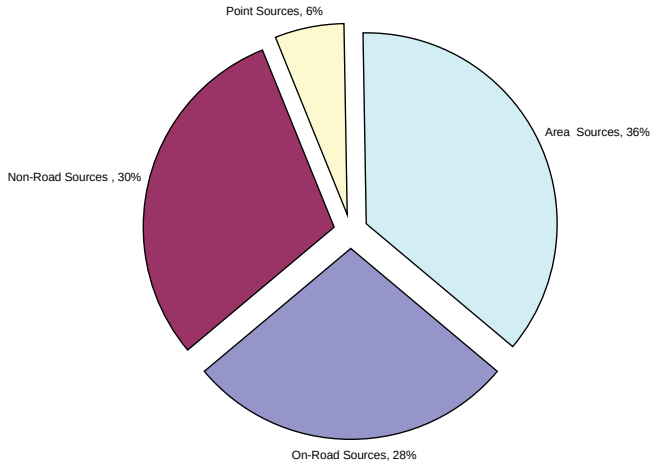
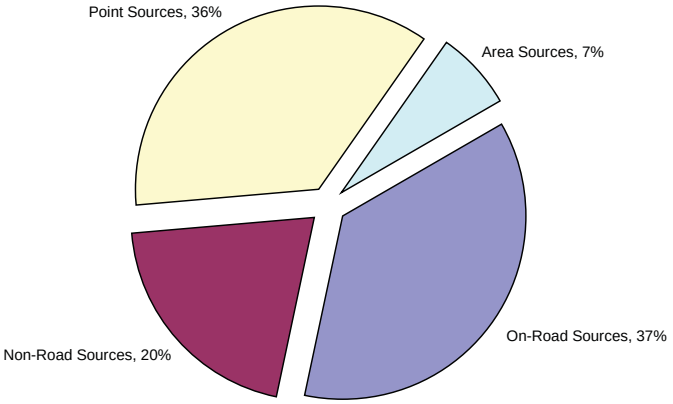
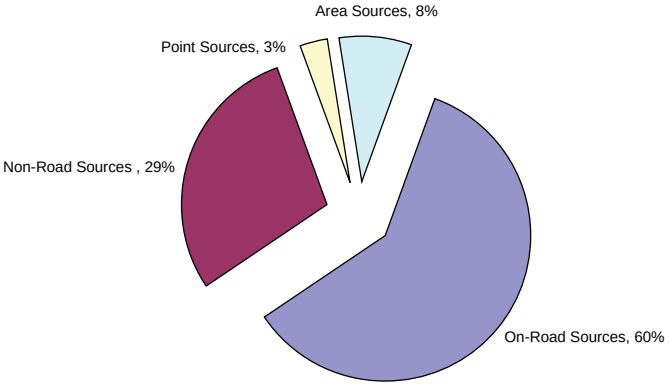


Exhibit 59
2008 Estimated Levels of Nitrogen Oxides Emissions by Source Category



while mobile sources are the primary contributors to nitrogen oxides, carbon monoxide, and VOCs. **Exhibits 58, 59, and 60** indicate the contribution of these source categories to VOCs, nitrogen oxides, and carbon monoxide. Photochemical reactions between nitrogen oxides and VOCs form ground level ozone.

Exhibit 60
2008 Estimated Levels of Carbon Monoxide Emissions by Source Category



Greenhouse Gas Emissions Inventory

Greenhouse gases allow sunlight to enter the atmosphere and then prevent heat from leaving. These gases are both naturally occurring and emitted by human activities such as burning of fossil fuels, industrial processes, agriculture, and deforestation. Changes in the atmospheric concentrations of greenhouse gases can alter the balance of energy transfers between the atmosphere, space, land, and the oceans (IPCC, 2001). The current concern is that since the

Industrial Revolution the global-average surface temperature of the Earth has been rising due to an amplification of greenhouse gases emitted by human activities.

In March 2009, the Michigan Climate Action Council, established by Executive Order 2007-42, issued the Climate Action Plan. This comprehensive report included a greenhouse gas inventory and forecast, recommended reduction goals, and potential actions to mitigate climate change in various sectors of the Michigan economy. The Center for Climate Strategies prepared the inventory and forecast report, presenting an assessment of emissions and anthropogenic (human-made) sinks that absorb greenhouse gases from the atmosphere. The inventory for 2005 and projections out to 2025 cover six types of gases: carbon dioxide (CO2), methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Emissions are reported using a common metric, CO2 equivalent (CO2e), which adjusts for the different global warming potential of the various gases.

Activities in Michigan accounted for approximately 248 million metric tons (MMt) of gross CO2e emissions, an amount equal to about 3.5 percent of total U.S. gross greenhouse gas emissions. From 1990 to 2005, Michigan's gross emissions increased about 12 percent, while national emissions rose by 16 percent. The principle sources of Michigan's greenhouse gas emissions are electricity consumption (36%), residential, commercial, and industrial fuel use (24%), and transportation (24%) **(Exhibit 61)**. Michigan's emissions are projected to continue growing to approximately 292 MMtCO2e by 2025, which is 32 percent above 1990 levels. These projections do not account for the severe global economic downturn.

Air Toxics Release Inventory

Air releases of toxic chemicals are reported annually as required by the federal Emergency Planning and Community Right-to-Know Act of 1986. Under this law, facilities in designated industrial sectors are required to report their process-related releases to air and other media and wasted of specific toxic chemicals. Only facilities that exceed activity thresholds for manufacturing, processing, or otherwise use of chemicals on the registry are required to report. Reports must be sent to the state and the USEPA, which compiles the information into the Toxics Chemical Release Inventory and makes it available to the public.

The Air Toxics Chemical Release Inventory information frequently is used to provide trends on particular media releases because of its availability and its longevity. For 2009, reported air releases in the state totaled 33 million pounds, which is a decrease of 37% compared to 2008. **Exhibit 62** shows an average of 46 million pounds of toxic air releases since the 2005 high of 53 million pounds.

The Toxics Chemical Release Inventory information presented in the Triennial Report is a statewide total of the data for specific reporting years and does not Indicate upward or downward trends

Exhibit 61
2005 Distribution of Michigan Greenhouse Gas Emissions by Economic Sector

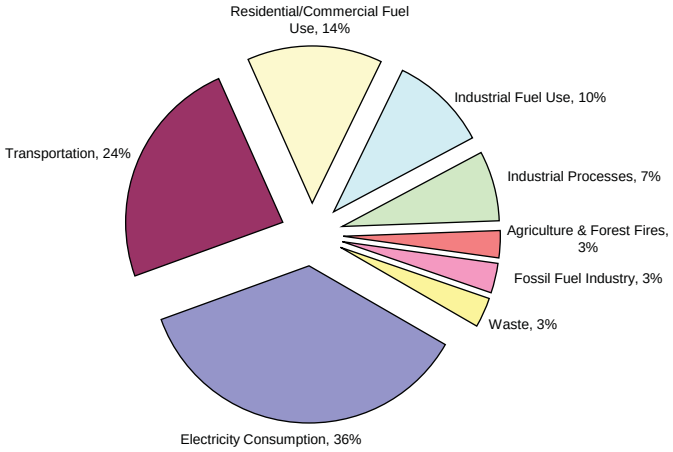
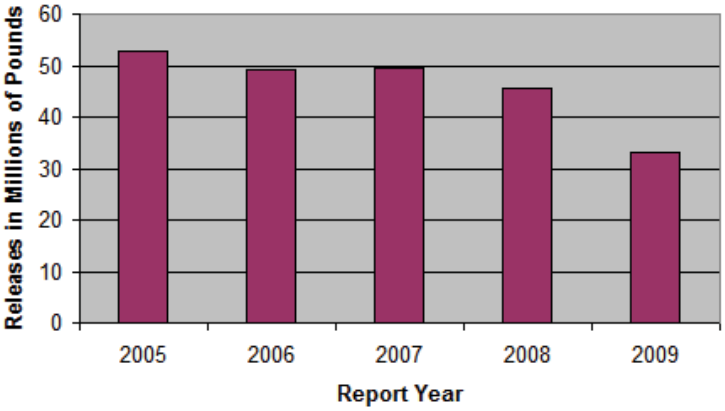


Exhibit 62. Air Toxics Release Inventory 2005-2009

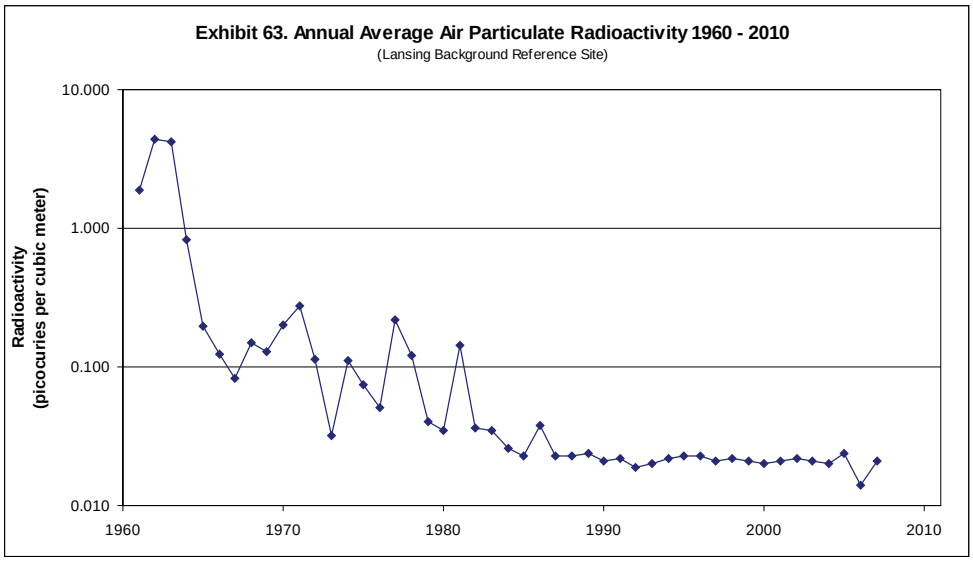


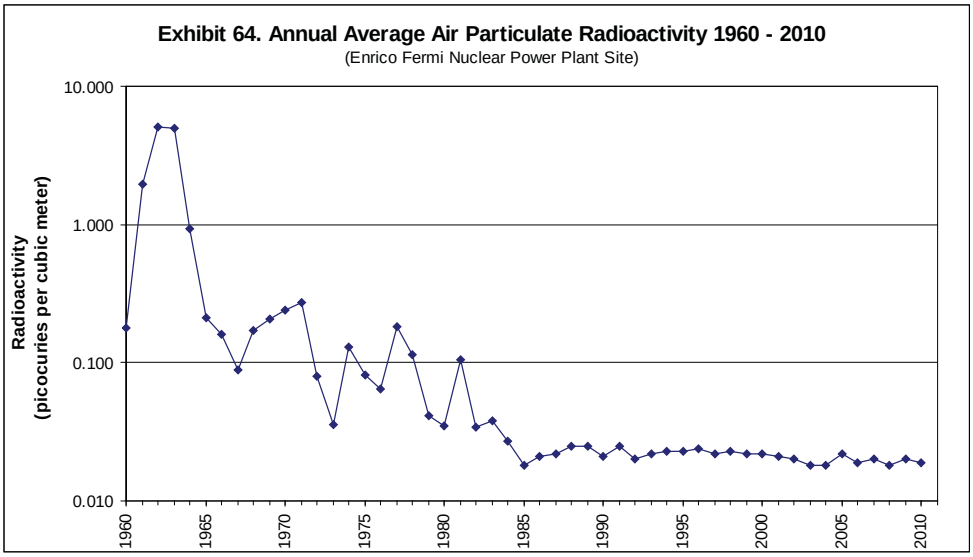
for individual pollutants or facilities. Caution also must be used with this measurement because the values are self-reported, may be estimates rather than actual measurements, and are not inclusive of all Michigan industries. Air toxics release data cannot be used to infer relative risks, absolute risks, or temporal trends for risk. Additional information on individual chemicals and facilities, including historical information, is available on the MDEQ Web site **(www.michigan.gov/deqsara)** or USEPA Web site (**www.epa.gov/tri)**.

Air Radiation Monitoring

The MDEQ is responsible for monitoring the potential for environmental impact due to the operation of nuclear power plants in Michigan. Baseline radiological data for the four nuclear power plant sites that operated in Michigan (Enrico Fermi, Big Rock Point, Palisades, and D.C. Cook) were established a minimum of one to three years prior to plant operation, which dates back to 1958 for the Enrico Fermi Nuclear Plant site. To date, off-site environmental impacts attributable to the operation of nuclear power plants in Michigan have not been detected. The data monitored by the MDEQ includes radioactivity in air particulates, radioactivity in milk, and, as discussed later in this report, radioactivity in surface waters. Annual reports on the overall quality of the radiological environment may be obtained by contacting the MDEQ.

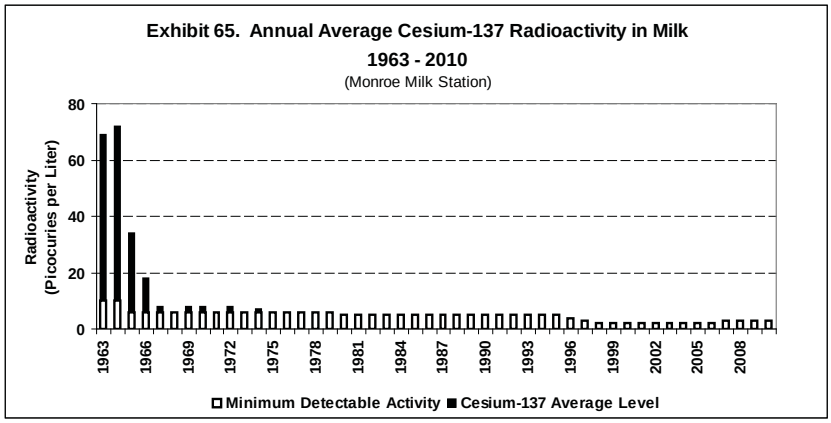
Since the inception of the program in the early 1980s, a general trend of decreasing levels of radioactive fallout from atmospheric testing of nuclear weapons has been observed, with the radioactivity associated with air particulates. A brief exception to this downward trend was observed in 1986 as a result of radioactive fallout from the Chernobyl Nuclear Power Plant accident in the former Soviet Union. Since 1986, the radioactivity levels associated with air particulates have returned to natural radiation background levels of 0.01 to 0.03 picocuries per cubic meter. A level of concern would be a three-month average exceeding one picocurie per cubic meter or several consecutive quarters exceeding 0.1 picocurie per cubic meter. A total of five sites are monitored throughout the state. **Exhibits 63 and 64** present measurements for the Lansing Background Reference and the Enrico Fermi Nuclear Power Plant sites, respectively, and may be considered representative for the other three monitoring locations. Data for 2010 from the monitoring locations demonstrate that radioactivity levels have continued to remain at natural background levels.

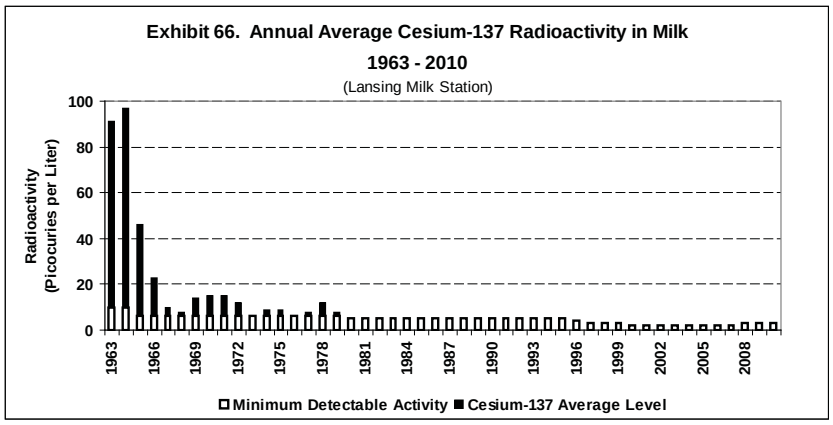




The MDEQ also monitors the level of radioactivity found in milk in order to assess the potential impact of radioactivity on the environment and human food chain. The radioactivity is characterized by determining the level of cesium-137. Cesium-137 is a radionuclide resulting from nuclear fission. It is highly suitable for this measurement since its chemical behavior is similar to that of potassium.

Exhibits 65 and 66 present radioactivity measurements taken from the Monroe and Lansing Milk Stations, respectively, which are representative of other milk monitoring locations in the state. Over the past 20 to 25 years, cesium-137 annual averages have remained below minimum detectable activity levels. Prior to 1980, but especially during the early 1960s, radioactivity levels in milk were significantly higher due to atmospheric nuclear testing. A level of concern would be an annual average exceeding 20 picocuries per liter.





WATER QUALITY

Combined, Sanitary, and Storm Water Sewer Systems

Over the years, the MDEQ has worked closely with municipalities to eliminate untreated sewage discharges from combined, sanitary, and storm water sewer systems. As a result, all cities have either corrected their combined sewer overflow problems (by replacement of the combined sewer system with separate storm and sanitary sewers or by providing retention and treatment of the overflow) or have an approved program in place that will lead to adequate control. Additionally, the MDEQ has worked with municipalities and industrial facilities to minimize the discharge of pollutants to surface water from storm water discharges. Both of these efforts have resulted in a continued reduction of nutrients, biological, heavy metal, and industrial pollutants to the waters of the state.

Sanitary sewer overflows generally are discharges of untreated sewage from municipal separate sanitary sewer systems, but they can occur from non-municipal systems as well. These systems are designed to carry domestic sewage, but not storm water. When a sanitary sewer overflow occurs, untreated sewage is released into city streets and low areas, including, in some cases, parks and other areas of public contact and surface waters, such as drainage ways, streams, and lakes, rather than being transported to a treatment facility. Sanitary sewer overflows are illegal and can constitute a serious environmental and public health threat.

Additional health threats occur when sewage from a public sewer system backs up into structures, such as residential basements, as a result of excess wet weather flow in the sewer system. Other sewer system deficiencies, such as mechanical or electrical failures at pump stations or structural failure of sewers due to age or accidents, also can result in discharges threatening the environment and public health.

In 1999 and early 2000, the MDEQ identified municipalities throughout the state that experienced discharges of sanitary sewage into waters of the state. In May 2000, the MDEQ announced a statewide strategy to identify and correct the discharge of untreated or inadequately treated sanitary sewage. The strategy emphasized the implementation of corrective action programs for those municipalities identified as a sanitary sewer overflow community with the goals of eliminating illegal sanitary sewer overflows and preventing new ones from occurring. In December 2002, the MDEQ adopted a statewide sanitary sewer overflow policy statement for implementation to accomplish these goals.

The MDEQ is keeping the public informed of the identified overflows in their communities by posting on the Internet a listing of untreated or partially treated sewage discharges and the waters to which the discharge occurs as the reports are received. The reporting of the discharge of untreated or partially treated sewage and the public posting are required by state statute.

Dischargers also are required to promptly notify local county health departments, potentially impacted neighboring municipalities, and the local media of such incidents. The MDEQ is taking actions to establish immediate control measures, where necessary, and require corrective action programs to eliminate illegal sewer discharges. An annual report of the discharge of untreated or partially treated sewage identifying the quantity of sewage discharge reported, and the corrective programs being undertaken is available on the MDEQ's Internet site **(www.michigan.gov/deq)**.

Surface Water and Beach Monitoring

All of Michigan's surface waters are designated and protected for total body contact recreation (swimming) from May 1 to October 31. In Michigan, a water body is considered suitable for total body contact recreation when the number of the indicator bacteria, E. coli, per 100 milliliters of water is less than or equal to 130, as a 30-day geometric mean. At no time should waters protected for total body contact recreation contain more than 300 E. coli per 100 milliliters of water in any individual sample. The MDEQ works in partnership with county health departments and other local entities to ensure that Michigan's surface waters are monitored for E. coli and protected for total body contact recreation.

The MDEQ awards federal funds from the Beach Act to local health departments to support E. coli monitoring at public beaches located along the Great Lakes shoreline. A summary of grant awards and monitoring information for Great Lakes beaches is shown in **Exhibit 67**. The number of counties that monitored beaches and the number of monitored beaches listed in Table 1 were supported with federal and local funds. In 2009, the MDEQ supplemented the Beach Act funds with approximately $210,000 to increase the duration of monitoring to at least 16 weeks for the majority of Great Lakes beaches.

The MDEQ awards state funds from the CMI-CWF to local health departments to support E. coli monitoring at public beaches located on inland lakes. A summary of grant awards and monitoring information for inland lake beaches is shown in

Exhibit 67 Summary of Great Lakes beach monitoring

Year	Number of grants awarded	Total award amounts	Number of counties that monitored	Number of beaches monitored
2011	23	$207,539	To be determined	To be determined
2010	23	$204,807	38	224
2009	23	$437,986	37	225
2008	23	$ 245,719	37	208
2007	23	$ 212,766	38	205
2006	23	$ 212,766	37	207
2005	21	$ 278,157	36	197
2004	19	$ 244,873	33	204

Exhibit 68 Summary of inland lake beach monitoring

Year	Number of grants awarded	Total award amounts	Number of counties that monitored	Number of beaches monitored
2011	To be determined	To be determined	To be determined	To be determined
2010	14	$187,423	42	206
2009	14	$187,423	37	189
2008	13	$ 100,000	37	259
2007	13	$ 100,000	38	269
2006	10	$ 117,576	40	233
2005	11	$ 100,000	33	209
2004	9	$ 100,000	41	290

Exhibit 68. The number of counties that monitored beaches and the number of monitored beaches listed in **Exhibit 68** were supported with CMI-CWF and local funds. In 2009, the grants were extended for a two year period with funding availability adjusted accordingly.

The MDEQ received 8 Great Lakes Restoration Initiative grants of $3.2 million in 2010 from the USEPA, Great Lakes National Program Office, to increase monitoring frequency, conduct beach sanitary surveys, and investigate potential sources of contamination at 224 Great Lakes public beaches.

E. coli monitoring data for beaches are reported by local health departments to BeachGuard, which is the MDEQ's Beach Monitoring Web site. The percentage of daily samples exceeding daily standards averaged 3 percent over the past eight years. An average of 21 percent of the monitored beaches reported at least one exceedance per year from 2003 to 2010. A summary of the beach monitoring data is shown in **Exhibit 69**.

Conservation Reserve Enhancement Program

The MDEQ has been working closely with the MDARD to implement a federal-state-local conservation partnership program, referred to as the Conservation Reserve Enhancement Program (CREP), to reduce significant environmental effects related to agriculture. Michigan is implementing conservation practices under the CREP in four critical watersheds (Saginaw Bay, Macatawa, River Raisin, and Western Lake Erie Basin) that have intense agricultural land use. The objectives of the program are to improve and protect water quality and to promote and enhance wildlife habitat by providing incentives to Michigan citizens for implementing conservation practices for a period of 15 years. Eligible conservation practices include filter strips, riparian buffer strips, field windbreaks, and wetland restorations. The MDEQ has agreed to supply Clean Michigan Initiative (CMI) - Clean Water Fund monies and CMI-Nonpoint Source (NPS) Pollution Control funds for the establishment of a livestock exclusion program, cost share for the implementation of Natural Resources Conservation

Exhibit 69 Summary of *E. coli* data for Beach Monitoring Program

Description	2005	2006	2007	2008	2009	2010
Counties with beach monitoring programs	52	58	58	57	57	59
No. of daily mean *E. coli* samples collected	4677	5609	5476	5,435	5,921	5,194
No. of samples exceeding the daily standard	143	200	145	154	212	209
% of samples exceeding the daily standard	3.1%	3.6%	2.6%	2.8%	3.6%	4.0%
Beaches with *E. coli* samples collected	406	440	474	467	414	430
No. of beaches exceeding the daily standard	82	99	77	75	83	108
% of beaches exceeding the daily standard	20.2%	22.5%	16.2%	15.8%	20%	25%

Service approved conservation practices, technical assistance from conservation districts in the CREP watersheds, and permanent conservation easements.

There are currently over 73,000 acres of CREP conservation practices that are either under contract or pending in Michigan. The goal for Michigan is to implement 85,000 acres of CREP practices in the four watersheds.

Over $7.5 million in CMI funds were awarded and utilized to acquire permanent conservation easements on 5,473 acres of the CREP practices. The funds resulted in 72 permanent conversation easements, covering 460 acres of filter strips, 3062 acres of restored wetlands and 1,951 acres of riparian buffers protected.

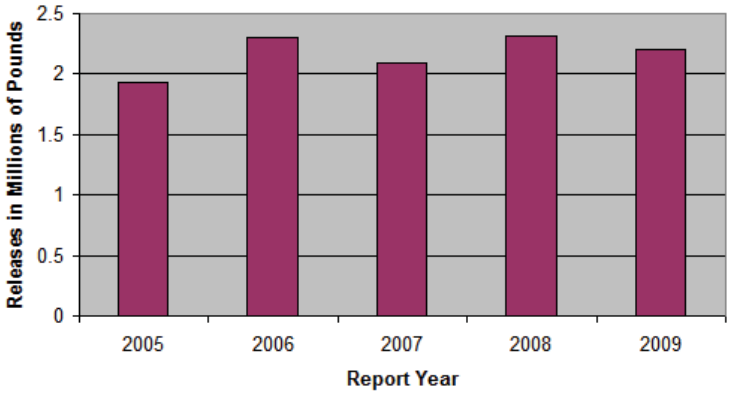
The success of the CREP will be measured in reduced sediment, phosphorus, nitrogen, pesticide, and pathogen inputs to surface waters resulting in improved water quality in Michigan.

Water Toxics Release Inventory

The federal Emergency Planning and Community Right-to-Know Act of 1986 requires facilities in designated industrial sectors to annually report their process-related releases of specific toxic chemicals to surface waters and other media. Only those facilities that exceed activity thresholds for manufacturing, processing, or otherwise use of chemicals on the registry are required to report. Reports must be sent to the state and the USEPA, which compiles the information into the Toxics Chemical Release Inventory and makes it available to the public.

The Water Toxics Chemical Release Inventory information frequently is used to provide trends on particular media releases because of its availability and its longevity. For 2009, releases of toxic chemicals to surface waters in the state totaled 2,204,842 million pounds (approx. 2.2 million), slightly less than the 2008 total of 2,314,242 million pounds (approx. 2.3 million). Since 2005, the reported annual toxic chemical releases to surface waters have fluctuated. **Exhibit 70** shows statewide toxic water releases since 2005.

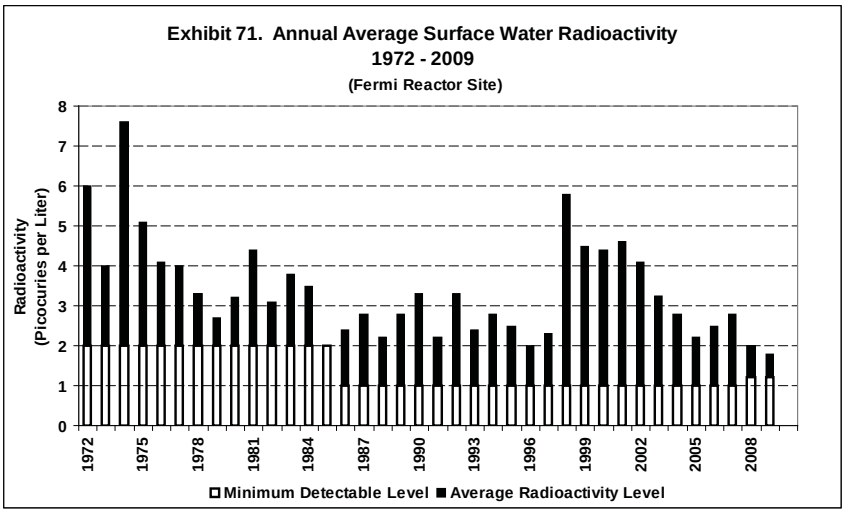
Exhibit 70 Water Toxics Release Inventory 2005-2009



The Toxics Chemical Release Inventory information presented in this Triennial Report is a statewide total of the data for specific reporting years and does not indicate upward or downward trends for individual pollutants or facilities. Caution also must be used with this measurement because the values are self-reported and may be estimates rather than actual measurements, and are not inclusive of all Michigan industries. Water toxics release data cannot be used to infer relative risks, absolute risks, or temporal trends for risk. Additional information on individual chemicals and facilities, including historical information is available on the MDEQ Web site **(www.michigan.gov/deqsara)** or USEPA Web site **(www.epa.gov/tri)**.

Surface Water Radiation

The MDEQ is responsible for monitoring the potential for environmental impact due to the operation of nuclear power plants in Michigan. One of the factors monitored is the level of radiation associated with nearby surface water. Surface water radioactivity averages have remained in the natural background range of one to six picocuries per liter since the inception of the monitoring program in 1972. A level of concern would be an annual average exceeding 50 picocuries per liter. **Exhibit 71** presents the annual radioactivity measurements for the monitoring stations near the Fermi Nuclear Power Plant. (Note: During 2010 the laboratory facilities were relocated. The surface water sample data for 2010 has not been compiled and the results are not included in **Exhibit 71**. The 2010 data will be included in the next triennial report.) These results are representative of what has been measured at the other nuclear power



plant locations in Michigan. Annual reports on the overall quality of the radiological environment may be obtained by contacting the MDEQ, Resource Management Division.

Drinking Water

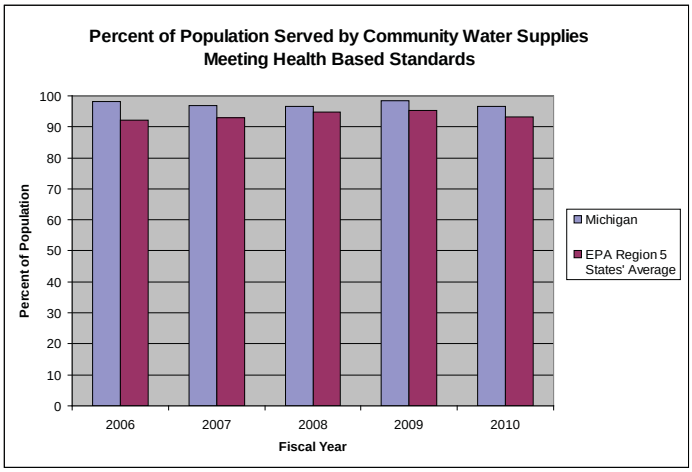
Microbiological, chemical, and radiological contaminants can enter water supplies. These contaminants may be produced by human activity or occur naturally. For instance, chemicals can migrate from disposal sites or underground storage systems and contaminate sources of drinking water. Animal wastes, pesticides, and fertilizers may be carried to lakes and streams by rainfall runoff or snow melt. Nitrates from fertilizers also can be carried by runoff and percolate through soil to contaminate ground water. Arsenic and radon are examples of naturally occurring chemical contaminants that may be released into ground water as it travels through rock and soil.

Effects of exposure to contaminants in drinking water will vary depending on many factors, including the type of contaminant, its concentration in drinking water, and how much contaminated water is consumed over what period of time. As of 2010, more than 90 contaminants are regulated in drinking water under the federal Safe Drinking Water Act. Additional contaminants are also regulated by drinking water standards that require certain treatment techniques to be applied if monitoring of the source water indicates potential for contamination. For example, if a surface water source is deemed vulnerable to Giardia or Cryptosporidium cysts that may originate from animal activity within a watershed, treatment methods such as disinfection and filtration become mandatory. These treatment techniques also remove a wide number of other microbiological parameters that could impact public health.

The MDEQ oversees 11,550 community and noncommunity public water systems by emphasizing prevention and early detection and correction of sanitary defects. Community water systems are those systems furnishing drinking water year-round to residential populations of 25 or more. Noncommunity water systems are public water systems serving 25 or more persons, 60 days or more per year and include campgrounds, restaurants, schools, churches, child care centers, and businesses with their own water supply. Sanitary surveys of public water systems are conducted routinely to assess the condition of water supply facilities, including source, treatment, distribution, and storage. The operation, maintenance and security of the system are also evaluated. Conclusions and recommendations are then provided to the system. Mutually acceptable schedules to complete necessary improvements are then developed and implemented. Public water systems are also required to have trained and certified operators in accordance with state law. MDEQ recognizes that competent operators are critical to identifying potential problems and making corrections before public health problems develop. The MDEQ also establishes monitoring requirements for community drinking water systems based on vulnerability and source water assessments.

The MDEQ maintains data on community and noncommunity water supplies that receive drinking water meeting all health-based standards. These data are derived from state reports of drinking water violations to the USEPA's national data system. The Michigan inventory consists of approximately 1,400 community water systems, including municipal systems, mobile home parks, nursing homes, public institutions, and housing developments such as subdivisions and condominiums. In the last 5 years, the percentage of the population served by community water systems meeting all health based standards ranged from a low of 96.5 percent to as high as 98.5 percent **(Exhibit 72)**. This is consistently above the average for EPA Region 5 states. Inspection, permitting, monitoring oversight, and enforcement of the 10,150 noncommunity water systems are delegated by the MDEQ to local health departments.

Exhibit 72



Each year the MDEQ spends millions of dollars providing safe drinking water to families or businesses with tainted private water wells when no viable, liable party is able to address the contamination. Since 1985, the MDEQ has spent about $100 million providing safe drinking water to Michigan residents whose well water is contaminated or threatened. The MDEQ actions at such sites have included:

1. Supplying affected homes/businesses with bottled water;
2. Sampling, monitoring or replacing impacted drinking water wells;
3. Providing hook-ups to municipal water when multiple private wells are tainted; and
4. Helping to build new municipal water supply systems when no feasible alternative is available.

The above corrective action projects have ranged in cost from a few thousand dollars to as high as several millions of dollars, have taken anywhere from a few days to multiple years to fully address problems, and have impacted anywhere from one family to thousands of people.

Arsenic

One contaminant that has presented a significant challenge for drinking water supplies in Michigan is arsenic. Arsenic is an element that occurs naturally and is widely distributed in the earth's crust. It is usually found in the environment combined with other elements such as oxygen, chlorine, and sulfur. Arsenic combined with these elements is referred to as inorganic arsenic. Arsenic combined with carbon and hydrogen is referred to as organic arsenic. Organic arsenic is less of a health concern than is inorganic arsenic. The most common form of human exposure to arsenic is from groundwater used for drinking or cooking.

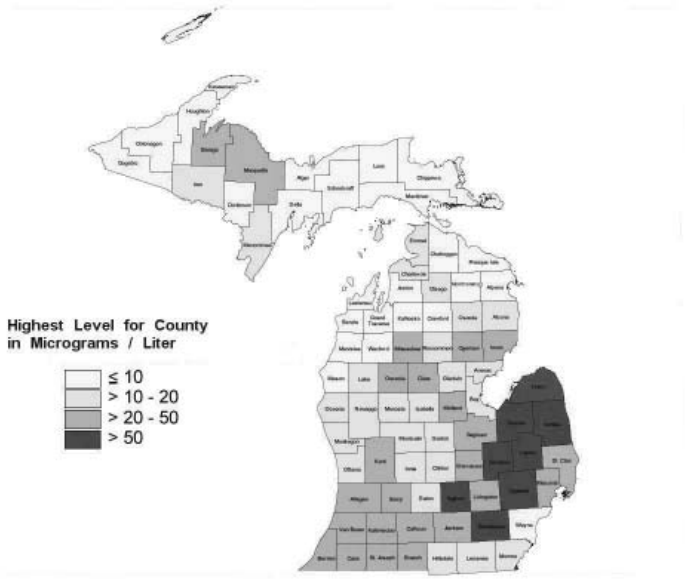
The manner in which arsenic affects humans is not fully understood. Common symptoms include thickening and discoloration of the skin, as well as stomach pain, nausea, vomiting, and diarrhea. It may also cause numbness in the hands and feet. Many of the symptoms of exposure to high levels of arsenic also are seen with other common illnesses, which makes it difficult for physicians to recognize. Some people may be affected by lower levels of arsenic while others remain unaffected. Young children, the elderly, people with long-term illnesses, and unborn babies are at greater risk since they can be more sensitive to chemical exposures. Babies are not exposed to arsenic through breast milk at levels of concern even when their mothers have been exposed.

In 2001 the USEPA promulgated a revised arsenic standard, reducing the maximum contaminant level (MCL) from 50 to 10 micrograms per liter based on new data demonstrating the carcinogenic effects of arsenic. The effective date for this revised standard was 5 years later, in January of 2006. Michigan has a relatively high number of public systems impacted by this revised arsenic standard, ranking 2nd among all states.

Based on compliance monitoring conducted in 2005, 108 community water systems exceeded this revised standard, with all but a few serving less than 3,300 residents. Many of these systems are non-municipal systems, such as manufactured housing communities, apartment complexes, condominium developments, subdivisions, etc. As of December 2010, all but 12 community systems have achieved compliance by replacing their source, consolidating with an adjacent system, or constructing treatment facilities. The remaining noncompliant systems are either following a compliance schedule established in a consent order or just recently exceeded the MCL and are evaluating alternative solutions. These systems periodically provide public notice to remind customers about the health threat.

Exhibit 73 presents ground water arsenic levels from Michigan counties. More precise locations of the sample locations within each county may be found on the MDEQ's Internet site **(http://michigan.gov/documents/deq/deq-wd-gws-ciu-statewide-as_270812_7.pdf)**. Private well owners in areas where arsenic levels are known to be elevated may contact their local health department to determine if sampling their well may be appropriate.

Exhibit 73 Arsenic



Nitrate

Another contaminant that continues to pose a problem for drinking water supplies is nitrate. Nitrate is a form of nitrogen combined with oxygen. It can be converted in the body to nitrite. The major adult intake of nitrate is from food rather than water, but sometimes excessive amounts of nitrate get into drinking water.

Nitrate can get into drinking water if a well is improperly constructed or located where it is subject to contamination sources. Shallow water wells in sandy unconfined aquifers are more vulnerable to nitrate contamination than deeper wells protected by overlying clay strata. Nitrate can also get into surface water intakes that are located in rivers and lakes that are subject to agricultural runoff and discharges of untreated sewage. Typical sources of nitrate contamination include:

1. Wastes from livestock operations;
2. Septic tank/drainfield effluent;
3. Crop and lawn fertilizers;
4. Municipal wastewater sludge application; and
5. Natural geologic nitrogen.

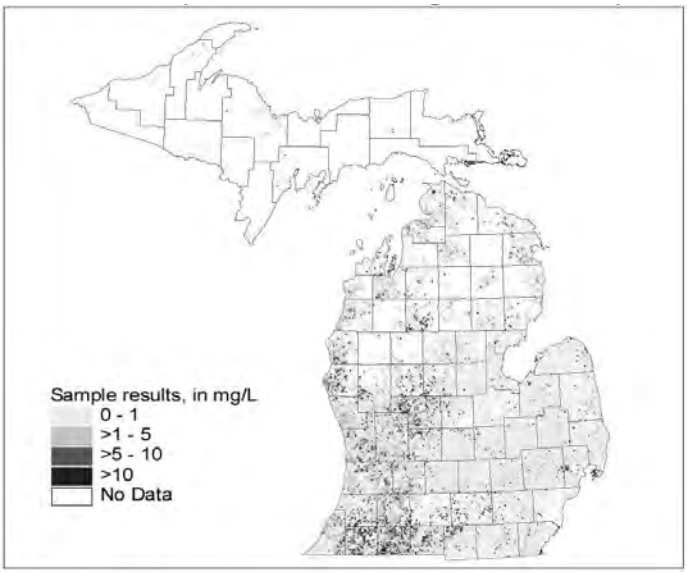
Elevated nitrate in drinking water can cause a disease called methemoglobinemia, a blood disorder primarily affecting infants under six months of age. Methemoglobinemia reduces the ability of the red blood cells to carry oxygen. The acutely poisoned person will have a blue discoloration of the skin due to the reduction of oxygen in the blood. The condition can be fatal if not attended immediately by a physician.

The USEPA has established a drinking water maximum contaminant level for nitrate (as nitrogen) at 10 milligrams per liter and nitrite at 1 milligram per liter. Michigan has adopted these standards.

Private water supply owners who find that they have excessive nitrate or nitrite levels should contact their local health department. Although, nitrate can be removed from drinking water using a complex process, it is generally recommended that, initially, an alternate source of drinking water be developed away from any contaminating sources and that bottled water be used for preparing infant formula. Further consultation with the local health department may be needed to develop more permanent, longer-term alternatives.

Exhibit 74 graphically presents averaged nitrate levels in ground water from Michigan counties.

Exhibit 74 Nitrate



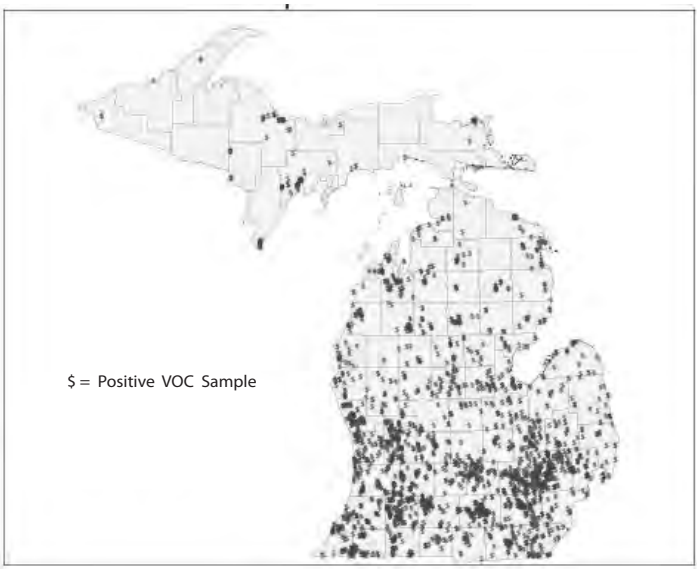
More precise locations of the sample locations within each county may be found on the MDEQ Internet site **(www.deq.state.mi.us/documents/deq-wd-gws-ciu-no3.htm)**.

Volatile Organic Chemicals

When found in drinking water, the source of VOCs is generally associated with an industrial solvent release, landfill leachate, chemical transportation spill, a fuel spill and leak, illegal waste disposal, etc. VOCs do not occur naturally in ground water.

Twenty-one VOCs that can pose a physical and/or biological risk to drinking water resources are currently monitored by the MDEQ. **Exhibit 75** presents the location of ground water samples from Michigan counties where the volatile organic chemicals have been found. More precise locations of the sample locations within each county may be found on the MDEQ's Internet site **(www.deq.state.mi.us/documents/deq-wd-gws-ciu-voc.htm**).

Exhibit 75 VOC



In 2006 MDEQ completed a two-year project to inventory and map ground water resources for the State of Michigan. MDEQ partnered with the United States Geological Survey and Michigan State University to produce maps that show ground water yielding capabilities for glacial and bedrock aquifers, depict ground water dependant surface water features, identify users of large quantities of ground water and provide other valuable ground water information. This mapping report, mandated and funded through legislation (2003 PA 148), was submitted to the Ground Water Conservation Advisory Council for their use in analyzing the need for water legislation. The council submitted their report to the Legislature in February 2006. The generated maps are available on the Internet **(www.gwmap.rsgis.msu.edu)**.

Water Diversions and Consumptive Use

Under the Great Lakes Charter of 1985, the Governors of the Great Lakes States and the Premiers of the Canadian Provinces of Ontario and Québec notify and consult with each other on proposals for diversions and consumptive uses of waters within the Great Lakes Basin of over five million gallons per day.

Additionally, the Governors have direct authority over the waters of the Great Lakes within the United States through the federal Water Resources Development Act of 1986, as amended. Under this Act, no bulk export or diversions of water from the Great Lakes Basin can take place without the unanimous approval of the Great Lakes Governors.

On December 13, 2005, the Great Lakes Governors and Premiers signed agreements that will provide unprecedented protections for the Great Lakes-St. Lawrence River Basin. The agreements include the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement, which is a good-faith agreement among the Great Lakes States, Ontario, and Québec that will be implemented in Ontario and Québec through Provincial laws, and in the States, through the Great Lakes-St. Lawrence River Basin Water Resources Compact (Compact).

The Compact includes the following points:

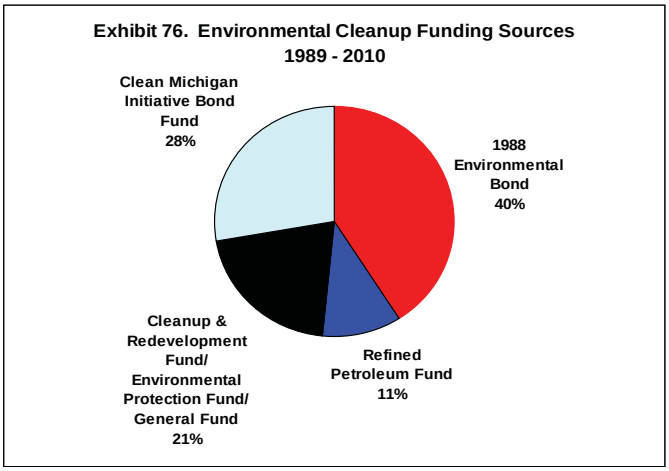
1. Sustainable use and responsible management of Great Lakes Basin waters;
2. Banning (with some limited exceptions) of new diversions of water from the Great Lakes Basin;
3. Use of a consistent standard to review proposed uses of Great Lakes Basin water;
4. Development of regional goals and objectives among the Compact members for water conservation and efficiency;
5. Improved collection and sharing of technical data among the Compact members; and
6. Continued public involvement in the implementation of the agreements.

On July 9, 2008, the Great Lakes States completed ratification of the Compact. In order to become law, it was necessary for the United States Congress to provide its consent. Federal consent legislation was introduced in both the United States House of Representatives and Senate. The Compact was approved by the U.S. Senate in August and the House of Representatives in late September. It then was sent to the President who signed the legislation into law and it came into force on December 8, 2008.

LAND QUALITY

Environmental Cleanups

Remediation (cleanup) of environmentally contaminated land is accomplished through state-funded actions and through actions conducted by liable parties and property owners. The sources of public funds that have been used for cleanup since 1989 are shown in **Exhibit 76**. Prior to passage of the CMI in November 1998, the MDEQ cleanup program was funded primarily by an Environmental Bond approved in 1988. Most of the 1988 Environmental Bond money was directed at performing cleanups to protect public health and the environment. Under the 1998 CMI, the primary focus was preparing contaminated sites for redevelopment. The Refined Petroleum Fund (RPF) is used to address contamination from leaking underground storage tanks.



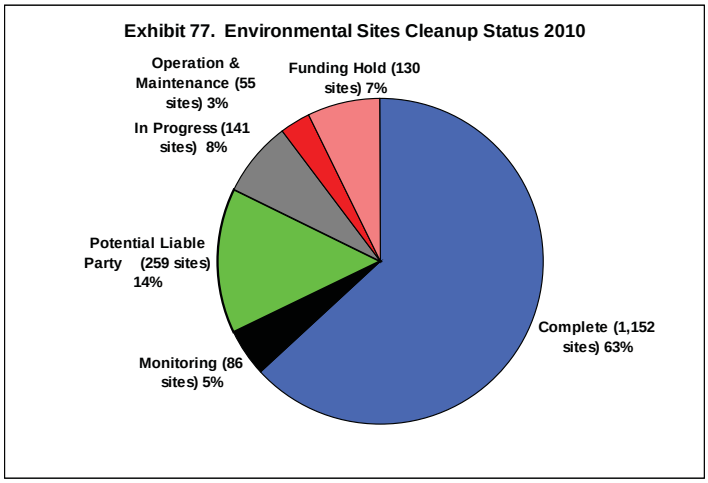
A total of $335 million has been earmarked from the CMI Fund for cleanup of environmentally contaminated sites, including leaking underground storage tank sites. To date, $144 million has been appropriated for work on 589 redevelopment related projects. The proceeding numbers are the same as those presented in 2008, as there have been no additional CMI appropriations since that time. A portion of the $335 million is set aside to address serious health and environmental problems at contaminated sites that do not have redevelopment potential. A total of $97 million has been appropriated for action at 213 sites in this category. Eight million dollars of the $335 million was designated for local units of government to address municipal landfills on the federal Superfund National Priorities List (NPL) and to clean up sites where a specific redevelopment proposal exists. Seventy-five million dollars was designated for Brownfield Redevelopment Grants and loans to local units of government for response activities at contaminated sites as needed to facilitate redevelopment. To date, a total of 58 grants and 44 loans have been awarded, totaling $61.8 million. The remaining $11 million of the $335 million is being used for administrative support costs. In addition to the $335 million, another $50 million from the CMI Fund has been awarded to 72 grant projects through a competitive grant process for waterfront improvements to promote economic development and public access to the waterfront.

Since 2006, $95 million has been appropriated from the RPF to address contamination caused by leaking underground storage tanks. The funds were proposed to be used at 318 sites.

Part of the work that has been conducted in Michigan includes cleanups at federal Superfund

sites on the NPL. Since Michigan began listing sites on the NPL, the use of 10 percent state-matching dollars secured approximately $265 million in federal monies for cleanups.

A total of 1,823 sites have been targeted for cleanup with public funds, beginning with the 1988 Environmental Bond program. At 259 of those sites, liable parties have come forward to perform necessary cleanup actions and are currently in the process of doing so. The current status of the cleanup work at publicly funded sites is presented in **Exhibit 77**. Cleanup activities are complete at 1,152 sites. At 86 additional sites, monitoring



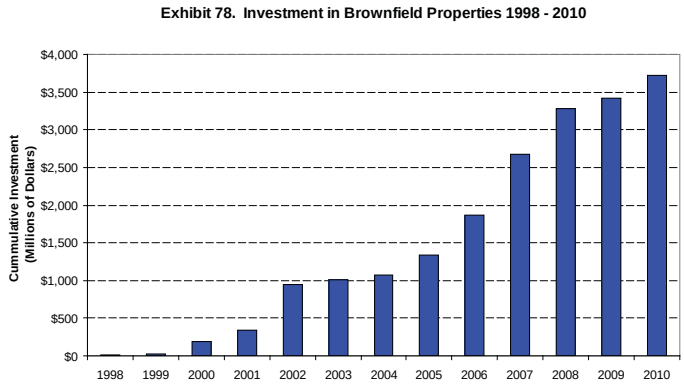
is being conducted to assure that further state-funded actions are not required. The two categories combined represent 68 percent of the sites where work has been undertaken. Cleanup systems have been constructed and operation and maintenance activities are ongoing at 55 sites. Cleanup work is in progress at 141 additional sites. Due to funding restraints, 130 projects are on hold until additional funds are secured.

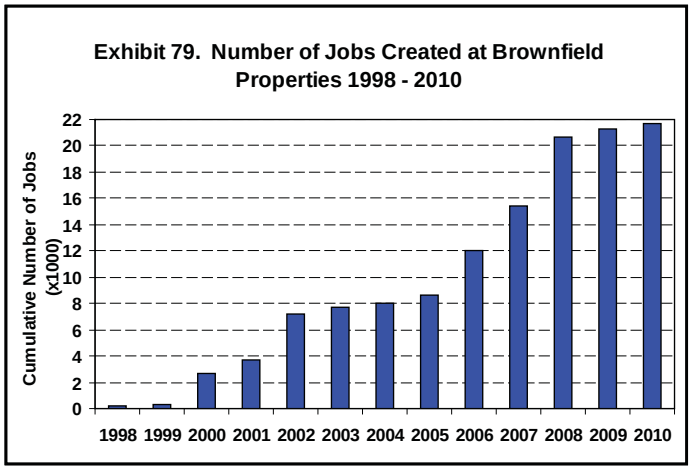
In 1995 Michigan's cleanup law was changed. One of the goals of the change was to promote redevelopment of contaminated property (referred to as Brownfield sites). Up until the time of the 1995 changes, any person who owned or operated contaminated property was responsible for cleaning up the contamination, regardless of whether they caused the problem. This was a serious impediment to the purchase and reuse of contaminated property that resulted in many new development projects going to undeveloped land or open space. In an effort to reduce this problem and to put contaminated property back into productive use, liability for property owners was changed to a causation standard. Under the 1995 changes to the state cleanup law, the person who caused contamination, rather than the person who buys or owns the contaminated property, is responsible for conducting the cleanup. In addition to cleanups conducted by these liable parties, non-liable property owners may still elect to conduct cleanups to increase their property value. They must, however, assure the safety of people who work or live at these sites.

Another change established in the 1995 amendments to the state cleanup law was the creation of risk-based cleanup criteria that are linked to land use. The use of these criteria helps to ensure that cleanups can be conducted in a cost effective manner. The risk-based system accounts for the fact that the use of a property dictates the type of exposures that will occur, and that risk depends on exposure. For example, industrial sites do not have children present and workers spend only a portion of the day at the work place. Because of these differences in exposure, different levels of cleanup may be allowed, while still providing the same degree of protection at residential, commercial, and industrial sites.

Site-specific cleanups allow the MDEQ and property owners to account for special circumstances at a site. The MDEQ has approved cleanup plans for 2,030 sites in land use categories other than residential. Cleanups meeting residential criteria have been completed at many more sites, including sites where spill response activities undertaken by liable parties have eliminated unacceptable risks to public health and the environment. Property owners and other liable parties have conducted cleanup work at additional sites for which the MDEQ does not maintain statistics.

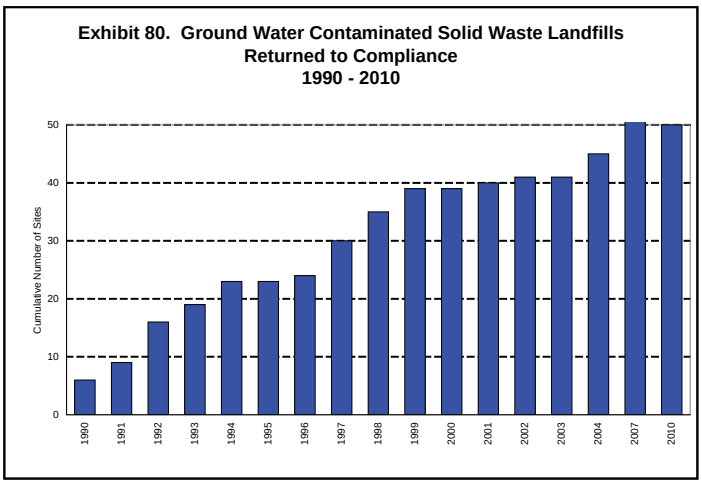
In the 2001, 2003, and 2006 Biennial Reports, information on the amount of private investment **(Exhibit 78)** and the number of jobs created **(Exhibit 79)** at brownfield properties was based on surveys conducted by the MDEQ at 33 communities between 1996 and 2002. Beginning with the 2008 Triennial Report, the data presented are based





on MDEQ review of work plans submitted by local Brownfield Redevelopment Authorities in accordance with the Brownfield Redevelopment Financing Act, 1996 PA 381, as amended. These numbers are estimates provided to the MDEQ prior to project construction and have not been verified post-construction.

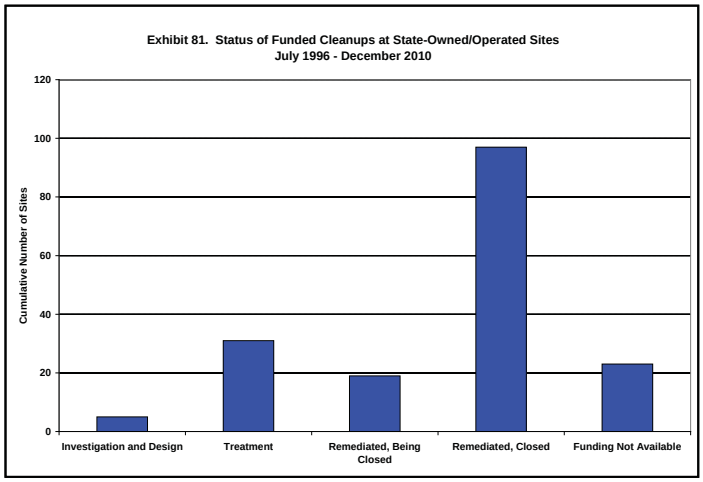
Michigan currently has a total of 134 municipal solid waste, industrial waste and construction and demolition waste landfills. This total includes landfills that are closed and others that are open and accepting waste, but it does not include facilities that operated before 1979, and which are addressed under the broader Environmental Cleanup Program, described above. Sixty-four of these landfills have been found to be contaminating ground water. Of these, 50 landfills (78%) have been cleaned up or have a corrective action ongoing. There are also eight sites where it is unknown if groundwater contamination exits. These sites are closed and no longer operating. Corrective action at the 50 landfills is in most cases being completed by the landfill owner. In a few cases it is necessary to use enforcement authorities to force the landfill owner/operator to address ground water contamination. This leaves 14 sites (22%) at which no actions to correct known ground water contamination are underway. The majority of these latter sites are closed and no longer operating. **Exhibit 80** shows the cumulative number of ground water contaminated landfills returned to compliance since 1990.



State-Owned Sites Cleanups

In addition to ensuring the cleanup of contaminated sites of others, the state is responsible for the cleanup of sites that it has contaminated as a result of its own operations. The state has identified a total of 175 such sites where it is responsible, as either the owner or operator, for environmental remediation. Of the 175 sites, 133 are underground or aboveground storage tanks; 18 are old landfills, dumps, or storage pits; 8 are shooting ranges; 9 are surface spills; 2 involve either asbestos removal or radioactive license decommissioning; and 5 have multiple sources of contamination.

In July 1996 a States Sites Cleanup Fund was established, into which a total of $30,965,100 has been made available to help the state fulfill its own environmental cleanup responsibilities. Currently, 128 of the 175 sites have been funded. Of the 175 funded sites, 97 have been cleaned up and closed; 19 have been cleaned up and are in the process of being closed; 31 are into long-term treatment to reduce the level of contamination; 5 are being investigated or are in the process of having a treatment design developed; and 23 sites

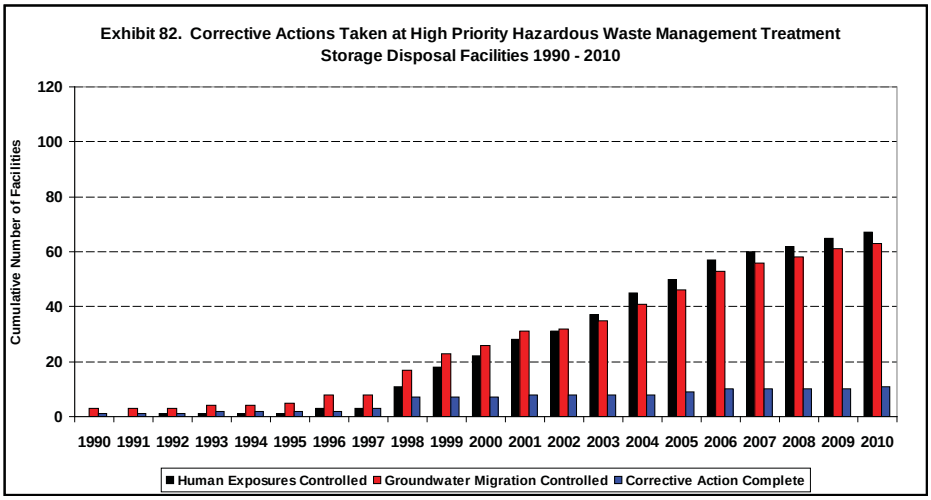


are partially cleaned, but currently inactive due to lack of available funding **(Exhibit 81)**.

Hazardous Waste Treatment, Storage, and Disposal Sites

There are 232 hazardous waste treatment, storage, and disposal sites in Michigan subject to corrective action requirements. The corrective action requirements have been in effect under Michigan law since 1995. Similar requirements have been in effect under federal law since 1984. In 1998 the USEPA delegated to Michigan the administration of the federal corrective action requirements at licensed facilities. The MDEQ has primary responsibility for overseeing the completion of corrective action at the licensed facilities.

Hazardous waste treatment, storage, and disposal facilities are subject to corrective action based on an assessment of the environmental contamination present and the risks each site poses to human health and the environment. Of the 232 identified sites, 119 have been ranked as high priority (i.e., sites having the worst contamination or risks). The environmental contamination problems at the remaining 113 sites are not as significant as those at the 119 high priority sites. To date, significant corrective action that has been taken at the high priority sites includes eliminating or controlling human exposure to contaminants such that there remains no unacceptable human health risk (67 sites), eliminating or controlling ground water contamination (63 sites), or completing the cleanup such that no further corrective action is required (11 sites) **(Exhibit 82)**.



Leaking Underground Storage Tanks

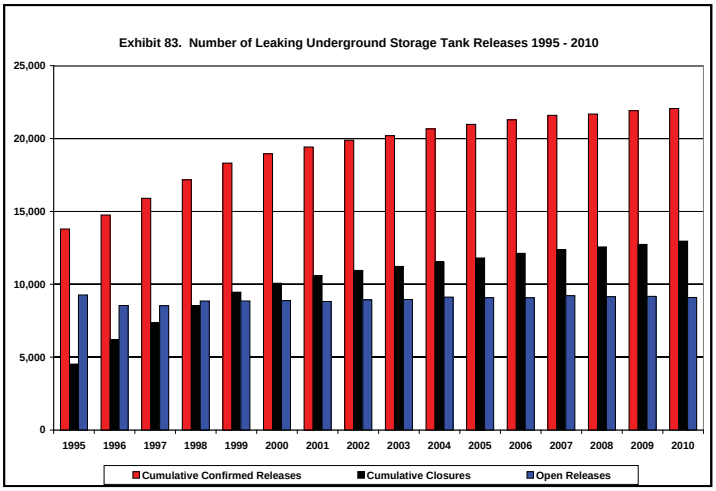
The predominant hazardous substances stored in underground storage tanks are petroleum products (gasoline and diesel fuel) and used oil. The primary constituents of petroleum include benzene, ethylbenzene, toluene, xylenes, and polynuclear aromatic hydrocarbons. These constituents can pose acute and chronic human health risks, with benzene being a known human carcinogen.

Leaking underground storage tanks can contaminate both the surrounding soil and the underlying groundwater. Of the two, groundwater contamination is much more difficult to cleanup and may impact drinking water wells. Most of the water supplies known to be affected have been replaced with alternate water supplies.

Historically, the Michigan Underground Storage Tank Financial Assurance (MUSTFA) Program was created in the late 1980s to assist owners with the cleanup of releases from underground storage tanks and the legislation established a 7/8 cent fee on refined petroleum products to fund the program. The fee collection rate was found to be insufficient for the large number of release sites. The MUSTFA Fund was declared insolvent, the program stopped accepting invoices from June 29, 1995, and bonds were sold to pay off invoices at hand. The bonds were paid off in 2003 from the generated fee.

Due to the large number of unaddressed releases in need of public cleanup funds, the fee was extended and the fund renamed the Refined Petroleum Fund. The July 2006 amendments to Part 215, Refined Petroleum Fund, of the NREPA, created the Refined Petroleum Fund Temporary Reimbursement Program (TRP). This program provided up to $64,000 to eligible former approved MUSTFA claimants who still had open releases that were high in risk to the public health and/or the environment. The TRP stopped accepting applications on August 29, 2007. Invoices were accepted until December 29, 2009, and approximately $30 million was expended. To date, no additional reimbursement programs have been proposed by the Legislature.

The cumulative closure of releases has increased from 4,530 in 1995 to 12,961 by the end of 2010 **(Exhibit 83)**. However, since 1997 the number of unaddressed releases from underground storage tanks has been slowly increasing from about 8,531 releases to almost 9,095 releases, due to new releases being discovered at a slightly faster rate than old ones are being cleaned up. In fact, more than 60 percent of confirmed releases are over 10 years old. It is estimated that about half of all open releases will require the use of state cleanup funds due to non-viable and recalcitrant owners/operators. The cost estimated to address only the orphan sites is estimated to exceed $1.5 billion. By contrast, since publication of the 2008 Biennial Report (from 2008 through 2010), only $63 million has been made available to the Leaking Underground Storage Tank Program for orphaned sites and approximately $30 million was expended on the TRP as described earlier, even though the refined petroleum fee collected $155 million in that same time period. The MDEQ is continuing internal re-prioritization of tasks as well as considering alternative deployment options for shrinking staff resources to adjust to decreasing funding levels.



State and federal rules require that owners/operators of underground storage tank systems comply with new federal technical standards (the state already had these requirements in place within prescribed setback areas for drinking water wells, and in delineated wellhead protection areas) and the state has opted to require secondary containment of all newly installed tank and piping systems.

Gasoline Additive Methyl Tertiary-butyl Ether

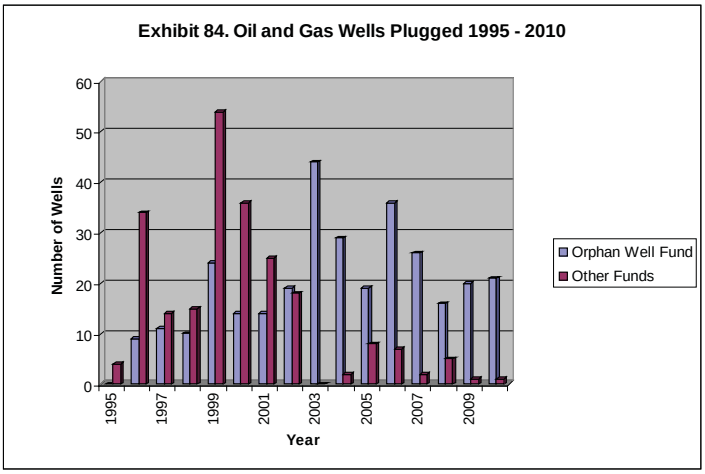
The gasoline additive methyl tertiary-butyl ether (MTBE) has been mandated in western and northeastern states to meet the reformulated gasoline requirements to help reduce carbon monoxide emissions and ozone formation. Since Michigan did not have as serious a problem as other states, it was never mandated by the USEPA to use reformulated gasoline. Concern about the potential health risk from ground water being contaminated by this additive has led to reexamination of its use by the USEPA.

Within Michigan, there exist residual amounts of MTBE in some gasoline supplied by pipelines that transfer fuel to Michigan from other states. For over 13 years, the MDEQ has required monitoring for MTBE at underground storage tank release sites. At sites where levels exceed safe concentrations, the MDEQ has taken action to address the contamination. Michigan instituted a ban on MTBE in June 2003. The acceptable level of MTBE in ground water at sites of contamination is 40 parts per billion (ppb), based on aesthetic criteria of taste and odor. The aesthetic criterion is significantly lower than the health-based criterion of 240 ppb. Consequently, an individual would taste or smell the MTBE before it posed a health risk.

Abandoned Oil and Gas Wells

Since commercial oil and gas production began in Michigan in 1925, over 57,000 oil and gas wells have been drilled. Approximately 19,000 of these wells

are in use today producing 20 percent of the natural gas and 3 percent of the oil used within the state. During 2008 through 2010 **(Exhibit 84),** 942 new wells were drilled.



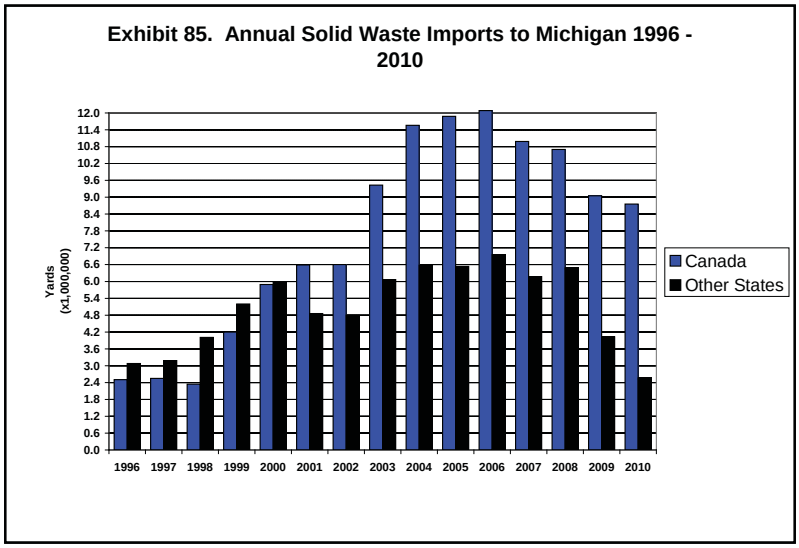
The MDEQ regulates oil and gas well drilling and production to conserve natural resources and to protect the environment, public health and safety, and property. Part of that effort is directed toward establishing optimal spacing of wells. During 2008 through 2010, the MDEQ made 242 determinations and issued 13 orders increasing the size of the tract assigned to a well. This allows fewer wells to develop an oil and gas reservoir and provides more flexibility for locating a well to protect the environment or property. The MDEQ also issued 4 orders establishing enhanced recovery projects, where gas or fluids are injected into a partially depleted reservoir, to increase the ultimate production. Three of those orders provided for injection of carbon dioxide, a beneficial use of this greenhouse gas.

When an oil and gas well is depleted, Michigan law requires the well owner to plug the well and restore the site. Abandoned wells that are not properly plugged can pose serious threats to the environment and public health and safety because they can serve as conduits for oil, gas, or brine to leak to the surface or into underground water supplies. Occasionally, a well owner dies or becomes insolvent and leaves an inactive well unplugged. The MDEQ plugs these orphan wells with funds provided from the state's Orphan Well Fund. The Orphan Well Fund was established in 1994 and is supported by taxes levied on oil and gas producers. In the case of an abandoned well that has a viable owner, the MDEQ may plug the well and clean up the site with money from the state's Environmental Response Fund or other sources, and pursue recovery of costs from the owner. The MDEQ has plugged 538 abandoned wells since 1995.

Solid Waste Imports

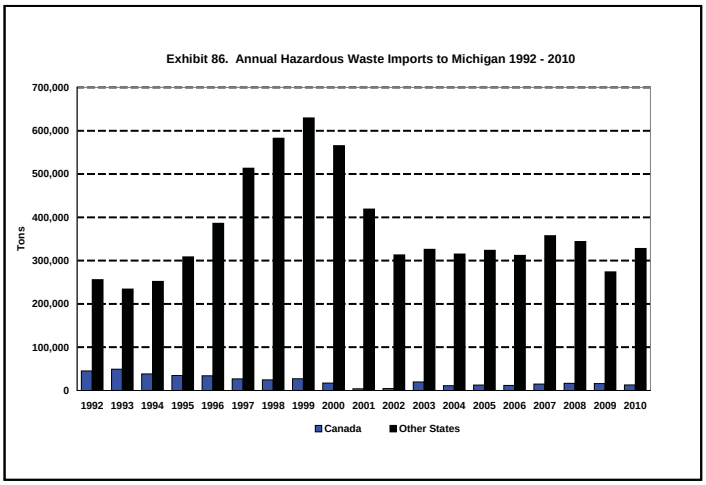
During the period 1995 – 2010, solid waste imports have ranged between 12.3 and 30.9 percent of the total amount of solid waste disposed of into Michigan landfills. During fiscal year 2010, the bulk of these imports, approximately 77 percent, came from Canada. Most of the remaining out-of-state waste comes into Michigan from nearby states such as Indiana, Illinois, Ohio, and Wisconsin as well as more distant states such as New Jersey and New York.

Solid waste imports decreased slightly in 2010 **(Exhibit 85),** but still made up approximately 25 percent of all waste disposed of in Michigan. (The overall amount of waste disposed in Michigan landfills from all sources also decreased.) Michigan still continues to be one of the largest importers of waste due to the relatively close proximity of Michigan landfills to other states and Canada, and the continuing inability of the state, due to federal interstate commerce rules, to restrict the import of waste from outside the state.

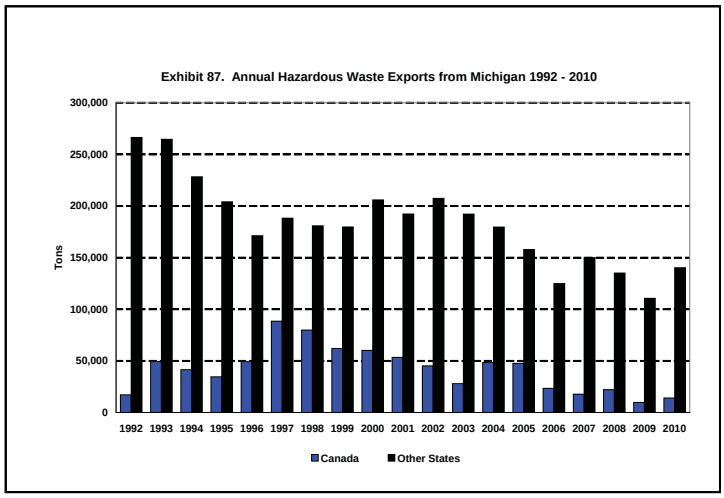


Hazardous Waste Imports and Exports

During the period from 1992 to 1999, the importation of hazardous waste to Michigan for disposal rose from approximately 301,000 tons per year to approximately 630,000 tons per year. Since then, it has declined to approximately 341,000 tons per year in 2010 **(Exhibit 86)**. The observed reduction in waste importation is due in part to the economy, the MDEQ's pushing for higher recycling rates, and better waste minimization practices by industry.



During the last eight years, the quantity of hazardous waste exported by Michigan has declined from approximately 253,000 tons per year in 2002 to approximately 154,000 tons per year in 2010 **(Exhibit 87)**. Comparing the import amounts to the export amounts, it can be seen that since 2002, the amount of hazardous waste imported has increased (approximately 318,000 tons per year in 2002 to approximately 341,000 tons per year in 2010), while the amount of waste exported has declined (approximately 253,000 tons per year in 2002 to approximately 154,000 tons per year in 2010). In 2010 Michigan remained a net importer of hazardous waste by approximately 187,000 tons per year.



Scrap Tires

Over 290 million scrap tires are generated each year in the U.S. Michigan contributes ten million scrap tires annually to that waste stream. In the past, millions of these scrap tires were abandoned or illegally stockpiled each year on vacant lands and inner-city back alleys. The illegal accumulations resulted in public health, environmental, and aesthetic problems for many communities, particularly from fires and mosquitoes.

In 1990 Michigan enacted legislation, which went into effect in 1991, to address the concerns related to scrap tires. The law was designed to help reduce illegal scrap tire accumulations and the public health and environmental concerns associated with these scrap tire waste piles. In 1991 it was estimated that more than 30 million scrap tires were stockpiled and more than 7.5 million additional scrap tires were being generated annually. Each year, the MDEQ discovers additional collection sites that are regulated by law and develops more accurate figures on scrap tire stockpile inventories. Most of the newly identified sites are not active and often not in a visible location. Consequently, the documented number of scrap tires stockpiled in identified noncompliant sites has increased since 1991. The number of tires reported as being removed also may change over time due to improved tracking and data quality methods.

State law required the MDEQ to make every effort to ensure that all abandoned scrap tires accumulated at collection sites prior to January 1, 1991, were cleaned up or collected by September 30, 2009. Additionally, the USEPA established a group of individuals representing various stakeholders to formulate a strategy for addressing scrap tires. The group established a recommended goal for mitigation of 65 percent of the number of stockpiled scrap tires in the U.S., using the 2003 amount as the base year, by 2012.

Whole motor vehicle tires have been prohibited from disposal in Michigan landfills since March 2004. While portions of tires (e.g., tire shreds) can still be disposed of in a landfill, the challenge continues to be promoting other management options, such as the use of scrap tires as raw materials for products or to produce energy.

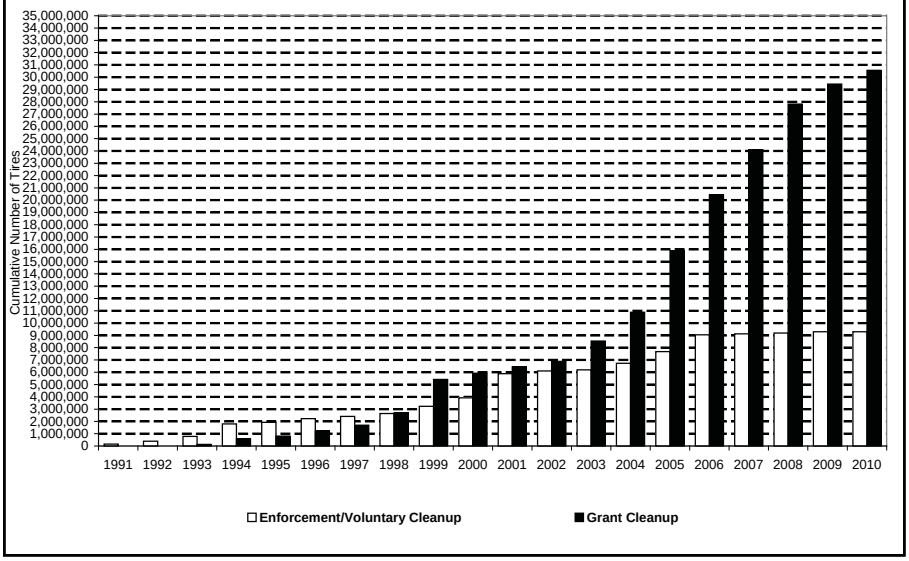
Much of the reduction in illegal stockpiles is due to Scrap Tire Cleanup Grants. Since the Legislature first appropriated funding in 1993, more than $27.2 million in public funds have cleaned up approximately 30.5 million passenger tire equivalents (PTEs) from the Michigan landscape. Approximately 9.3 million additional PTEs have been cleaned up through compliance and enforcement efforts. The cleanup of these public and privately owned properties has helped restore the environmental quality and economic value of more than 1,000 sites across the state. **Exhibit 88** shows the cumulative totals of tires removed by the MDEQ grant program and those removed voluntarily or through enforcement actions. As of November 2009, it is estimated that approximately 664,000 scrap tires remain in illegal stockpiles around the state, with about 388,000 of these being pre-1991 scrap tires.

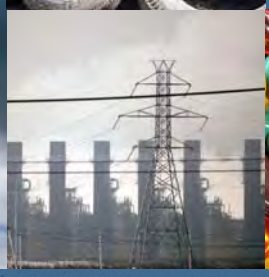
Behind the Scrap Tire Program's success to date are a continuing appropriately funded Scrap Tire Cleanup Grant Program to address abandoned scrap tires and those collected prior to the 1991 enactment of the legislation addressing scrap tires, and consistent enforcement of the statute, which helps to ensure a level playing field for those voluntarily meeting the statutory requirements.

The Scrap Tire Program is funded by a $1.50 tire disposal surcharge on each motor vehicle certificate of title that is collected by the Secretary of State pursuant to Section 806 of the Michigan Vehicle Code, 1949 PA 300, as amended, and deposited into the Scrap Tire Regulatory Fund. These fees provide money for cleanup, market development, and end-user grants and administration of the Program. Amendments to the Michigan Vehicle Code in December 2006 extended the sunset for the Program funding to December 31, 2012.

As part of the ongoing effort to continuously improve the Scrap Tire Program, the MDEQ has sought, and continues to seek, input from key stakeholders. The Scrap Tire Advisory Committee (STAC) meets periodically to advise the MDEQ on implementation of the Scrap Tire Program and to address challenges and opportunities in the Program as they arise.

Exhibit 88. Scrap Tire Cleanup Program 1991 - 2010





Emerging Contaminants of Concern

INTRODUCTION

The USEPA defines an emerging contaminant as "a chemical or material that is characterized by a perceived, potential or real threat to human health or the environment or a lack of health standards." A contaminant may also be emerging because a new source or a new pathway to humans has been discovered or a new method of detection or treatment technology has been developed.

Seven of these emerging contaminants are described in this section of the report. Three of these contaminants -- Pharmaceuticals and Personal Care Products, Polychlorinated Naphthalenes and Perfluorinated Compounds (previously discussed as Perfluooctane sulphites) -- were identified in the 2005 Biennial Report. Two others -- Ethylene Diamine Tetraacetic Acid and Nanomaterials – were first discussed in the 2008 Triennial Report. Two new emerging contaminants – Endocrine Disrupting Chemicals and n-Propyl-Bromide – are discussed for the first time in this Triennial Report.

IDENTIFIED CONTAMINANTS

Endocrine Disrupting Chemicals

As the name suggests, endocrine disrupting chemicals (EDCs) are substances that have an adverse effect on the endocrine system. The endocrine system consists of many glands that produce various hormones to regulate numerous physiological processes, including growth and reproduction. Most chemicals will alter any biological system, including the endocrine system, at high doses; currently, the concern is with chemicals that can impact the endocrine system at very low doses.

The USEPA has established the Endocrine Disruptor Screening Program (EDSP) to determine if specific chemicals have the ability to mimic the effects of male and female hormones or impact the thyroid system. Effects on humans, fish, and wildlife are being evaluated. The majority of the chemicals currently being studied are pesticides and the inert ingredients of pesticide formulations (see **http://www.epa.gov/endo/** for progress updates) but not all pesticides are endocrine disruptors and not all endocrine disruptors are pesticides. Perchlorate, mentioned in the 2008 Triennial Report, is a known endocrine disruptor, as are some industrial chemicals such as polychlorinated biphenyls, and some surfactants such as nonylphenol ethoxylate. Bisphenol A and phthalates, compounds frequently used as plasticizers, are suspected to be endocrine disruptors.

There is limited scientific understanding of EDCs at this time. It is expected that the EDSP will improve the regulatory decision-making process as it pertains to EDCs.

Pharmaceuticals and Personal Care Products (PPCPs)

PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter pharmaceutical drugs, veterinary drugs, fragrances, and cosmetics. PPCPs refer in general, to any product used by individuals for personal health or cosmetic reasons or used by agribusiness to enhance growth or health of livestock. A number of PPCPs act as Endocrine Disrupting Chemicals (see previous section). Since the 1970s, low levels of PPCPs have been detected in our nation's surface water and groundwater, which are the sources for our drinking water. More recent studies have confirmed the presence of PPCPs in some Michigan waters.

PPCPs have been found at trace levels in some drinking water supplies throughout the country, including Michigan. Detection of these compounds at very low levels (parts per trillion) have not been

considered to be a human health concern, although studies are ongoing.

While there are no known health risks to people at the low levels detected, the presence of PPCP pollution is an emerging concern because medicines are produced and prescribed in increasing volumes each year. Absent improvements in disposal and treatment methods, concentrations of PPCPs in the environment are likely to increase.

PPCPs enter our environment, and particularly our water systems, when drugs, fragrances, and cosmetics are either disposed of or excreted after use. One of the primary pathways for PPCPs to enter our drinking water supplies is through waste water treatment plant discharges. Most waste water and drinking water treatment systems are not currently equipped with technologies that effectively remove PPCPs. The USEPA and other organizations and agencies are currently studying this important issue.

Wastewater and drinking water treatment plants typically do not perform analyses for PPCPs. Current research suggests that granular activated carbon, powdered activated carbon, and ozone may be effective treatment processes in removing many PPCPs from the water. These treatment processes currently are in use by some drinking water treatment plants in Michigan.

Various county, state, and national organizations have initiated pharmaceutical take back programs in Michigan to discourage the continued flushing of unused medications as a means of disposal. Additional information regarding the many issues surrounding PPCPs as an environmental contaminant may be found on the USEPA Web site **(http://www.epa.gov/ppcp/)**.

Perfluorinated Compounds

Perfluorinated compounds (PFCs) represent a family of nearly 200 man-made surface active chemical compounds that are included in hundreds of commercial product formulations because of their ability to impart stain, water, and flame resistance to the products. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are the most common PFCs. Because of their widespread detection in humans, wildlife and the environment, production of PFCs in the U.S. has phased out since 2002 and alternative substances have been substituted in their place.

PFCs do not occur naturally in the environment and once they have been released, they are highly resistant to degradation and are considered persistent contaminants. PFCs have recently been detected in Michigan groundwater and in several species of aquatic and terrestrial wildlife. Researchers throughout the Great Lakes region have determined a bioconcentration factor of 1,000 for PFOS and a biomagnification factor of 10 to 20, meaning that levels of PFOS can increase up the food chain.

It remains unclear how the general population may be exposed to PFCs, although ingestion of contaminated food and drinking water have been suggested. The recent nomination for addition of PFCs to the USEPA's Unregulated Contaminant Monitoring Program will assist in determining their occurrence and levels in the public drinking water supply throughout the state. Efforts are underway to determine whether there is industry in Michigan that would manufacture, use or dispose of these compounds in sufficient quantity to require tracking or regulation.

Polychlorinated Naphthalenes

Polychlorinated naphthalenes (PCNs) are a group of compounds that are used as cutting oils; engine oil additives; insulation; water repellents; and some wood, paper, and fabric preservatives. PCNs are persistent and tend to bioaccumulate in the environment. PCNs have been found in the Arctic, urban air, wildlife, and human tissues including breast milk. Consumption of contaminated fish is considered an important route of exposure of humans to PCNs. In a 2000 study, PCNs were measured in fish whole body and fillets collected from Michigan waters, including the Great Lakes, during 1996 to 1997. PCNs were found in all the fish analyzed. Concentrations of total PCNs in fish ranged from 19 to 31,400 picograms per gram (wet weight). In a joint study involving the MDEQ, Yokohama (Japan) National University, and MSU, sediment from the upper Detroit and lower Rouge Rivers in southeast Michigan, and sediments from a nonpoint source location in Lake Michigan were

analyzed. PCNs were found in all sediments from all locations with their concentrations ranging from 0.08 to 190 nanograms per gram. PCNs recently were added to the list of parameters monitored as part of the state/federal Chinook and Coho Salmon Trend Monitoring Program, and the USEPA's Whole Fish Trend Monitoring Program.

Nanomaterials

Nanoscale technology involves engineering materials and devices from elements such as carbon, iron, silver, titanium, and zinc into various structures (rods, tubes, spheres) that are scaled down to 100 nanometers or less in one or more dimensions. Due to their nanoscale size, these nanomaterials possess unique chemical, biological, and physical properties as compared to larger particles of the same material composition. These unique properties, in turn, have made nanomaterials increasingly attractive for a wide range of scientific, environmental, industrial, and medical applications. Currently, there are more than 1,300 manufacturer-identified, nanotechnology-based products in consumer marketplace categories that include health and fitness, home and garden, food and beverage, automotive, electronics, and computers.

As is often the case with any new technology, the public health and environmental effects of nanomaterials remain mostly unknown. It is generally believed that the surface area and surface properties (the physics) of nanomaterials represent a greater indicator of their potential toxicity than does their composition (the chemistry). Nanoparticles, like other ultrafine particulates, are more easily transportable deep into the lung. Inhalation exposure is most likely to occur in the occupational setting. Environmental inhalation exposure is uncertain, but expected to be low because most products currently in use contain nanomaterials embedded in a solid matrix.

Little is known about the short- or long-term effects of nanomaterials on aquatic and terrestrial ecosystems as techniques for identifying and quantifying these substances in environmental media remain unavailable. While there is very limited information regarding the environmental fate and transport of these substances, nanomaterials are expected to persist in the environment, a property that could allow them to be transported over great distances. Therefore, the entire nanomaterial "life cycle" poses multi-media issues. It is predicted that most significant environmental releases of nanomaterials will occur during their disposal and recycling. The effect of combustion on nanomaterials is unknown.

Nanomaterial production levels are currently estimated to be in the thousands of tons per year and are increasing. Currently there is no state or federal tracking or regulation of the manufacture or use of nanomaterials, although the USEPA requires that nanomaterials that make claims of antimicrobial properties be registered under the Federal Insecticide, Fungicide, and Rodenticide Act. The USEPA has also established a voluntary program, the Nanoscale Materials Stewardship Program, to collect data on environmental and human health risks and benefits. Regulation of nanomaterials is quite problematic because pollutants are generally tracked and regulated by mass, which is not a practical measure for nanomaterials. It is unclear how introduction of nanomaterials into the environment could be controlled or measured. This, coupled with their unknown potential for toxicity, underscores the importance of toxicity testing and regulatory goals for nanomaterials.

Ethylene Diamine Tetraacetic Acid

Ethylene diamine tetraacetic acid (EDTA) is a chelating agent that binds with metal ions to form metal-EDTA complexes. EDTA is used in various applications including detergents, water treatment, pulp and paper industry, personal care products, food industry, metal cleaning, and in medical treatment for heavy metal poisoning.

The environmental concern for EDTA is its ability to form complexes with metals which makes them more water soluble. EDTA also has the ability to sequentially exchange cations depending on available metals and relative affinity of EDTA for each. This creates the potential for movement of various metals in the groundwater that may result in contamination of drinking water wells or impacts to surface water from venting groundwater. At several Michigan sites, EDTA has entered groundwater and mobilized a variety of metals that are normally bound to soil or aquifer material. Metals that have been detected at levels of potential concern in drinking water wells, associated with release of EDTA to groundwater, include cobalt, iron, lead, manganese, and nickel. EDTA does not readily degrade in the groundwater environment.

n-Propyl-Bromide

n-Propyl-bromide (n-PB), also known as 1-bromoproane, is a solvent that is currently being used to replace ozone-depleting chlorofluorocarbons (such as trichloroethane and some Freons) and as a replacement for perchloroethylene. This solvent may be used where there is a need to dissolve fats, waxes or resins and can be used in degreasing and spray adhesives. n-PB is used in the electronics industry for degreasing circuit boards and in the drycleaning industry as a replacement for perchloroethylene. The use of n-PB is increasing 10-15% each year and several drycleaners in Michigan are currently using n-PB.

Studies indicate that n-PB may be more toxic than perchloroethylene although some companies are marketing it as a safe and "green" alternative. There are two cases in the United States that have been published documenting neurologic illness associated with exposure to n-PB in occupational settings. Extensive animal data and limited human data have demonstrated that n-PB can harm the reproductive system and the nervous system. The primary route of exposure is through inhalation although n-PB can also enter the body through the skin. It is unclear at this time how the general population may be at risk to n-PB exposures.

In 2007 the European Community and California required n-PB to be labeled as a reproductive hazard. In 2009 the National Toxicology Program drafted a report that found clear evidence of carcinogenicity based on a two-year inhalation rodent bioassay for n-PB. The USEPA has already not allowed the use of n-PB for use in adhesives and aerosols. Ongoing research will be monitored to assess the current applications of n-PB.

Copies of this report may be obtained free of charge by either printing it in Adobe Reader Portable Document Format from the Internet at: www.michigan.gov/deq or by contacting the Office of Environmental Assistance of the Michigan Departments of Environmental Quality at 517-241-0490.

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