THIRA Hazard Analysis

August 2012 DRAFT

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THIRA Hazard Analysis
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Steps 1 and 2 (beginning)

Michigan has had a very respectable record of planning for all foreseeable threats and hazards. This most recent process, the Threat and Hazard Identification and Risk Assessment (THIRA), begins with information from the most recent edition of the Michigan Hazard Analysis (June 2012) and Michigan Hazard Mitigation Plan (March 2011). This information is used to identify and contextualize the many threats and hazards that Michigan faces (steps one and two of the THIRA process as described in CPG 201, "Threat and Hazard Identification and Risk Assessment Guide"). More than 30 types of hazards have been identified (as required by THIRA, Step 1) and placed into context (as required by THIRA, Step 2). **For detailed listings of historical events and threats for each of the hazards described in this document, please refer to the 2012 edition of the Michigan Hazard Analysis.** That document also provides extensive listings of programs and initiatives related to Michigan's hazards, as well as additional information about Michigan's infrastructure and current circumstances. In order to keep this THIRA document limited to a manageable size, those types of information have generally not been included here. Since those documents are publicly available at the Michigan State Police Publications Web Site, this THIRA document instead focuses upon an overview and context that leads to the narrowing of Michigan's threats and hazards down to a more limited set of more specific ones, from which a set of scenarios were derived in order to help assess Michigan's capabilities and resource gaps.

The Michigan State Police Emergency Management and Homeland Security Publications web site address is:
http://www.michigan.gov/msp/0,4643,7-123-1593_3507-14743--,00.html

To begin with, this document presents a general profile of Michigan's lands, cities, population, and selected economic features. It then systematically presents an overview of all known hazards and threats that could cause an emergency or disaster situation to affect Michigan.

This draft document is being made available to all agencies and persons within the State of Michigan (and beyond), as part of the THIRA requirement to inform and involve the whole community. Any ideas, comments, corrections, or other feedback may be sent to Mike Sobocinski by e-mail at sobocinskim@michigan.gov, by fax at (517) 333-4987, or by telephone at (517) 336-2053.

BRIEF PROFILE OF THE STATE OF MICHIGAN

Michigan has a land area of 58,216 square miles and a population of about 9.9 million persons. Its 83 counties include numerous urbanized areas, including Metropolitan Detroit. Most Michigan residents live within these urbanized areas, which are mostly located in the southern portion of the State. Michigan is completely covered by local, incorporated government entities—every inch of the State is part of a township, city, or village, and all residents of these minor civil divisions are also residents within one of Michigan's counties. This constitutes a general political and taxation structure for Michigan's many communities, although additional districts overlay these areas as well, such as school districts and congressional districts.

Located in the midst of four of the Great Lakes, Michigan's fundamental geographic feature is its division into Lower and Upper Peninsulas. The Lower Peninsula encompasses approximately 70% of Michigan's total land area, and the Upper Peninsula accounts for the other 30%. The two peninsulas are divided by the Straits of Mackinac, which allow Lake Michigan to drain into Lake Huron. The southern half of the Lower Peninsula has a level to gently rolling surface, with hills rising to elevations between 1,000 and 1,200 feet. The northern half of the Lower Peninsula has higher elevations, with hilly belts of glacial origin reaching elevations of 1,200 to 1,700 feet. The eastern half of the Upper Peninsula is fairly level and often swampy. The western half is higher and more rugged. Michigan has borders on four of the five Great Lakes and has the longest shoreline of any inland state—about 3,200 miles. Michigan also has over 10,000 inland lakes and 36,000 miles of streams.

Michigan has a diversified economy based on agriculture, manufacturing, tourism, services, and professional trades. More automobiles and trucks are produced in Michigan than in any other state. Michigan is the nation's top producer of office furniture, a major source of information technology and software, and a national leader in machine tools, chemicals, and plastics. Michigan is also one of the nation's leading agricultural producers, consistently ranking number one in several product categories.

Michigan has a well-developed, multi-modal transportation system that supports the state's diversified economic activities. The highway system consists of a network of interstate, federal, state, and local routes that connect Michigan communities to major metropolitan areas and economic markets around the country. Michigan has 19 airports that offer commercial passenger jet service to major domestic and international destinations. Freight railroad lines link Detroit and other metropolitan areas with Chicago and other major manufacturing and business centers in the United States and Canada. Michigan also offers 40 Great Lakes ports to facilitate waterborne commerce. Each year, Michigan's transportation system helps move 240 million tons of cargo by truck, rail, air, and ship.

Due to its geography and location, Michigan will always be threatened by natural hazards. The State of Michigan and local governments must always be prepared to manage those types of events when they occur. Due to the frequency of occurrence and the historical vulnerability of the population to those hazards, most communities should probably rate natural hazards as their primary emergency management concern. The principal natural hazard threats to Michigan are tornadoes, floods, thunderstorm winds and lightning, severe winter weather, wildfires, and extreme temperatures.

Michigan's principal technological hazard threats include infrastructure failures, hazardous material incidents, structural fires, major transportation accidents, and petroleum and natural gas pipeline accidents. (It should be noted that many of these threats are a direct or indirect result of the state's position as a major national and international manufacturing and business center. The technological threats present in Michigan are not unlike those present in other industrialized states of similar size and character.)

Michigan's principal human-related hazards include public health emergencies, terrorism and similar criminal activities (including cyber-attacks), and civil disturbances.

State of Michigan Profile Map

Michigan has a diverse population, a diversified economy, and a broad array of physical environments, community types, and living arrangements. A new map of Michigan has been created specifically to explain some of this diversity for readers who need to quickly estimate the potential impacts of a disaster event within some area of the state. It appears on the next page.

Many maps of Michigan (or the United States as a whole) do not include relevant information about neighboring lands, so this brief profile of Michigan will first make mention of the fact that it is adjacent to the states of Ohio, Indiana, and Wisconsin, as well as the Canadian province of Ontario. Michigan's area includes substantial portions of four of the Great Lakes (Superior, Michigan, Huron, and Erie), as well as smaller Lake St. Clair (northeast of Detroit). Despite the prominence of Great Lake shorelines in Michigan's geographic situation, it is extensively connected with its three neighboring states, and with the Canadian province of Ontario. These connections include physical highways, marine ferries and shipping traffic, critical infrastructure (e.g. pipelines, power lines), and communication networks (phone lines, cellular towers, broadcast signals, the internet).

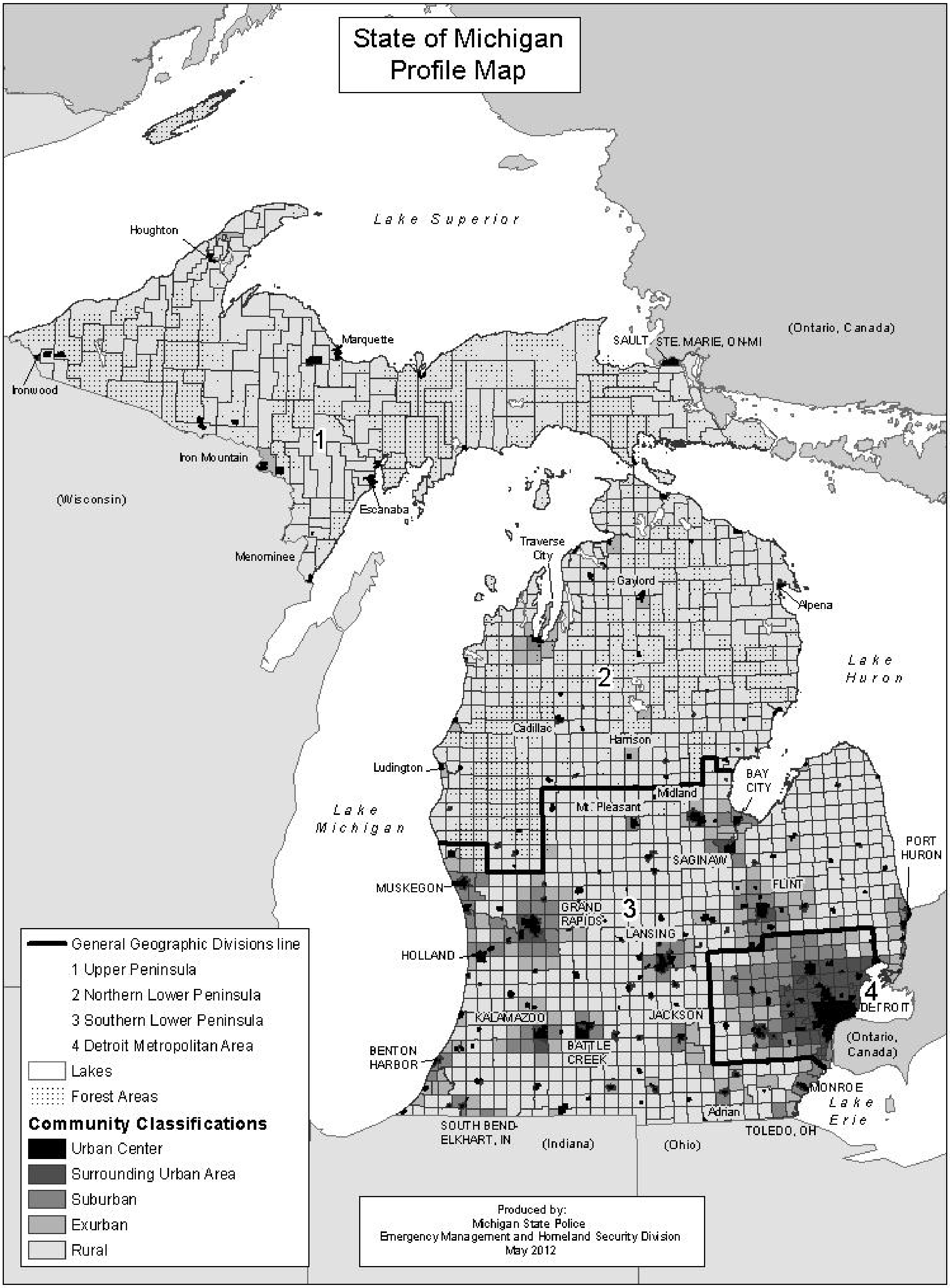
The new Michigan Profile Map presents the State of Michigan in a manner that emphasizes its large number of local governments, and provides basic information about how most of its people, industry, and resources are geographically distributed. The next few pages will provide an explanation of the information shown on this map, with suggestions about how to interpret and use the information in assessing risks at the state and local levels, as well as emergency management concerns and needs.

The Michigan Profile Map is primarily intended for use in emergency management assessments, and an analysis of various kinds of hazards—natural, technological, and human-related. No single map can contain all the information that is relevant for these tasks, so the Michigan Profile Map should merely serve as a starting point, to be supplemented by the many other specialized maps that have been made by Michigan's state government departments (or that are available from other sources).

The Michigan Profile Map was designed to present a selective overview of the general characteristics of Michigan's present settlement, land use, and industrial patterns. Since many of these patterns correspond with differences in climate and vegetation, it was deemed useful to designate four general geographic divisions within the state:

Geographic Division	Number of Counties	Population (2010 census)	Percent of State Total
1. The Upper Peninsula	15	311,361	3.2%
2. Northern Lower Peninsula	29	717,977	7.3%
3. Southern Lower Peninsula	34	4,464,620	45.2%
4. Metropolitan Detroit	5	4,389,682	44.4%
STATE TOTAL	83	9,883,640	

It must be emphasized that these divisions are not meant to correspond with existing planning regions, emergency management districts, Urban Area Security Initiative areas, or census economic areas. The "Community Classification" categories on the map need to be thoroughly explained, in order to fully understand how the map was designed (and how the general geographic divisions were defined). This explanation follows the map on the next page. It is worth noting at the outset that some communities may include areas that better resemble the description for a different category (e.g. a large park may have a rural character within a large central city), and this map doesn't attempt to provide such detail. These classifications are meant only to provide an overview of the State, rather than to precisely indicate local land use patterns.


State of Michigan
Profile Map
Lake Superior
Houghton
Marquette
Ironwood
SAULT STE. MARIE, ON-MI
(Ontario, Canada)
1
Iron Mountain
(Wisconsin)
Escanaba
Menominee
Traverse City
Gaylord
Alpena
Lake Huron
2
Cadillac
Harrison
Ludington
Midland
BAY CITY
Mt. Pleasant
Lake Michigan
SAGINAW
PORT HURON
FLINT
MUSKEGON
GRAND RAPIDS
3
LANSING
HOLLAND
4
DETROIT
KALAMAZOO
JACKSON
BATTLE CREEK
BENTON HARBOR
(Ontario, Canada)
MONROE
Lake Erie
Adrian
SOUTH BEND-ELKHART, IN
(Indiana)
(Ohio)
TOLEDO, OH
General Geographic Divisions line
1 Upper Peninsula
2 Northern Lower Peninsula
3 Southern Lower Peninsula
4 Detroit Metropolitan Area
Lakes
Forest Areas
Community Classifications
Urban Center
Surrounding Urban Area
Suburban
Exurban
Rural
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
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Urban Centers

Michigan has many cities located across its lands, from the very small (Omer, population 313) to the very large (Detroit, population 713,777), and many of these date back to the 1800s as official corporate entities. These historical cities appear in black on the map, representing areas that tend to have the greatest densities in population, infrastructure, and the built environment. Only cities have been included in this classification (not villages or townships), but not all cities have been designated as urban centers. Because of the different forms that urban development took in the post-depression, post-WWII period in which automobile accommodations had become the norm, only cities that had incorporated before the end of World War II were included in this category.

Most of these cities contain a traditional downtown area that has long attracted people from outlying areas to engage in commercial or recreational activities, to meet with government representatives, to visit hospitals, or to meet with others in other social, civic, or religious activities. Some of the most historically significant structures in Michigan are located within these cities, and they also contain a vast amount of Michigan's vital government facilities, hospitals, police and military resources, large educational institutions, and major industrial firms. Some of these "urban center" cities contain relatively small downtowns, in cases where they function as "suburbs" near a larger central city, but they have still been classified here as urban centers because their initial formation conformed to a particular style of development that was predominant before World War II. For example, the streets tended to be laid out in the form of a grid, urban designs tended to be focused upon regular access to a thriving central downtown district, and much less accommodation was made for the use of private automobiles by residents.

Dense development patterns and an emphasis upon efficiency characterized most urban center construction projects. Historically, it was to the advantage of most residents and businesses to locate as close as possible to shared transportation and utility resources, and these were designed to accommodate the needs of the persons using them at their time of construction. Many of these designs (for example, combined sewer systems that handle both sanitary and storm drainage functions) are still being changed even today, to accommodate the needs of a larger population that is more productive, enjoys a higher standard of living, and uses more energy to power its higher-technology devices, buildings, and industries. The systems present in these urban centers tend to be the most complex found in the state, and although the capacity to repair most breakdowns in these systems is usually readily available within the larger cities, the complexity and corollary impacts of such breakdowns are also likely to be greater. For example, if a power failure causes traffic signals to fail, this will have a smaller impact upon roadway congestion in a rural area than it would in a central city. Despite the great population density within large urban centers, these communities tend to have a large number of roadways available for use, and the traditional "grid" pattern of street design has long offered a huge number of alternative routes by which people could evacuate an area by car (for short distances).

Surrounding Urban Areas

Since World War II, most of the urban functions that had historically been contained within the urban centers quickly grew beyond the boundaries of those cities. It used to be that the costs of transportation, construction, and urban utilities had required most developments to take place within a city. After World War II, the widespread availability of affordable automobiles, and an increased capacity to affordably build and supply utilities to outlying areas, meant that new projects of all kinds could be built in many possible locations beyond the existing central cities. For many businesses and residents, it still made sense to live near the central city, but many decided not to stay within the political boundaries of the existing cities. A great many new cities incorporated near the older central cities after World War II, typically by converting part or all of an existing township into a city, through a special voting process. Some recent geography texts refer to these areas as "the outer city" (with central cities termed as "the inner city").

Even though some of these new cities (e.g. Southfield) grew to include impressive high-rise office buildings and major expressway interchanges, they still tend to be distinguished from the older urban centers by having a lower average density of population, more widely spaced and modern buildings and infrastructure, and transportation arrangements that are focused upon the predominance of private automobiles. In these locations, it is harder for a resident to choose a residence that allows convenient access to public transit, places of work, hospitals, government offices, and shopping areas unless a car is used to access them. For some types of hazards, the less dense design of these cities is very helpful.

For example, contagious illness is much easier to control when people do not need to use public transit systems, and do not live in very crowded residential patterns.

The function of these areas within a broader metropolitan area becomes clearer when looking at the overall land development patterns, as shown on the Michigan Profile Map, rather than focusing only upon the political boundaries between adjacent cities. Whereas large cities in the 19th Century tended to expand through the annexation of adjacent lands, and to contain numerous wards (districts) within them, the 20th Century tended to instead favor urban expansion across a contiguous array of politically (and fiscally) independent cities. On the positive side, this development pattern provided a greater amount of political control by residents over their local governments. On the negative side, certain parts of each urban area tended to become increasingly worse off in fiscal terms, since local taxes were no longer shared throughout an entire urban area. Similarly, various types of infrastructure and services sometimes became increasingly difficult to coordinate across municipal boundaries, and the functions and services provided by urban centers were sometimes not adequately compensated for by users who lived outside of the providing city. Neighboring cities would often spend money on redundant services and facilities, rather than pooling their funds together into combined systems that could benefit from an economy of scale. However, from an emergency management perspective, these redundancies of services and infrastructure could sometimes result in increased local resilience—the seeming inefficiencies of duplicate systems and services could sometimes pay off when an infrastructure breakdown in one city could be offset by the continued functioning of the infrastructure in an adjacent city.

Any city known to have incorporated after World War II has been included in the “surrounding urban area” category instead of being classified as part of an urban center. However, some heavily populated townships have also been classified in this category, as urban. (No effort has been made in these classifications to try to preserve the often contradictory and overly simplistic ideas that many persons still have about the concept of a “suburb”—there is often little practical difference in the character of communities that did or did not vote to officially become cities.) Any Michigan township with a population density of at least 1400 persons per square mile of land area has been classified within this category, as “urban.” These communities (whether townships or cities) often may not contain traditional downtown districts, but frequently do have specialized areas for shopping (shopping malls), conducting business (office complexes), and manufacturing products (industrial parks). Although these highly separated land uses may seem inconvenient from the perspective of transportation access, economic efficiency, and design regulations, there are often emergency management benefits realized from this design, in that a disaster in one location (e.g. an industrial explosion or hazardous materials spill) might not affect any of the other locations (or types of activities associated with them).

In terms of evacuation potential, most of these cities have very few local roads that were laid out in the traditional “grid” pattern, but there still tend to be a limited number of alternative routes available. Many neighborhoods might seem maze-like at first, but may allow traffic to eventually wind its way to the other side. Many of these cities (and urban townships) do have a moderate number of “collector” roads that can provide some congestion relief for traffic.

Suburban Areas

In this classification system, a suburb indicates only a township of moderate development and population density, located near an urban center. No cities are included in this classification. Townships with a population density between 277 and 1399 persons per square mile of land area have generally been given this classification as “suburban.”

Many of these suburban areas are charter townships, and the main distinctions between a charter township and a city involve a cap on the township’s tax rate, a charter township’s acceptance of a pre-defined charter, and a self-imposed set of restrictions upon the types and densities of land uses permitted in the township. Although some of these land use restrictions might seem at first to be artificial and arbitrary to an observer, in most cases the restrictions are roughly in accordance with the level of development that one would ordinarily expect to occur in the outlying and newest districts of a city, anyway. Thus, although one tends not to see a skyscraper in the midst of a low-density residential neighborhood, there are many cases in which new factories or warehousing operations are built on the outskirts, especially along rivers or railroad tracks that may be vital to these facilities. Indeed, one of the main trends of the 20th

Century that continues to this day is the increased economic feasibility of building many types of projects in outlying locations, and some suburban areas contain important industrial, office, shopping, and recreational facilities.

For emergency management purposes, the main distinction between the previous "urban" classification and the "suburban" one is that a lesser density of development will be typical in the suburban areas. A disaster in a suburban area will tend to affect fewer people than a comparable disaster within an urban area. However, due to the limited revenue streams for developing the suburban area's infrastructure, suburban areas tend to be more vulnerable to transportation back-ups, to the point of making some areas excessively difficult to evacuate quickly. Few, if any, suburban neighborhood streets are laid out in "grid" fashion, and many neighborhoods may not provide any way for vehicles to cross through them to main roads on their other side. Expressway ramps and bridges over rivers might be far too few in number and capacity, leading to excessive traffic backups on area expressway routes (and the few main streets that connect with it), if one of those ramps or bridges becomes unusable. The community's main (arterial) roads are often just slightly revamped versions of the original "country roads" that existed before all the new suburban growth. Often, the addition of occasional turn lanes have been the only upgrades that have taken place during the community's recent decades of development, and these two-lane roads would quickly become clogged with traffic when an accident occurs or an evacuation is attempted.

SPECIAL NOTE: Every inch of Michigan's land area is not only considered to be a part of one of Michigan's 83 counties, but is also considered to be part of a "minor civil division" (a city, village, or township). The United States census tends to treat villages more like special taxation areas within townships, rather than as small cities, but Michigan also has a great number of small communities that are neither villages nor cities. In this document, these communities will be called "towns," with the understanding that this word has a distinctive meaning to refer to the communities located within Michigan's townships. The Michigan Profile Map shows the boundaries of all of these many townships, but does not show all the small villages and "towns." Most rural areas include such "towns," and although some are mere hamlets, barely distinguished from the rural areas around them, others may be quite sizeable. Such "towns" tend to include either their own post office or school district, and thus may be called by a completely different name than the surrounding township (or may cross over the borders of adjacent townships).

Exurban Areas

The term "exurb" refers to a fairly low-density township whose residents commute regularly to a larger area for many or most of their needs. Suburbs tend to provide a moderate number of urban amenities, including employment, to their residents, but exurbs tend merely to provide residential housing areas and a few minimal services and provisions. In many cases, basic groceries are obtained from a traditional village, "town," or small city that had existed before a commuter population had moved into the area. Exurbs do not contain enough employment opportunities for the residents who live there, and so in addition to residents who choose to commute long distances to work (or who are able to "telecommute"), exurbs may also be home to a large proportion of retirees. Exurbs are generally low in population and development density (except for the central villages or small urban centers that tend to serve them). Various services (including health care) tend to be very limited in these areas.

Townships with a population density between 139 and 276 persons per square mile of land area have generally been classified as exurbs. Some exceptions were granted, such as Breitung Township (near Iron Mountain), in which part of the very large township (67.7 square miles of land area) functioned as a suburb, while another part was quite rural. Another exception was made for the City of Mackinac Island, since its overall population density was rural (it has one of the smallest populations among Michigan cities) and it is generally only accessible by ferry or airplane. Although most suburbs exist on the farthest fringes of urban areas, a few additional types of areas also received this classification, such as communities that are not connected with cities, used for resorts, retirement living, or seasonal homes. An example is Houghton Lake, in Roscommon County, which has a "town" around the lake's shores, but is not actually a city. Some communities were designated as exurbs merely because its center was a "town" or village rather than a city. The United States census tends to treat villages as a special taxation zone within a township, and the Michigan Profile Map was predominantly based upon census data.

Rural Areas

Most of Michigan has been classified as "rural" on the Michigan Profile Map. This does not in any way indicate that these areas are unimportant! In addition, it must be noted that a great number of villages and "towns" exist throughout these rural areas, but are not marked on the map, due to their comparatively small sizes. (Please review the SPECIAL NOTE on the previous page, for more information about the meaning of "town" in this document.)

Some of Michigan's most productive, famous, and important industries are found throughout its rural areas. For example, extraction industries have been quite important to Michigan, whether the mining that had once caused the Western Upper Peninsula to thrive, or the petroleum and natural gas deposits that are increasingly in demand worldwide, or even just Michigan's abundant supplies of fresh water. Logging, farming, the cattle industry, and facilities for renewable energy (e.g. wind farms or hydroelectric dams) are other important facilities and infrastructure that exist in Michigan's rural areas. Due to the limitations inherent in the use of only a single statewide map, these types of production were not represented graphically. However, more information is presented later in this document, as well as in the passages that follow, describing Michigan's general geographic divisions.

With this in mind, the following paragraphs provide general descriptions of each area's characteristics that were considered to be most relevant for an analysis of risks and hazard impacts. Where information is provided about population centers, the 2010 census has been the source of information used. The "urban areas" designated by the U.S. Census have tended to be presented here as the most relevant means of conveying information about most of Michigan's populated areas, since they are defined in terms of actual land use rather than mere political boundaries. Some of the official urban areas have already been classified as part of a larger metropolitan area (e.g. Ann Arbor), and that status will be clarified in the descriptions that follow (along with alternative ways of conceptualizing and classifying these areas).

1. The Upper Peninsula

As shown on the Michigan Profile Map, most of the Upper Peninsula is covered with forest lands, and most inhabitants live in small cities, villages, and towns in the midst of these forests. These communities are often very old. The Upper Peninsula used to have a huge timber and mining industry, during the 19th Century, and had lost most of its population during the 20th Century after these industries had declined in size. (In 1910, Calumet-Laurium used to be one of Michigan's most populous communities—Houghton County had a population of 88,008 and Calumet Township's population of 32,845 was comparable to that of Jackson, Kalamazoo, or Lansing at the time, but today the township only has 6,489 residents.) The Upper Peninsula's historic mining industry makes certain portions of it more vulnerable than the rest of the State to a ground subsidence hazard.

The Upper Peninsula is predominantly rural, and every one of its counties has a population density that is well below the State's average. Because the area developed during the 1800s, most of its cities have areas that are very old and date from that time period. The Upper Peninsula is adjacent to Wisconsin and Ontario, Canada, and some cities are part of urban areas that cross over state (and national) borders. These cross-border urban areas include Sault Ste. Marie (Ontario and Michigan), Iron Mountain-Kingsford (Michigan and Wisconsin), and Marinette-Menominee (Wisconsin and Michigan).

Taking into account the broader metropolitan areas, then, the city of Sault Ste. Marie might be considered the most significant for the Upper Peninsula. Although the Michigan portion of this area has only about 14,000 people, the much larger Canadian city of Sault Ste. Marie dominates an urban area of nearly 100,000 total population. All marine traffic going from Lake Huron to Lake Superior passes through the Soo Locks, in this area. This includes marine traffic traveling to and from major ports such as Duluth (Minnesota) and Thunder Bay (Ontario, Canada). The only Interstate Highway in the Upper Peninsula (I-75) goes through this city and crosses the International Bridge into Canada. The Mackinac Bridge is another vital element of Michigan's infrastructure, providing a highway connection between Michigan's Upper Peninsula and its Lower Peninsula. Several high-quality surface highways cross the Upper Peninsula and provide the main routes for its truck traffic. Along with freight trains, these highways pass through large areas of State and National Forest Lands, which means that wildfires are one of the most significant threats in the area.

The Upper Peninsula's urban areas, ranked by population size according to the 2010 U.S. census, are:

(Sault Ste. Marie Ontario-MI)	92,914	(2011 Canadian statistics plus 2010 U.S. census)
Marquette	26,946	
Escanaba	20,850	
(Marinette-Menominee, WI-MI)	19,431	
Iron Mountain-Kingsford	19,228	
Houghton	15,452	
Sault Ste. Marie (Michigan part only)	14,144	(within the city, rather than in the defined Urban Area)
Ishpeming-Negaunee	12,301	(in Marquette County)
Laurium-Calumet	7,325	(in Houghton County)
Ironwood	7,134	(in Gogebic County)
Kinross	6,555	(in Chippewa County)
Manistique	3,482	(in Manistique County)
Newberry	3,225	(in Luce County)
Iron River	3,208	(in Iron County)
Munising	2,972	(Alger County)
St. Ignace	2,531	(Mackinac County)

The Upper Peninsula has a much larger forestry sector than the other parts of the state. Its percentages employed in the construction, manufacturing, and retail trade sectors are significantly larger than for Michigan as a whole. This is also true for the "accommodation and food services" sector of the economy.

2. The Northern Lower Peninsula

This area is predominantly rural in nature, and (as shown on the Michigan Profile Map) is widely covered with forest lands, but includes significant resort and tourist areas, and profitable groves of fruit-growing trees. It is a popular area for hunters, and has a large proportion of its housing units dedicated to seasonal and recreational uses (e.g. hunting lodges, summer cabins). Large state and national forest areas are located in this part of the state, as indicated on the Michigan Profile Map. Many small cities, villages, and towns are located throughout the area's 29 counties. A generally good system of surface highways connects the area. Trains are limited to freight uses, rather than passenger travel. A few airports and passenger ferries are in operation within the area, and there are some excellent ports for handling marine traffic.

The urban areas in the Northern Lower Peninsula, ranked by population according to the 2010 U.S. census, are:

Traverse City	47,109	
Alpena	14,258	
Cadillac	11,690	
Ludington	10,710	(in Mason County)
Manistee	9,606	(in Manistee County)
Houghton Lake	8,300	(in Roscommon County)
Gaylord	8,298	(in Otsego County)
Petoskey	8,210	(in Emmet County)
Au Sable-Oscoda	6,384	(in Iosco County)
Clare	5,597	(in Clare County)
Cheboygan	4,517	(in Cheboygan County)
Fremont	4,496	(in Newaygo County)
East Tawas	4,372	(in Iosco County)
Charlevoix	4,179	(in Charlevoix County)
Grayling	3,858	(in Crawford County)
Harrison	3,589	(in Clare County)
Boyne City	3,501	(in Charlevoix County)

Newaygo	3,335	(in Newaygo County)
Gladwin	2,934	(in Gladwin County)
Kalkaska	2,668	(in Kalkaska County)
Rogers City	2,560	(in Presque Isle County)
Hart	2,556	(in Oceana County)

The Northern Lower Peninsula has larger forestry, fishing, and hunting sectors than most other parts of the state, as well as the majority of Michigan's employment in extractive industries (oil, gas, mining, and quarrying). The area's percentages employed in the construction, retail trade, and the health care and social assistance sectors are significantly larger than for Michigan as a whole. This is also true for the "accommodation and food services" sector of the economy.

3. The Southern Lower Peninsula (excluding Metro Detroit)

This area contains many medium-sized urban areas and most of Michigan's traditional farming and livestock grazing lands. It is adjacent to the States of Indiana and Ohio, and the Canadian province of Ontario. Some out-of-state metropolitan areas extend into this part of Michigan, such as South Bend, Elkhart, Michigan City, Toledo, and Sarnia. This part of the state is extremely well-served by the Interstate Highway System, and many colleges and State universities are found throughout the area. Many features of historic and scenic interest draw tourists from other parts of the state and country. University sports venues, the Michigan International Speedway, minor league baseball, many different museums, zoos, professional theaters, historic sites, and well-known manufacturing facilities (e.g. Kellogg breakfast cereals) are numbered among the area's many cultural attractions.

The largest urban areas connected with the Southern Lower Peninsula (outside of Metropolitan Detroit) are:

Grand Rapids	589,060	(Grand Rapids UA plus exurban Lowell, Dorr, Sparta, Cedar Springs UAs)
(Toledo, OH-MI)	507,643	(Monroe County has suburban/exurban parts of the Toledo UA.)
Flint	362,078	(or 370,307 if suburban Holly is included from the Metro Detroit area)
Lansing	319,849	(Lansing's UA of 313,532 plus exurban Williamston's UA of 6,317)
(South Bend, IN-MI)	278,165	(Some suburban/exurban parts are located in Berrien and Cass counties.)
Kalamazoo	221,443	(Kalamazoo's UA of 209,703 plus exurban Otsego-Plainwell pop. of 11,740)
(Sarnia-Port Huron, ON-MI)	176,661	(Port Huron UA from 2010 U.S. census + Sarnia 2011 population statistic)
Muskegon	171,848	(161,280 Muskegon UA, plus exurban Whitehall-Montague UA of 10,568)
(Elkhart, IN-MI)	143,592	(Some suburban/exurban parts are located in Berrien and Cass counties.)
Saginaw	126,265	
Holland	99,941	
Jackson	90,057	
Port Huron	87,106	(Michigan UA only, not including the Canadian Sarnia area)
Battle Creek	78,393	
Bay City	70,585	
(Michigan City-LaPorte, IN-MI)	66,025	(One exurb of the UA is located in the southwest corner of Berrien Co.)
Benton Harbor-St. Joseph	61,022	
Midland	59,014	
Monroe	51,240	(Detroit's southern suburbs do overlap with Monroe's northern suburbs.)
Adrian	44,823	(in Lenawee County)
Mt. Pleasant	37,447	(in Isabella County)
Owosso	22,426	(in Shiawassee County)
Alma-St. Louis	16,924	(in Gratiot County)
Coldwater	16,876	(in Branch County)
Ionia	14,409	(in Ionia County)
Big Rapids	14,241	(in Mecosta County)
Lapeer	13,424	(in Lapeer County)
Sturgis	13,040	(in St. Joseph County)

Charlotte	12,682 (in Eaton County)
Hillsdale	11,646 (in Hillsdale County)
Paw Paw Lake-Hartford	11,589 (in Berrien and Van Buren Counties)
Three Rivers	10,820 (in St. Joseph County)
Greenville	9,743 (in Montcalm County)
Albion	9,219 (in Calhoun County)
Paw Paw	8,684 (in Van Buren County)
St. Johns	8,425 (in Clinton County)
Hastings	7,713 (in Barry County)
Marshall	7,683 (in Calhoun County)
Berrien Springs	7,358 (in Berrien County)
Allegan	6,322 (in Allegan County)
Dowagiac	6,082 (in Cass County)
South Haven	5,791 (in Van Buren County)
Belding	5,789 (in Ionia County)
Eaton Rapids	5,408 (in Eaton County)
Caro	5,113 (in Tuscola County)
Portland	5,020 (in Ionia County)
Frankenmuth	4,972 (in Saginaw County)
Durand	4,854 (in Shiawassee County)
Wayland	4,518 (in Allegan County)
Perry	4,290 (in Shiawassee County)
Constantine	4,074 (in St. Joseph County)
Coopersville	3,951 (in Ottawa County)
Dundee	3,799 (in Monroe County)
Imlay City	3,792 (in Lapeer County)
Vassar	3,714 (in Tuscola County)
Bad Axe	3,490 (in Huron County)
Blissfield	3,303 (in Lenawee County)
Middleville	3,236 (in Barry County)
Somerset	2,910 (in Hillsdale County)
Sandusky	2,775 (in Sanilac County)
Brooklyn	2,773 (in Jackson County)
Almont	2,719 (in Lapeer County)
Gun Lake	2,660 (in Barry County)
Douglas-Saugatuck	2,570 (in Allegan County)

The Southern Lower Peninsula (outside of Metro Detroit) has a larger proportion of its workers in the manufacturing sector than other parts of the state. Its percentages employed in educational and other services are significantly larger than for Michigan as a whole. It has many colleges and universities. Lansing is the state capital and contains many government agencies. Among the many recreational and cultural attractions are large stadiums and performance venues, which tend to require special preparation and management when it comes to protecting attendees from threats and hazards. Various convention centers and downtown areas tend to regularly attract large numbers of persons, who similarly may require special planning to protect them from threats and hazards.

4. Metropolitan Detroit

This area contained the first large Michigan settlements, which developed into the expanding City of Detroit throughout the industrial revolution and then became world-famous as "The Motor City." The largest American automobile companies tended to develop in this area of Michigan, and eventually became "the big three"—Ford, General Motors, and Chrysler, with their world headquarters located in Dearborn, Detroit, and Auburn Hills, respectively. Although the area's population increased by the greatest amount during the first half of the 20^{th} Century (Detroit's peak census population was in 1950, at 1,849,568 persons), the metro area continued to increase slowly for 50 years thereafter—until the most recent census revealed the effects of various economic challenges, which registered an overall decline of modest proportions (while most of the metropolitan counties continued to grow at a decent rate).

The largest urban areas in the Metropolitan region, according to the 2010 U.S. census, are:

Detroit	3,863,533 (or 4,182,779, including 319,246 in the Windsor area in Ontario)

(NOTE: 3,734,090 are in Metro Detroit, plus 119,509 in the Howell-Brighton suburban UA and the exurbs of Richmond and Fowlerville, 6,140 and 3,794 respectively.)

Ann Arbor	313,536 (306,022 in Ann Arbor plus 7,514 in the exurb of Milan)

(NOTE: Detroit and Ann Arbor might be considered one Metro area of 4,177,069; or 4,496,315 with Windsor.)

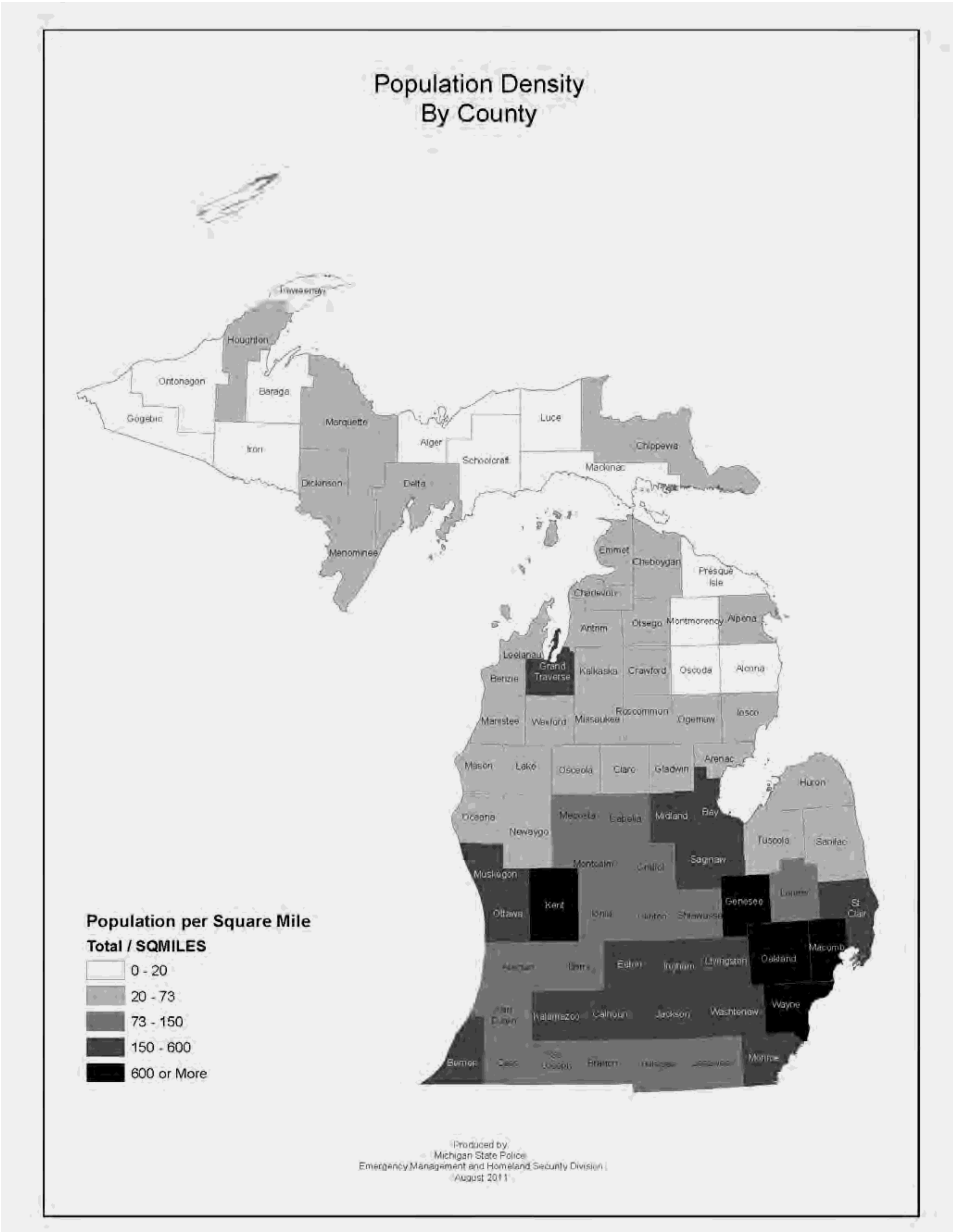
Holly	8,229 (suburb of Flint)
Chelsea	5,329

The area employs a larger percentage of its workforce in certain economic sectors than other parts of Michigan do. These sectors include wholesale trade, transportation and warehousing, information, finance and insurance, real estate, management, and professional, scientific, and technical services. The arts, entertainment, and recreation sector is also a bit larger, percentagewise, than it is in other parts of the State.

Michigan's Significant Hazards in each Geographic Division

The following list summarizes the hazards that have been proven to be likely within the following geographic divisions within Michigan. A hazard is still possible in these areas even if it is not listed here, but this list merely provides a rough indicator of the different kinds of events that are typically identified as a major threat within local and regional hazard analyses across different parts of the State.

1. Upper Peninsula (15 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Wildfires, Invasive Species, Subsidence.
   Technological Hazards: Structural fires, Infrastructure Failures.
   Human-Related Hazards: Civil Disturbances, Nuclear Attack, Public Health Emergencies, Terrorism.
2. Northern Lower Peninsula (29 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Wildfires, Invasive Species.
   Technological Hazards: Structural fires, Scrap Tire Fires, Oil and Gas Well Accidents, Infrastructure Failures.
   Human-Related Hazards: Nuclear Attack, Public Health Emergencies, Terrorism.
3. Southern Lower Peninsula (34 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Ice/Sleet Storms, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Invasive Species, Earthquakes.
   Technological Hazards: Structural fires, Scrap Tire Fires, Hazardous Materials Incidents, Nuclear Power Plant Emergencies, Pipeline Accidents, Oil and Gas Well Accidents, Infrastructure Failures, Energy Emergencies, Transportation Accidents.
   Human-Related Hazards: Civil Disturbances, Nuclear Attack, Public Health Emergencies, Terrorism.
4. Metropolitan Detroit (5 counties)
   Natural Hazards: Thunderstorms, Severe Winter Weather, Severe Winds, Tornadoes, Ice/Sleet Storms, Extreme Temperatures, Flooding, Shoreline Hazards, Dam Failures, Drought, Invasive Species.
   Technological Hazards: Structural fires, Scrap Tire Fires, Hazardous Materials Incidents, Nuclear Power Plant Emergencies, Pipeline Accidents, Infrastructure Failures, Energy Emergencies, Transportation Accidents.
   Human-Related Hazards: Civil Disturbances, Nuclear Attack, Public Health Emergencies, Terrorism.


Population Density
By County
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Iron
Alger
Luce
Schoolcraft
Chippewa
Mackinac
Dickinson
Delta
Menominee
Emmet
Cheboygan
Presque Isle
Charlevoix
Antrim
Otsego
Montmorency
Alpena
Leelanau
Grand Traverse
Benzie
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Arenac
Mason
Lake
Osceola
Clare
Gladwin
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Montcalm
Gratiot
Saginaw
Muskegon
Kent
Genesee
Lapeer
St Clair
Ottawa
Ionia
Shiawassee
Oakland
Macomb
Eaton
Ingham
Livingston
Wayne
Kalamazoo
Calhoun
Jackson
Washtenaw
Berrien
Cass
Branch
Monroe
Population per Square Mile
Total / SQMILES
0 - 20
20 - 73
73 - 150
150 - 600
600 or More
Produced by
Michigan State Police
Emergency Management and Homeland Security Division
August 2011

The following table presents selected economic information for Michigan and its four geographic divisions (as defined in this document). Various economic sectors have been listed, along with their shares of Michigan's annual payroll and employment (as of March 2009 information from the County Business Patterns source). The percentage of total employment within each geographic division is also presented. Please note that because of the way this data was compiled from subcomponents (some of which were unavailable), the division totals do not equal 100%. Nevertheless, this information is considered useful to identify the sectors that are comparatively more important in different parts of the state.

2009 County Business Patterns		MICHIGAN	MICHIGAN	U.P.	N.L.P.	S.L.P.	Metro
NAICS code	**NAICS code description**	**% annual payroll**	**% of workers**	**% of workers**	**% of workers**	**% of workers**	**% of workers**
------	Total for all sectors	100.0%	100.0%	89.1%	94.1%	97.1%	97.9%
11----	Forestry, fishing, hunting, and Agriculture Support	0.1%	0.1%	0.6%	0.2%	0.0%	0.0%
21----	Mining, quarrying, and oil and gas extraction	0.2%	0.2%	0.0%	0.8%	0.1%	0.0%
22----	Utilities	1.4%	0.6%	0.3%	0.1%	0.0%	0.1%
23----	Construction	4.2%	3.4%	4.9%	4.9%	3.6%	3.1%
31----	Manufacturing	16.8%	13.9%	16.6%	14.7%	17.3%	11.1%
42----	Wholesale trade	6.4%	4.7%	2.2%	2.5%	4.6%	5.1%
44----	Retail trade	7.4%	13.2%	16.9%	17.9%	14.1%	12.2%
48----	Transportation and warehousing	2.7%	2.8%	1.9%	1.7%	2.6%	3.2%
51----	Information	3.1%	2.2%	1.1%	1.2%	1.7%	2.7%
52----	Finance and insurance	6.4%	4.6%	3.5%	3.5%	4.0%	5.0%
53----	Real estate and rental and leasing	1.2%	1.5%	0.9%	1.0%	1.3%	1.8%
54----	Professional, scientific, and technical services	11.3%	7.1%	3.9%	3.5%	4.2%	8.5%
55----	Management of companies and enterprises	7.1%	3.0%	0.0%	0.3%	1.6%	4.1%
56----	Administrative & Support & Waste Management & Remediation Services	5.8%	7.8%	4.0%	2.8%	6.0%	7.6%
61----	Educational services	1.3%	2.1%	0.4%	0.8%	2.2%	1.7%
62----	Health care and social assistance	17.3%	16.8%	13.9%	19.6%	17.2%	16.5%
71----	Arts, entertainment, and recreation	1.1%	1.5%	0.8%	1.3%	1.3%	1.7%
72----	Accommodation and food services	3.2%	9.7%	12.5%	12.5%	10.0%	9.2%
81----	Other services (except public administration)	2.8%	4.7%	4.7%	4.9%	5.2%	4.3%
99----	Industries not classified	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Michigan's position as a national and international manufacturing and business center virtually assures that the state will remain vulnerable to hazardous material incidents and other technological hazards. Extensive planning and preparation has been done to aid in responding to these types of events, and that work must continue and perhaps even be expanded as the number and potential impacts of technological hazards continues to grow.

Michigan, which contains three operating commercial nuclear power plants, has continued to develop and expand its capabilities to respond to a nuclear accident. Although stringent steps are taken at each plant to ensure safe and trouble-free power generation, accidents can occur. To combat that possibility, Michigan must continue to be a leader in nuclear safety to ensure that the state's residents are adequately protected from the potentially harmful effects of an accidental radioactive material release.

Unfortunately, Michigan has experienced major acts of terrorist-like criminal action. On May 18, 1927, a disgruntled taxpayer set off a bomb in a schoolhouse in Bath, killing 45 persons (mostly children) and injuring 58 others. Most recently, in 2009, Michigan narrowly avoided having a major terrorist act occur on its soil, as an attempt to bomb a passenger airline over Detroit did not succeed. As evidenced by the mounting history of criminal and terrorist events and plots—the bomb blasts at the World Trade Center in 1993, the tragic destruction of the Murrah Federal Center in Oklahoma City in 1995, the September 2001 terrorist strikes in New York City and Washington D.C., the 1996 Summer Olympics bomb in Atlanta, lethal shooting events at Columbine High School (1999), Fort Hood in Texas (2009), and Washington D.C. in 2002—constant vigilance is needed by all citizens to prevent and deter future events of this type.

Finally, substantial actions must be taken to mitigate the hazards outlined in this report. Hazard mitigation is defined as "any action taken before, during or after a disaster or emergency situation to permanently eliminate or reduce the long-term risk to human life and property from natural, technological and human-related hazards." Hazard mitigation actions, especially if implemented in a coordinated, inter-governmental, inter-disciplinary manner, can effectively reduce the damage, suffering, injury, and loss of life and property associated with these hazards. That, in turn, helps reduce disaster response and recovery costs, saving untold millions of dollars in public and private disaster relief assistance. In addition, hazard mitigation can greatly reduce the social, economic and political disruptions that disasters bring to bear on Michigan communities. The old adage "an ounce of prevention is worth a pound of cure" is certainly true when it comes to disasters.

It is for those reasons that this Hazard Analysis is coordinated with the Michigan Hazard Mitigation Plan, the Michigan Emergency Management Plan, the Michigan Citizen-Community Emergency Response and Coordinating Council, the Threat and Hazard Identification and Risk Assessment process (THIRA), and other plans, groups, agencies, and processes. Continuing to promote and advance the art and science of hazard mitigation will help ensure that Michigan's citizens are protected, to the maximum extent possible, from the harmful impacts of future disasters.

The following table attempts to "compare apples with oranges" by presenting estimated annual impacts from each type of hazard (although some hazards are too new or unclear to have a precise set of impacts accurately estimated in such a clear-cut manner). This table is still a work in progress and could benefit from the insights, research, and analysis of subject matter experts. The more detailed chapters that follow will present more information and explanations about each type of hazard, organized into overarching sections by general hazard type (natural, technological, human-related).

Hazard Analysis Summary Table

	Average annual events	Average annual deaths	Average annual injuries	Average annual property damage	Development trend effects	Risk rating: casualties	Risk rating: property	Risk Rating: economic costs	Risk rating: Infrastructure	Risk rating: Environment	Frequency as a top local hazard
Hail	~25	0.0	0.0	$15 million	+	0	2	2	1	1	Some
Lightning	~12	1.5	10.7	$1.4 million	=	1	1	2	2	2	Some
Ice and sleet storms (damage estimate includes snowstorms)	2.2	>1	>1	~$12 million	+	1	2	3	3	1	Some
Snowstorms	>1	>1	>1	(included above)	+	1	1	2	2	1	Many
Severe winds	~8	2	20	~$25 million	+	1	2	3	3	1	Many
Tornadoes	~16	4	60	$17.8 million	+	2	2	3	3	2	Many
Extreme heat	~7	2?	?	?	=	2	0	2	2	0	Some
Extreme cold	~30	5?	?	$millions	=	2	2	3	3	1	Some
Fog	0.5	?	?	?	+	1	0	1	1	0	None
Flooding	>1	0.4	0.5	~$80 million	+	1	2	3	3	2	Some
Shoreline hazards	>1	~2	~4	>$10 million	+	1	2	3	2	1	Some
Dam failures	~2?	0?	0?	$thousands	+	2	2	3	2	2	Some
Drought	0.5	0	0	$millions	?	0	0	3	1	2	Few
Wildfires	>550	3.7	?	~$1 million +	+	2	2	3	2	3	Some
Invasive species	?	?	>1	$millions	?	1	2	3	1	3	None
Earthquakes	0.3	0	0	$165,000	+	1	1	2	2	2	Few
Subsidence	0.4	0	0	mere thousands?	+	1	1	1	1	1	Few
Celestial impacts (impacting object)	<1	0	0	<$1,000	+	0	1	1	1	1	None
Celestial impacts (space weather)	~0.3	0	0	$millions?	+	0	1	2	2	0	None
Structural fires (major)	>1	>5	>10	>$many millions	-	2	2	2	1	2	Few
Scrap tire fires	0.5	0	0	$thousands	=	0	1	2	1	2	Few
Hazardous materials incident (fixed site)	~7	>1	>1	$millions	+	2	2	2	2	2	Some
Nuclear Power Plant	0.02	0	0	0	+	0	1	2	2	2	Few
Hazardous materials (transportation)	~13	>1	>1	$many thousand	+	2	2	2	2	2	Some
Oil & gas pipelines	>1	~0.7	~1.4	$millions	+	1	2	2	2	2	Few
Oil & gas wells	0.2	<1	<1	?	+	1	1	1	1	1	Few
Infrastructure failures	>1	<1	<1	$many millions	+	1	1	3	3	2	Some
Energy emergencies	~1	0	0	?	+	0	0	2	2	1	None
Transportation accidents (major)	>1	>1	>1	$many thousands	+	2	1	2	1	1	Few
Catastrophic incidents	<1	>1	>1	?	=	1	0	2	2	2	None
Civil Disturbances	<1	>1	>1	$thousands	=	2	2	2	1	1	Few
Nuclear Attack	0	0	0	?	-	2	2	2	2	2	Many
Public Health Emergencies	?	>1	>1	?	-	2	0	2	2	1	Few
Terrorism and Similar Activities	<1	>1	>1	?	=	2	2	2	2	2	Some

"**Average annual**" numbers are medium-term estimates only. Medium-term means that most estimates were based upon decades' worth of data, to predict future decades' risk. Numbers that could not yet be validly determined are marked "?"

Development trend effects use the following symbols to estimate the effects from Michigan's recent land use trends (which still mainly involve the construction of suburban, exurban, and rural detached homes for persons moving out of denser areas).

"+" means increasing risks, "=" means few net effects, "-" means decreasing risks, "?"means trends are unclear

Risk Ratings are based upon the estimated severity of average annual impacts (medium-term), as follows:

"0" means negligible: The risks as currently known are not likely to cause any emergency-level event.

"1" means minor: There is a known although infrequent chance for impacts of moderate or purely local severity.

"2" means significant: A regular pattern of moderate effects, or an infrequent chance of severe impacts.

"3" means major: A regular pattern or high risk of major impacts, of statewide significance.

"**Frequency as a top local hazard**" refers to the number of local plans listing this as one of their top hazards. Categories include "Many," "Some," "Few," and "None." Note that because FEMA requires the analysis of natural hazards, but not technological and human-related hazards, local plans are inclined to favor the listing of natural hazards.

THIRA Hazard Analysis

Michigan has had a very respectable record of planning for all foreseeable threats and hazards. This most recent process, the Threat and Hazard Identification and Risk Assessment (THIRA), begins with information from the most recent edition of the Michigan Hazard Analysis (June 2012) and Michigan Hazard Mitigation Plan (March 2011). This information is used to identify and contextualize the many threats and hazards that Michigan faces (steps one and two of the THIRA process as described in CPG 201, "Threat and Hazard Identification and Risk Assessment Guide"). More than 30 types of hazards have been assessed.

In order to make such a large array of hazards more comprehensible, they have been organized so that the most closely-related hazards are located near each other in the same general sections. There is extensive overlap between natural hazards. Similarly, technological hazards and human-related hazards tend to share a great deal in common with each other. Therefore, three major divisions have been used in this part of the THIRA document, to match these three major hazard classifications. Some major sections include subsections organized so that document users can more easily find information about hazards that are closely related to each other. Persons who need information about weather hazards, for example, do not need to switch between sections separated by hundreds of pages, but instead can refer specifically to a single section of this plan.

This document begins with a section on **natural hazards**. It makes sense to list these hazards first, because they so commonly affect Michigan. There is not a single part of Michigan that isn't susceptible to severe weather, for example. Within the natural hazards section, weather hazards have been listed first. Most of the weather hazards subsection deals with violent weather events such as thunderstorms and tornadoes, but there is also an entire component that addresses hazardous winter weather. One of the weather-related hazards, extreme temperatures, addresses both summer and winter weather issues in one section.

Many weather hazards affect the hydrological conditions in Michigan and its local communities, and therefore the weather hazards section is immediately followed by a section dealing with hydrological hazards—flooding and drought. The flood hazard section includes three major components—inland (riverine) flooding, Great Lakes shoreline hazards, and dam failures. The shoreline hazards component not only includes information about flooding, but other topics relevant to coastline areas along the Great Lakes—storm surges (seiches), rip currents, Great Lakes water recession, and shoreline erosion.

The first two natural hazard subsections flow well into a consideration of Michigan's two main ecological hazards—wildfires and invasive species. Both weather and hydrological conditions affects Michigan's ecological conditions, and its vulnerability to wildfires and invasive species. The natural hazards section wraps up with a subsection on Michigan's geological hazards. Although these are not insignificant, they tend not to pose as much direct risk to Michigan as the other types of natural hazards. There is also a section titled "Celestial Impacts," which considers such issues as solar storms that have the potential to disrupt important infrastructure, and the impact or threatened impact of physical bodies upon the Earth's land, sea, or atmosphere, the latter of which is rare as a hazard but has the potential for impacts that are truly catastrophic. These issues are given a realistic assessment that can offset some of the alarmist media presentations that have appeared in recent years.

The **technological hazards** section includes two major subsections—one dealing with industrial hazards and the other with infrastructure problems. Within the industrial hazards subsection are components dealing with fires, hazardous materials incidents of various kinds, nuclear power plant issues, and accidents involving Michigan's oil and gas pipelines and wells. Within the subsection on infrastructure problems are components dealing with various forms of infrastructure failure, energy emergencies, and major transportation accidents.

The final major section of the hazard analysis, **human-related hazards**, contains five components, including a new consideration of the general topic of catastrophic incidents (national emergencies). In the past decade, major national incidents involving terrorism and hurricanes have made it clearer than ever how interconnected we all must be. We as a state experience both direct and indirect effects from events that take place elsewhere in the nation and the world. This new component of the hazard analysis provides an overview of events, such as 9/11 and Hurricanes Katrina and Rita, whose scale may necessitate extensive activities within Michigan even though the direct impacts of the event primarily occurred outside of our state. The section on civil disturbances has recently been extensively rewritten, to add additional information from social science research. Similarly, the section on nuclear attack was also recently rewritten, to better reflect the new post-Cold War era in which the role of terrorist nuclear threats is of even greater concern. This is followed by an updated section on public health emergencies, which includes new information about the threat of pandemics, and the final section on terrorism has, like the nuclear attack section, been almost entirely rewritten, to better reflect the current geopolitical situation, as well as advances in our understanding of the threat, as informed by recent events and new research in homeland security studies.

The result of these changes is meant to be a document that is as comprehensive, up-to-date, and valid as possible, while still being easy to use. If there is a question about any of the information in this document, inquiries can be directed to Mike Sobocinski at (517) 336-2053 (or sobocinm@michigan.gov) and the information can then be double-checked or its basis explained.

Although lengthy lists of historical incidents are not included in this document, the information can be found in the 2011 edition of the Michigan Hazard Mitigation Plan. For the 2012 THIRA process, past information has merely been summarized so that new forms of analysis could be presented while keeping the document of modest size. With an introductory overview now provided to readers, an outline of the full hazard analysis section is hereby presented, as a quick guide to the many pages that follow:

I. Natural Hazards
- A. Weather Hazards
  - 1. Storms
- a. Thunderstorms, including hail and lightning
- b. Winter storms, including ice, sleet, snow
  - 2. Severe Winds
  - 3. Tornadoes
  - 4. Extreme Temperatures
  - 5. Fog
- B. Hydrological Hazards
  - 1. Flooding
    - a. Riverine flooding
    - b. Great Lakes Shoreline Hazards
    - c. Dam failures
  - 2. Drought
- C. Ecological Hazards
  - 1. Wildfires
  - 2. Invasive species
- D. Geological Hazards
  - 1. Ground Movement
    - a. Earthquakes
    - b. Subsidence
- 2. Celestial Impacts **(new section)**

II. Technological Hazards
- A. Industrial Hazards
  - 1. Fires
    - a. Structural fires
    - b. Scrap tire fires
  - 2. Hazardous Materials Incidents

a. Hazardous Materials Incidents – Fixed Site (including industrial accidents)
b. Nuclear Power Plant Emergencies
c. Hazardous Materials Incidents – Transportation
d. Petroleum and Natural Gas Pipeline Accidents
c. Oil and natural gas well accidents
B. Infrastructure Problems
1. Infrastructure Failures
2. Energy Emergencies
3. Transportation Accidents (air, rail, highway, marine)
III. Human-Related Hazards
A. Catastrophic Incidents (National Emergencies) **(new section)**
B. Civil Disturbances
C. Nuclear Attack
D. Public Health Emergencies
E. Terrorism and Similar Criminal Activities

Information about these hazards is summarized in the following table. Note that it was not yet considered valid at this point to attempt to fill in every part of the table with valid summary information. Feedback is requested to help compare these hazards and thus validly prioritize the most threatening of them.

Hazard Analysis Summary Table

	Average annual events	Average annual deaths	Average annual injuries	Average annual property damage	Development trend effects	Risk rating: casualties	Risk rating: property	Risk Rating: economic costs	Risk rating: Infrastructure	Risk rating: Environment	Frequency as a top local hazard
Hail	**~25**	**0.0**	**0.0**	**$15 million**	+	**0**	**2**	**2**	**1**	**1**	**Some**
Lightning	**~12**	**1.5**	**10.7**	**$1.4 million**	=	**1**	**1**	**2**	**2**	**2**	**Some**
Ice and sleet storms (damage estimate includes snowstorms)	**2.2**	>1	>1	**~$12 million**	+	**1**	**2**	**3**	**3**	**1**	**Some**
Snowstorms	**>1**	>1	>1	(included above)	+	**1**	**1**	**2**	**2**	**1**	**Many**
Severe winds	**~8**	**2**	**20**	**~$25 million**	+	**1**	**2**	**3**	**3**	**1**	**Many**
Tornadoes	**~16**	**4**	**60**	**$17.8 million**	+	**2**	**2**	**3**	**3**	**2**	**Many**
Extreme heat	**~7**	**2?**	**?**	**?**	=	**2**	**0**	**2**	**2**	**0**	**Some**
Extreme cold	**~30**	**5?**	**?**	**$millions**	=	**2**	**2**	**3**	**3**	**1**	**Some**
Fog	**0.5**	**?**	**?**	**?**	+	**1**	**0**	**1**	**1**	**0**	**None**
Flooding	**>1**	**0.4**	**0.5**	**~$80 million**	+	**1**	**2**	**3**	**3**	**2**	**Some**
Shoreline hazards	**>1**	**~2**	**~4**	**>$10 million**	+	**1**	**2**	**3**	**2**	**1**	**Some**
Dam failures	**~2?**	**0?**	**0?**	**$thousands**	+	**2**	**2**	**3**	**2**	**2**	**Some**
Drought	**0.5**	**0**	**0**	**$millions**	**?**	**0**	**0**	**3**	**1**	**2**	**Few**
Wildfires	**>550**	**3.7**	**?**	**~$1 million +**	+	**2**	**2**	**3**	**2**	**3**	**Some**
Invasive species	**?**	**?**	**>1**	**$millions**	**?**	**1**	**2**	**3**	**1**	**3**	**None**
Earthquakes	**0.3**	**0**	**0**	**$165,000**	+	**1**	**1**	**2**	**2**	**2**	**Few**
Subsidence	**0.4**	**0**	**0**	**mere thousands?**	+	**1**	**1**	**1**	**1**	**1**	**Few**
Celestial impacts (impacting object)	**<1**	**0**	**0**	**<$1,000**	+	**0**	**1**	**1**	**1**	**1**	**None**
Celestial impacts (space weather)	**~0.3**	**0**	**0**	**$millions?**	+	**0**	**1**	**2**	**2**	**0**	**None**
Structural fires (major)	**>1**	**>5**	**>10**	**>$many millions**	-	**2**	**2**	**2**	**1**	**2**	**Few**
Scrap tire fires	**0.5**	**0**	**0**	**$thousands**	=	**0**	**1**	**2**	**1**	**2**	**Few**
Hazardous materials incident (fixed site)	**~7**	**>1**	**>1**	**$millions**	+	**2**	**2**	**2**	**2**	**2**	**Some**
Nuclear Power Plant	**0.02**	**0**	**0**	**0**	+	**0**	**1**	**2**	**2**	**2**	**Few**
Hazardous materials (transportation)	**~13**	**>1**	**>1**	**$many thousand**	+	**2**	**2**	**2**	**2**	**2**	**Some**
Oil & gas pipelines	**>1**	**~0.7**	**~1.4**	**$millions**	+	**1**	**2**	**2**	**2**	**2**	**Few**
Oil & gas wells	**0.2**	**<1**	**<1**	**?**	+	**1**	**1**	**1**	**1**	**1**	**Few**
Infrastructure failures	**>1**	**<1**	**<1**	**$many millions**	+	**1**	**1**	**3**	**3**	**2**	**Some**
Energy emergencies	**~1**	**0**	**0**	**?**	+	**0**	**0**	**2**	**2**	**1**	**None**
Transportation accidents (major)	**>1**	**>1**	**>1**	**$many thousands**	+	**2**	**1**	**2**	**1**	**1**	**Few**
Catastrophic incidents	**<1**	**>1**	**>1**	**?**	=	**1**	**0**	**2**	**2**	**2**	**None**
Civil Disturbances	**<1**	**>1**	**>1**	**$thousands**	=	**2**	**2**	**2**	**1**	**1**	**Few**
Nuclear Attack	**0**	**0**	**0**	**?**	-	**2**	**2**	**2**	**2**	**2**	**Many**
Public Health Emergencies	**?**	**>1**	**>1**	**?**	-	**2**	**0**	**2**	**2**	**1**	**Few**
Terrorism and Similar Activities	**<1**	**>1**	**>1**	**?**	=	**2**	**2**	**2**	**2**	**2**	**Some**

"**Average annual**" numbers are medium-term estimates only. Medium-term means that most estimates were based upon decades' worth of data, to predict future decades' risk. Numbers that could not be validly determined are marked "?"

Development trend effects use the following symbols to estimate the effects from Michigan's recent land use trends (which still mainly involve the construction of suburban, exurban, and rural detached homes for persons moving out of denser areas).

"+" means increasing risks, "=" means few net effects, "-" means decreasing risks, "?"means trends are unclear

Risk Ratings are based upon the estimated severity of average annual impacts (medium-term), as follows:

"0" means negligible: The risks as currently known are not likely to cause any emergency-level event.

"1" means minor: There is a known although infrequent chance for impacts of moderate or purely local severity.

"2" means significant: A regular pattern of moderate effects, or an infrequent chance of severe impacts.

"3" means major: A regular pattern or high risk of major impacts, of statewide significance.

"**Frequency as a top local hazard**" refers to the number of local plans listing this as one of their top hazards. Categories include "Many," "Some," "Few," and "None." Note that because FEMA requires the analysis of natural hazards, but not technological and human-related hazards, local plans are inclined to favor the listing of natural hazards.

I. Natural Hazards
A. Weather Hazards

The following outline summarizes the significant weather hazards covered in this section:

1. Storms
   a. Thunderstorms, including hail and lightning
   b. Winter storms, including ice, sleet, snow
2. Severe Winds
3. Tornadoes
4. Extreme Temperatures
5. Fog

These weather hazards can be thought of in general terms, according to whether they involve winter weather conditions or not. The winter storms section, and half of the extreme temperatures section, should be referred to for a good overview of Michigan's winter weather hazards. The other sections focus upon weather conditions that predominate in the non-winter months. However, it must be admitted that fog and strong winds may be present during the winter season as well, (although the strongest winds in Michigan usually occur during transition periods between warm and cool weather, and in association with severe thunderstorms). Strong winter winds may occur in conjunction with sleet and ice, and are a specific part of blizzard events, all described in the winter weather section. When ice and sleet have already weakened an area's tree limbs, power lines, and infrastructure, winter winds are often the final straw that causes tree limbs (or entire trees) to topple across roads or utility lines, causing life-threatening infrastructure breakdowns during periods of extreme cold. A big part of why this updated analysis now addresses all weather hazards within a single section is because there may not always be neat and precise distinctions between the different events. It makes sense to study these related topics together and then consider areas of overlap and similarity. But the most essential aspects of Michigan's winter weather hazards are described in the two sections: winter storms and extreme temperatures.

The non-winter months usually see the other types of severe weather hazards—thunderstorms and tornadoes, lightning and hail, and extreme heat. Thus, most of this section of the hazard analysis describes hazards that regularly occur during the non-winter months. The seasons in Michigan do not completely match those seen on the standard calendar, and they vary a little bit depending upon the area of the State being considered. As will be described further in the material on each hazard, Michigan's weather is affected by its location in the middle of the Great Lakes. Locations next to, or distant from, a Great Lakes shoreline, will often have different weather patterns and hazard risks. There is also a general trend relating to how far to the north the area under consideration is located. Michigan may be thought of in terms of three broad geographic divisions: the Upper Peninsula, the Northern Lower Peninsula, and the Southern Lower Peninsula. The Upper Peninsula, in addition to containing the northernmost locations and the areas of highest elevation (e.g Mount Arvon in Baraga County, at 603m), also has areas that are more exposed to weather patterns blowing in from the west, without the extent of moderating Lake Michigan influence enjoyed by the Lower Peninsula. This exposes the Upper Peninsula to colder average temperatures and longer winters. The Lower Peninsula contains a northern region that contains large areas of woodland, as well as areas of hilly landscape and higher elevation (e.g. Grove Hill, in northern Osceola County, at 522m) than its southern region, in which agricultural and urban land uses are predominant.

In terms of population density, a difference can also be clearly found between the three general regions of Michigan. The Upper Peninsula has extensive stretches of highly rural areas across its 15 large and irregularly-shaped counties (Luce and Iron are the only ones with simple rectangular borders on three sides), with moderately-sized cities (or urban areas) fairly widely separated from each other. Although the largest of these is currently the city of Marquette, Marquette County's population density (an average of 36 persons per square mile) is the same as that for the counties of Dickinson (with the Iron Mountain/Kingsford urban area as its economic focus) and Houghton (with the

Houghton/Hancock urban area as its current economic focus area, although a century or more ago it would have been the thriving mining area around Calumet), followed closely by Delta County (with its Escanaba/Gladstone metro area and an average of 33 persons per square mile). The population density ranges to as low as 4 persons per square mile (in Keweenaw, which is also Michigan's northernmost and least populous county).

In the Northern Lower Peninsula, the population densities by county tend to be higher, and Traverse City stands out as the key city whose urban area is significantly larger than any others in the region. Grand Traverse County has an average of 167 residents per square mile—more than double the population density of any other county in the Northern Lower Peninsula, and nearly five times as much as any of the (geographically larger) Upper Peninsula counties just named. Apart from this exception, all other counties in the Northern Lower Peninsula range from 17 to 67 persons per square mile. The southern "boundary" of the Northern Lower Peninsula, in terms of county population density, might reasonably be described as the line of counties from Arenac across to Lake County, and then slightly south to include the counties of Newaygo and Oceana. Every county south of this "line" has a significantly higher population density (although the two agricultural "Thumb" counties of Huron and Saniliac, which could be described as lying to the East of this "line," are exceptions, at 43 and 46 persons per square mile but are classified as part of the Southern Lower Peninsula since they are located across the Saginaw Bay and have primarily agricultural functions amidst a "ring" of major metropolitan areas).

In the Southern Lower Peninsula, apart from the two agricultural "Thumb" counties of Huron and Sanilac, every county has a higher population density than any of the counties within the Northern Lower Peninsula region just described (excluding Grand Traverse County). Population densities range from 72 persons per square mile (Tuscola County) up through the Wayne County maximum of 3,356 persons per square mile. (All statistics here are based upon figures from the 2000 census.)

Although these three general Michigan regions each have different degrees of risk and vulnerability from weather hazards, it is important to note that <u>all</u> of them are at-risk from each of the hazards in this section. The risks merely vary by degree and severity of the "typical" impact. Every one of Michigan's 83 counties has experienced severe thunderstorms and at least one confirmed tornado. Every county is also susceptible to strong winds, extreme temperatures, and severe winter weather. The variation across Michigan is primarily one of likelihood and the range of intensity.

Therefore, for the weather hazards, it may make sense to think in terms of two parts of the year: winter and non-winter. Although mild snowfall and cold temperatures may occur a little bit outside of the main period of wintry weather, such events tend not to be serious ones, and therefore a general distinction can be made between the "winter weather risk season" and the "non-winter weather risk season." The winter weather risk season is defined in terms of historically documented events involving extreme cold and significant snowstorms. Seasons of winter weather risk include months during which record low temperatures are near enough to zero to make it likely that wind chill advisories would be issued, and when record snowfall levels have amounted to several inches. Even if these events are less likely on the "edges" of the season, since they have occurred, it made sense to define risk periods in terms of these possibilities. On the flip side, all the other months are susceptible to extreme heat (months in which record high temperatures go above 90 degrees Fahrenheit and thus make it likely that a heat advisory might need to be issued.

On the basis of this historical analysis, it was determined that the risk periods for extreme temperature and snowfall events can be assigned to the following months, for Michigan's three general regions. (NOTE: Do not use these seasons to define severe wind risks. For example, strong tornadoes have occurred recently in October.)

1. Southern Lower Peninsula: Winter risk season from late November to early April
Non-winter risk season from early May to late September
(extend that last risk season to early October for the southernmost tiers of counties, such as Berrien and Wayne)

2. Northern Lower Peninsula: Winter risk season from early November to April
Non-winter risk season from late May to late September

3. Upper Peninsula — Winter risk season from Late September to May
Non-winter risk season from late May to early September

Some variation may be expected between counties, especially shoreline counties that observe the tempering effect of the Great Lakes, but these may be good "rules of thumb" for the times of the year when different types of weather risks will occur in different parts of Michigan. The extreme heat hazard, for example, will affect the Upper Peninsula for a somewhat shorter time period each year than it does the Southern Lower Peninsula. However, this difference does not change the fact that once the risk season has arrived, both areas are at risk. In July, for example the City of Ironwood has recorded a record high temperature of 103 degrees, and although the record high temperatures in the Southern Lower Peninsula have reached 108 degrees, the all-time highest recorded temperature in Michigan actually came from the Northern Lower Peninsula, when Oscoda County hit 112 degrees (although the major weather stations at other locations across the region report records of 106 degrees). Thus, although there are differences and trends between regions and within them, the fact that all have experienced extreme heat waves must be recognized. In other words, the commonalities shared by Michigan's regions are more important than the differences, when it comes to weather-hazard preparedness and mitigation.

Historic Precipitation and Snowfall Records at Various Michigan Locations

Southern Lower Peninsula	**Record Precipitation**	**Record Snowfall**
Adrian (Lenawee County)	4.74" (Sept. 3)	15.0" (Jan. 26)
Benton Harbor (Berrien County)	6.60" (May 30)	25.0" (Dec. 6)
Coldwater (Branch County)	5.37" (June 26)	17.0" (Jan. 26)
Ann Arbor (Washtenaw County)	4.54" (Aug. 6)	15.8" (Dec.1)
Bloomingdale (Van Buren Co.)	9.78" (Sept. 1)	20.0" (Dec. 10)
Detroit (Wayne County)	4.74" (July 31)	24.5" (April 6)
Jackson (Jackson County)	5.31" (June 21)	16.0" (March 17)
Pontiac (Oakland County)	4.75" (Oct. 1)	18.0" (Dec. 2)
Flint (Genesee County)	6.04" (Sept. 10)	14.5" (Jan. 26)
Grand Rapids (Kent County)	4.22" (June 5 & Aug. 19)	16.1" (Jan. 26)
Port Huron (St. Clair County)	3.97" (Sept. 7)	14.3" (March 27)
Harbor Beach (Huron County)	6.04" (Sept. 10)	18.0" (Feb. 21)
Big Rapids (Mecosta County)	7.64" (Sept. 11)	16.0" (Jan. 30)

The counties listed above start with the southernmost tier in Michigan, and proceed generally northward, tier by tier.

Northern Lower Peninsula	**Record Precipitation**	**Record Snowfall**
Alpena (Alpena County)	5.14" (Sept. 3)	18.2" (Feb. 22)
East Tawas (Iosco County)	3.72" (Aug. 16)	20.0" (Feb. 14)
Gaylord (Otsego County)	5.00" (Aug. 17)	20.0" (Nov. 23)
Gladwin (Gladwin County)	5.00" (May 20)	15.0" (Dec. 11)
Traverse City	4.30" (Aug. 23)	16.0" (Jan. 25 & Nov. 29)
Upper Peninsula	**Record Precipitation**	**Record Snowfall**
Hancock (Houghton County)	3.58" (May 17 & Sept. 4)	26.5" (Jan. 18)
Ironwood (Gogebic County)	6.72" (July 21)	24.0" (Dec. 16)
Munising (Alger County)	3.51" (May 31)	20.0" (March 15)
Sault Ste. Marie (Chippewa Co.)	5.92" (Aug. 3)	26.6" (Dec. 10)

Source: Extreme Michigan Weather, by Paul Gross (2010, University of Michigan Press, Ann Arbor)

NOTE: The updated and newly added text for this section of the 2012 Michigan Hazard Analysis has benefited greatly from the following two books:
Extreme Michigan Weather, by Paul Gross. University of Michigan Press, Ann Arbor, 2010. (including its extensive records of weather extremes, selections of which have been added above, and to the section on extreme temperatures in the main text itself, plus additional feedback from direct contact with the author.)
Michigan Geography and Geology, edited by Randall Schaetzl, Joe Darden, and Danita Brandt. Pearson Custom Publishing, New York, et al., 2009. (especially chapter 19)

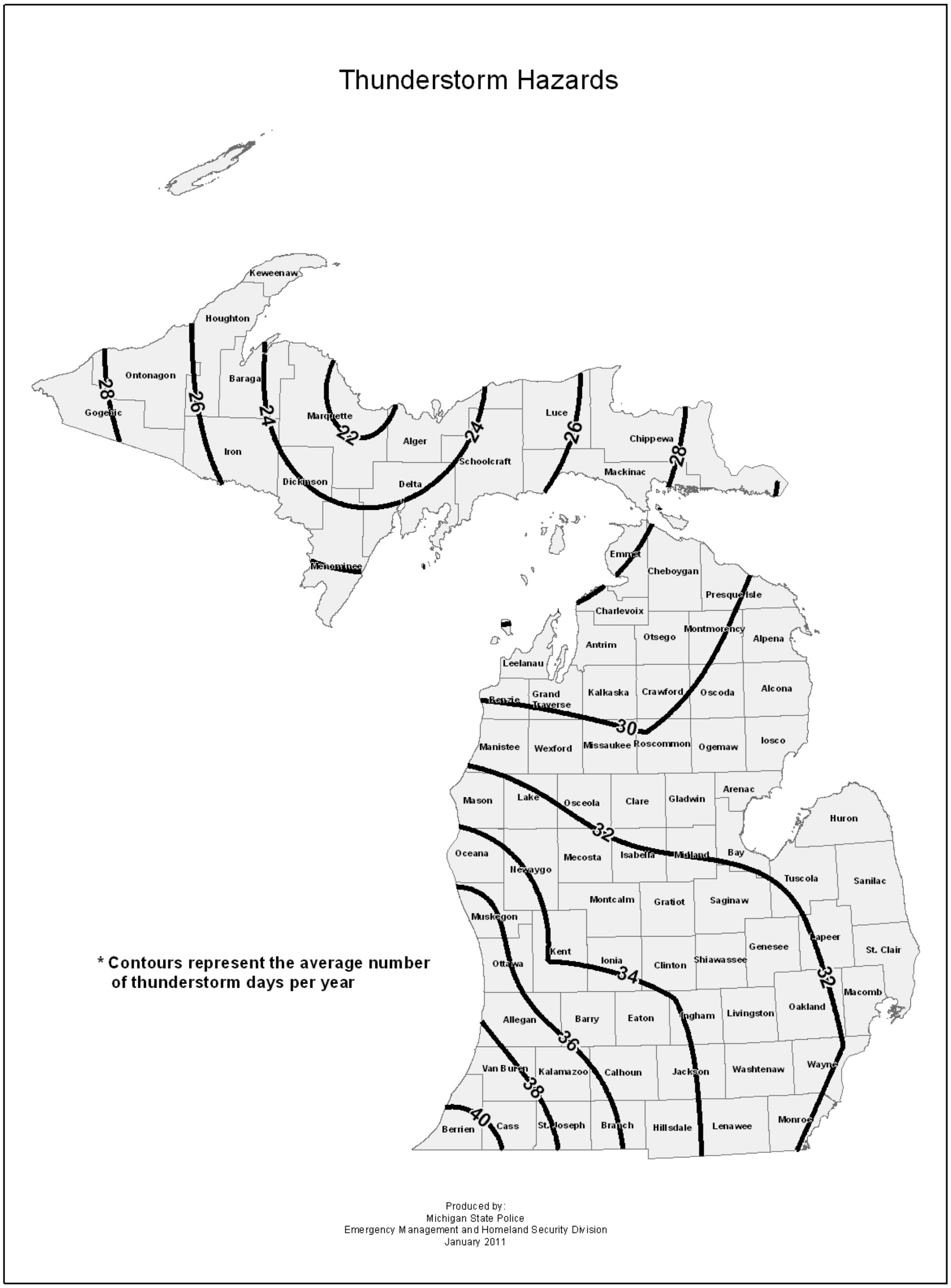
Overlap Between Weather Hazards and Other Sections of the Hazard Analysis

Extreme summer heat can increase the chances of wildfires (which has its own chapter in the "Ecological Hazards" section of this plan). Weather events involving precipitation have effects upon local hydrology. Heavy precipitation, and/or melting snow, can cause flooding. Ice jams and log jams (a source of which may include woody debris toppled into drains and streams by strong winds) can also cause flooding. For more information about flooding, please refer to the sections on Riverine and Shoreline flooding in the next section of this hazard analysis, dealing with "Hydrological Hazards." Also in the hydrological section is a chapter on droughts, which also have their origin in weather, but stem from experiencing too little precipitation rather than too much.

There is a strong connection between all of these extreme weather events and the "technological hazard" of infrastructure failure, which has its own chapter in the "Technological Hazards" section of this plan. Severe weather has also been a factor in major transportation accidents, which also has a chapter of its own in the Technological Hazards section.

Thunderstorm Hazards

Severe thunderstorms are weather systems accompanied by strong winds, lightning, heavy rain, and possibly hail and tornadoes. Severe thunderstorms can occur at any time in Michigan, although they are most frequent during the warm spring and summer months from May through September. The potential thunderstorm threat is often measured by the number of "thunderstorm days" – defined as days in which thunderstorms are observed. As the map below indicates, various areas in Michigan are subject to an average of at least 20 thunderstorm days per year, and up to just over 40 days per year in the state's southwestern corner. The Lower Peninsula, in general, is subject to approximately 28-40 thunderstorm days per year, while the Upper Peninsula average is closer to 20-30 thunderstorm days per year. This new map was based upon new weather service data from various weather stations within (and near) Michigan.



Thunderstorms form when a shallow layer of warm, moist air is overrun by a deeper layer of cool, dry air. Cumulonimbus clouds, frequently called "thunderheads," are formed in these conditions. These clouds are often enormous (up to six miles or more across and 40,000 to 50,000 feet high) and may contain tremendous amounts of water and energy. That energy is often released in the form of high winds, excessive rains, lightning, and possibly hail and tornadoes.

Thunderstorms are typically short-lived (often lasting no more than 30-40 minutes) and fast moving (30-50 miles per hour). Strong frontal systems, however, may spawn one squall line after another, composed of many individual thunderstorm cells. Severe thunderstorms may also cause severe flood problems because of the torrential rains that they may bring to an area. Thunderstorms sometimes move very slowly, and can thus dump a tremendous amount of precipitation onto a location. Flooding can result, including flash floods, "urban flooding," and riverine flooding. Please refer to the hydrological hazard section for more information about these hazards.

The following sections address in greater detail these specific thunderstorm hazards: 1) hail; 2) lightning; 3) severe winds; and 4) tornadoes (although several of these hazards can also occur when no thunderstorm activity is evident).

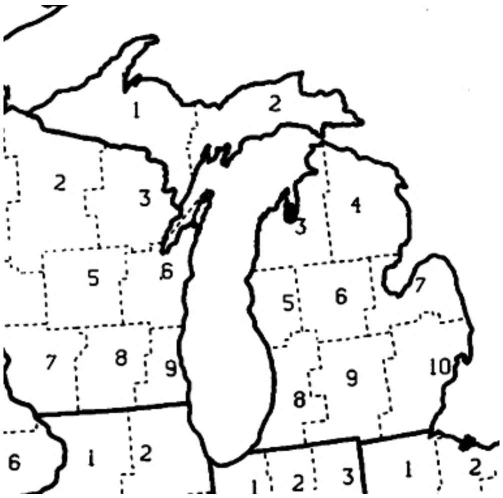
One positive aspect of assessing thunderstorm risks comes from the fact that thunderstorm hazards have some degree of predictability and are closely monitored by the National Weather Service. In addition to daily forecasts, which predict the probability of rainy or stormy weather, the NWS system of Watches and Warnings helps communities understand when there is a potential risk of severe thunderstorms, or if severe thunderstorms are imminent. When the NWS issues a "Severe Thunderstorm Watch," it means that thunderstorms with large hail and damaging winds are possible in your area. When the NWS issues a "Severe Thunderstorm Warning," it signifies that severe thunderstorms (with the damaging winds and hail) are in your area or are imminent.

The NWS has five offices that serve Michigan and are responsible for monitoring and providing predictions and bulletins for the entire state. The five offices are in Grand Rapids, Detroit, Gaylord, Marquette, and North Webster (Indiana). These stations provide information on severe weather watches and warnings, but also provide useful Doppler Radar images that track the movement of thunderstorms in your area. The North Webster office covers portions of southwest Michigan (www.weather.gov/iwx); the Grand Rapids station covers the remainder of southwest Michigan (www.weather.gov/grr); the Detroit station covers Southeast Michigan (www.weather.gov/dtx); the Gaylord station covers the north central portion of the Lower Peninsula and the eastern edge of the Upper Peninsula (www.weather.gov/apx); and the Marquette station examines the majority of the Upper Peninsula (www.weather.gov/mqt).

Since thunderstorms bring the potential for dangerous hail, lightning, straight-line winds, and tornadoes, it is necessary to further examine each of those hazards. **Useful historical information on hail, severe winds, lightning, and tornadoes for your county can be found through the National Climatic Data Center's Storm Data website at** http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms. Data for each county in the state are listed there, and there are historical records of significant events for hail (from 1955 for most counties); lightning (from 1993); severe winds (from 1955); and tornadoes (from 1950).

Michigan's 10 climate divisions (for the monitoring and analysis of precipitation)

Source: Rainfall Frequency Atlas of the Midwest, by Floyd A Huff and James R. Angel. Midwestern Climate Center and Illinois State Water Survey, 1992



Instructions for the Use of This Section

This section is useful for the assessment of rain and thunderstorm events, with implications also for flash flooding. It allows various levels of rainfall precipitation events to be interpreted in terms of their severity, based upon the historical frequency with which such events had occurred in the past.

The map at left shows Michigan's ten climate divisions, each of which is matched with data in the multi-page table below. (See **page 197** for a list of counties located within each division.) The table contains sections listing numbers for each of Michigan's ten divisions. For a given precipitation event, find the row that most closely matches the duration of the rainfall event. Move across the row to find the number that is closest to the number of inches of rainfall for that event. The column in which that number appears tells the "recurrence interval" for that level of precipitation. A recurrence interval is the average amount of time that elapses between precipitation events of that particular severity level. Longer recurrence intervals indicate a more severe event. The most extreme events listed in the table are those with a 100-year recurrence interval. Such events are so severe that they are expected (on average) to occur only about one time per century. Precipitation-based flooding is more likely to result from events with a longer recurrence interval. Any Michigan rainfall amounts that exceed the values listed in the table are very rare and severe indeed!

As an example of the procedure described above, if an Ingham County event had caused 3 inches of rain to fall during a 6-hour period, the Division 9 section of the table contains a row labeled "6-hr" and the column that most closely matches the 3" rainfall amount contains a value of 3.07", matching up with a 25-year recurrence interval (definitely a major rainfall event).

Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for each given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.69	2.04	2.35	2.76	3.17	3.45	4.28	5.34	6.17	7.27	8.11	8.99
01	5-day	1.41	1.69	1.91	2.22	2.55	2.77	3.38	4.23	4.91	5.86	6.65	7.50
01	72-hr	1.24	1.46	1.65	1.91	2.20	2.39	2.96	3.69	4.29	5.11	5.79	6.49
01	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.64	3.31	3.84	4.59	5.20	5.86
01	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.39	3.00	3.48	4.17	4.73	5.32
01	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.25	2.82	3.27	3.92	4.45	5.00
01	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.08	2.61	3.03	3.63	4.12	4.63
01	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.79	2.25	2.61	3.13	3.55	3.99
01	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.53	1.92	2.23	2.67	3.03	3.40
01	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.39	1.74	2.02	2.42	2.74	3.09
01	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.12	1.41	1.64	1.96	2.22	2.50
01	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.29	1.54	1.75	1.97
01	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.65	0.81	0.94	1.13	1.28	1.44
01	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.73	0.88	0.99	1.12
01	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.29	0.36	0.42	0.50	0.57	0.64
02	10-day	1.61	1.94	2.23	2.62	3.02	3.28	3.93	4.78	5.44	6.43	7.22	7.98
02	5-day	1.25	1.50	1.70	1.97	2.26	2.46	3.00	3.71	4.25	5.11	5.81	6.55
02	72-hr	1.15	1.35	1.52	1.77	2.03	2.21	2.62	3.27	3.78	4.57	5.23	5.94
02	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.31	2.98	3.49	4.24	4.88	5.55
02	24-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.09	2.71	3.19	3.87	4.44	5.03
02	18-hr	0.86	1.00	1.09	1.26	1.44	1.56	1.96	2.55	3.00	3.64	4.17	4.73
02	12-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.82	2.36	2.78	3.37	3.86	4.38
02	6-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.57	2.03	2.39	2.90	3.33	3.77
02	3-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.34	1.73	2.04	2.48	2.84	3.22
02	2-hr	0.53	0.61	0.67	0.78	0.88	0.96	1.21	1.57	1.85	2.24	2.58	2.92
02	1-hr	0.43	0.50	0.55	0.63	0.72	0.78	0.98	1.27	1.50	1.82	2.09	2.36
02	30-min	0.34	0.39	0.43	0.49	0.56	0.61	0.77	1.00	1.18	1.43	1.64	1.86
02	15-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.73	0.86	1.04	1.20	1.36
02	10-min	0.19	0.22	0.24	0.28	0.32	0.35	0.44	0.57	0.67	0.81	0.93	1.06
02	5-min	0.11	0.13	0.14	0.16	0.18	0.20	0.25	0.33	0.38	0.46	0.53	0.60

Page 2 of Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for each given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
03	10-day	1.63	1.96	2.26	2.66	3.06	3.33	3.99	4.92	5.65	6.66	7.50	8.35
03	5-day	1.29	1.54	1.75	2.02	2.33	2.53	3.10	3.91	4.57	5.46	6.23	7.04
03	72-hr	1.09	1.27	1.44	1.67	1.92	2.09	2.62	3.36	3.96	4.86	5.56	6.35
03	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.34	3.02	3.55	4.31	4.94	5.60
03	24-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.09	2.70	3.21	3.89	4.47	5.08
03	18-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.96	2.54	3.02	3.66	4.20	4.78
03	12-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.82	2.35	2.79	3.38	3.89	4.42
03	6-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.57	2.03	2.41	2.92	3.35	3.81
03	3-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.34	1.73	2.05	2.49	2.86	3.25
03	2-hr	0.52	0.60	0.66	0.76	0.86	0.94	1.21	1.57	1.86	2.26	2.59	2.95
03	1-hr	0.42	0.49	0.53	0.62	0.70	0.76	0.98	1.27	1.51	1.83	2.10	2.39
03	30-min	0.33	0.38	0.42	0.49	0.55	0.60	0.77	1.00	1.19	1.44	1.65	1.88
03	15-min	0.24	0.28	0.31	0.36	0.40	0.44	0.56	0.73	0.87	1.05	1.21	1.37
03	10-min	0.19	0.22	0.24	0.28	0.31	0.34	0.44	0.57	0.67	0.82	0.94	1.07
03	5-min	0.10	0.12	0.13	0.15	0.17	0.19	0.25	0.32	0.39	0.47	0.54	0.61
04	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.77	4.56	5.22	6.10	6.85	7.60
04	5-day	1.26	1.51	1.70	1.98	2.27	2.47	2.99	3.68	4.23	4.97	5.58	6.23
04	72-hr	1.12	1.31	1.48	1.72	1.98	2.15	2.63	3.27	3.75	4.45	5.00	5.60
04	48-hr	1.00	1.17	1.30	1.51	1.74	1.89	2.32	2.88	3.33	3.93	4.43	4.95
04	24-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.11	2.62	3.04	3.60	4.06	4.53
04	18-hr	0.89	1.03	1.13	1.30	1.48	1.61	1.98	2.46	2.86	3.38	3.82	4.26
04	12-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.84	2.28	2.64	3.13	3.53	3.94
04	6-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.58	1.96	2.28	2.70	3.05	3.40
04	3-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.35	1.68	1.95	2.30	2.60	2.90
04	2-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.22	1.52	1.76	2.09	2.35	2.63
04	1-hr	0.44	0.51	0.56	0.65	0.74	0.80	0.99	1.23	1.43	1.69	1.91	2.13
04	30-min	0.35	0.40	0.44	0.51	0.58	0.63	0.78	0.97	1.12	1.33	1.50	1.68
04	15-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.71	0.82	0.97	1.10	1.22
04	10-min	0.20	0.23	0.25	0.29	0.33	0.36	0.44	0.55	0.64	0.76	0.85	0.95
04	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.25	0.31	0.36	0.43	0.49	0.54
05	10-day	1.64	1.97	2.27	2.67	3.07	3.34	4.14	5.28	6.21	7.59	8.75	10.02
05	5-day	1.38	1.65	1.86	2.16	2.48	2.70	3.36	4.30	5.07	6.25	7.26	8.36
05	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.88	3.74	4.46	5.45	6.31	7.26
05	48-hr	1.04	1.22	1.36	1.58	1.81	1.97	2.53	3.34	4.01	4.97	5.81	6.73
05	24-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.28	3.00	3.60	4.48	5.24	6.07
05	18-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.14	2.82	3.38	4.21	4.93	5.71
05	12-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.98	2.61	3.13	3.90	4.56	5.28
05	6-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.71	2.25	2.70	3.36	3.93	4.55
05	3-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.46	1.92	2.30	2.87	3.35	3.88
05	2-hr	0.57	0.66	0.72	0.83	0.95	1.03	1.32	1.74	2.09	2.60	3.04	3.52
05	1-hr	0.46	0.53	0.58	0.67	0.76	0.83	1.07	1.41	1.69	2.11	2.46	2.85
05	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.84	1.11	1.33	1.66	1.94	2.25
05	15-min	0.26	0.31	0.34	0.39	0.44	0.48	0.62	0.81	0.97	1.21	1.41	1.64
05	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.48	0.63	0.76	0.94	1.10	1.27
05	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.27	0.36	0.43	0.54	0.63	0.73
06	10-day	1.76	2.12	2.44	2.87	3.30	3.59	4.31	5.36	6.21	7.46	8.51	9.54
06	5-day	1.44	1.72	1.95	2.26	2.59	2.82	3.40	4.22	4.89	6.11	7.17	8.31
06	72-hr	1.23	1.45	1.64	1.90	2.18	2.37	2.88	3.62	4.24	5.27	6.17	7.18
06	48-hr	1.09	1.28	1.42	1.65	1.90	2.06	2.51	3.17	3.71	4.59	5.35	6.20
06	24-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.27	2.85	3.34	4.15	4.84	5.62
06	18-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.13	2.68	3.14	3.90	4.55	5.28
06	12-hr	0.89	1.04	1.13	1.31	1.49	1.62	1.97	2.48	2.91	3.61	4.21	4.89
06	6-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.70	2.14	2.50	3.11	3.63	4.22
06	3-hr	0.65	0.76	0.83	0.96	1.09	1.19	1.45	1.82	2.14	2.66	3.10	3.60
06	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.32	1.65	1.94	2.41	2.81	3.26
06	1-hr	0.48	0.56	0.61	0.70	0.80	0.87	1.07	1.34	1.57	1.95	2.27	2.64
06	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.05	1.24	1.54	1.79	2.08
06	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.77	0.90	1.12	1.31	1.52
06	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.48	0.60	0.70	0.87	1.02	1.18
06	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.34	0.40	0.50	0.58	0.67

Page 3 of Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.57	1.89	2.18	2.56	2.94	3.20	3.88	4.75	5.39	6.21	6.83	7.48
07	5-day	1.22	1.46	1.66	1.92	2.21	2.40	2.96	3.68	4.23	4.99	5.61	6.26
07	72-hr	1.11	1.30	1.47	1.70	1.96	2.13	2.62	3.28	3.78	4.49	5.05	5.66
07	48-hr	1.02	1.20	1.33	1.54	1.78	1.93	2.37	2.97	3.41	4.03	4.52	5.04
07	24-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.14	2.65	3.05	3.56	3.97	4.40
07	18-hr	0.90	1.05	1.15	1.33	1.51	1.64	2.01	2.49	2.87	3.35	3.73	4.14
07	12-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.86	2.31	2.65	3.10	3.45	3.83
07	6-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.61	1.99	2.29	2.67	2.98	3.30
07	3-hr	0.62	0.72	0.78	0.91	1.03	1.12	1.37	1.70	1.95	2.28	2.54	2.82
07	2-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.24	1.54	1.77	2.06	2.30	2.55
07	1-hr	0.45	0.52	0.57	0.66	0.75	0.82	1.01	1.25	1.43	1.67	1.87	2.07
07	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.79	0.98	1.13	1.32	1.47	1.63
07	15-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.72	0.82	0.96	1.07	1.19
07	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.45	0.56	0.64	0.75	0.83	0.92
07	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.26	0.32	0.37	0.43	0.48	0.53
08	10-day	1.81	2.18	2.51	2.95	3.39	3.69	4.33	5.23	5.96	7.39	8.63	10.03
08	5-day	1.48	1.77	2.00	2.32	2.67	2.90	3.45	4.27	4.95	6.16	7.28	8.46
08	72-hr	1.29	1.52	1.72	1.99	2.29	2.49	3.00	3.75	4.41	5.50	6.45	7.51
08	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.63	3.32	3.91	4.93	5.83	6.82
08	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.37	3.00	3.52	4.45	5.27	6.15
08	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.23	2.82	3.31	4.18	4.95	5.78
08	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.06	2.61	3.06	3.87	4.58	5.35
08	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.78	2.25	2.64	3.34	3.95	4.61
08	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.52	1.92	2.25	2.85	3.37	3.94
08	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.37	1.74	2.04	2.58	3.06	3.57
08	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.11	1.41	1.65	2.09	2.48	2.89
08	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.30	1.65	1.95	2.28
08	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.64	0.81	0.95	1.20	1.42	1.66
08	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.74	0.93	1.11	1.29
08	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.36	0.42	0.53	0.63	0.74
09	10-day	1.77	2.13	2.45	2.89	3.32	3.61	4.26	5.15	5.83	6.81	7.60	8.40
09	5-day	1.43	1.71	1.93	2.24	2.58	2.80	3.36	4.10	4.71	5.57	6.27	6.99
09	72-hr	1.27	1.49	1.68	1.95	2.24	2.44	2.93	3.59	4.16	4.95	5.59	6.28
09	48-hr	1.17	1.37	1.52	1.77	2.03	2.21	2.66	3.28	3.79	4.50	5.10	5.73
09	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.42	2.98	3.43	4.09	4.63	5.20
09	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.27	2.80	3.22	3.84	4.35	4.89
09	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.11	2.59	2.98	3.56	4.03	4.52
09	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.82	2.24	2.57	3.07	3.47	3.90
09	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.55	1.91	2.20	2.62	2.96	3.33
09	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.40	1.73	1.99	2.37	2.69	3.02
09	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.14	1.40	1.61	1.92	2.18	2.44
09	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.90	1.10	1.27	1.51	1.71	1.92
09	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.65	0.80	0.93	1.10	1.25	1.40
09	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.51	0.63	0.72	0.86	0.97	1.09
09	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.36	0.41	0.49	0.56	0.62
10	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.82	4.64	5.27	6.11	6.79	7.51
10	5-day	1.28	1.53	1.73	2.01	2.31	2.51	3.05	3.68	4.16	4.78	5.26	5.74
10	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.74	3.34	3.76	4.31	4.74	5.16
10	48-hr	1.08	1.26	1.41	1.63	1.88	2.04	2.48	3.04	3.44	3.96	4.36	4.78
10	24-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.26	2.75	3.13	3.60	3.98	4.36
10	18-hr	0.97	1.13	1.23	1.43	1.62	1.76	2.12	2.59	2.94	3.38	3.74	4.10
10	12-hr	0.90	1.04	1.14	1.32	1.50	1.63	1.97	2.39	2.72	3.13	3.46	3.79
10	6-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.69	2.06	2.35	2.70	2.99	3.27
10	3-hr	0.66	0.77	0.84	0.97	1.10	1.20	1.45	1.76	2.00	2.30	2.55	2.79
10	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.31	1.59	1.82	2.09	2.31	2.53
10	1-hr	0.48	0.56	0.62	0.71	0.81	0.88	1.06	1.29	1.47	1.69	1.87	2.05
10	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.02	1.16	1.33	1.47	1.61
10	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.74	0.85	0.97	1.07	1.18
10	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.47	0.58	0.66	0.76	0.84	0.92
10	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.33	0.38	0.43	0.48	0.52

Hail

Conditions where atmospheric water particles from thunderstorms form into rounded or irregular lumps of ice that fall to the earth.

Hazard Description

Hail is a product of the strong thunderstorms that frequently move across the state. As one of these thunderstorms passes over, hail usually falls near the center of the storm, along with the heaviest rain. Sometimes, strong winds occurring at high altitudes in the thunderstorm can blow the hailstones away from the storm center, causing an unexpected hazard at places that otherwise might not appear threatened.

Most hailstones range in size from a pea to a golf ball, but hailstones larger than baseballs have occurred with the most severe thunderstorms. Hail is formed when strong updrafts within the storm carry water droplets above the freezing level, where they remain suspended and continue to grow larger until their weight can no longer be supported by the winds. They finally fall to the ground, battering crops, denting autos, and injuring wildlife and people. Large hail is a characteristic of severe thunderstorms, and it may precede the occurrence of a tornado.

Hazard Analysis

The National Weather Service began recording hail activity in Michigan in 1967. Statistics since that time indicate that approximately 50% of the severe thunderstorms that produce hail have occurred during the months of June and July, and nearly 80% have occurred during the prime growing season of May through August. As a result, the damage to crops from hail is often extensive.

The incidence of hail follows the incidence of severe thunderstorms. Therefore, those areas of the state most prone to severe thunderstorms are also the areas most prone to large and damaging hail. Generally, severe thunderstorms that produce hail occur more frequently in the southern half of the Lower Peninsula than any other area of the state. However, damaging hail has occurred in every part of Michigan. A major damaging hail event can be expected at least every 2 to 3 years.

The National Weather Service forecasts of severe thunderstorms usually give sufficient warning time to allow residents to take appropriate action to reduce the effects of hail damage on vehicles and some property. However, little can be done to prevent damage to crops. More details about the severity of Michigan events, and resulting damages, will be presented in the subsection, below, about significant Michigan hailstorms. At least $100 million in property and crop damage has occurred from hail events in Michigan since 1990. In 2009, the official cut-point that denotes severe hail events was increased from 0.75” to 1.00”.

Impact on the Public

Hail generally causes minor property damage within its area of impact, but large hail also discourages the public from outdoor activities and events, due to concerns involving safety and comfort.

Impact on Public Confidence in State Governance

If hail causes infrastructure failures, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impacts of hail. Fortunately, most episodes of hail are brief and it is usually easy to take cover to avoid being injured.

Impact on the Environment

Hail is a product of strong thunderstorms, usually occurs along with the heaviest rain, and ranges in size from a pea to a golf ball (and in some rare occurrences, a baseball). The primary effects on the natural environment include physical damage to vegetation such as forests, plants, and crops, and physical harm to wildlife species. Plants with well-established root systems will seldom die, but some younger or smaller forms of vegetation may not survive a severe hail storm. Hail can damage some fruit and vegetable plants and render them unsuitable for consumption by humans. This can also lead to an increased risk of bacteria that can kill healthy trees as well as nearby wildlife. The impact of hail can cause soil erosion that can exacerbate flooding, and large ice can potentially clog or reduce the effectiveness of drainage paths, culverts, and grates.

Lightning

The discharge of electricity from within a thunderstorm.

Hazard Description

Lightning is a random and unpredictable product of a thunderstorm's tremendous energy. The energy in the storm produces an intense electrical field like a giant battery, with the positive charge concentrated at one end and the opposite charge concentrated at the other. Lightning strikes when a thunderstorm's electrical potential (the difference between its positive and negative charges) becomes great enough to overcome the resistance of the surrounding air. Bridging that difference, lightning can jump from cloud to cloud, cloud to ground, ground to cloud, or even from the cloud to the air surrounding the thunderstorm. Lightning strikes can generate current levels of 30,000 to 40,000 amperes, with air temperatures often superheated to higher than 50,000 degrees Fahrenheit (hotter than the surface of the sun) and speeds approaching one-third the speed of light.

Hazard Analysis

Globally, there are about 2,000 thunderstorms occurring at any given time, and those thunderstorms cause approximately 100 lightning strikes upon the ground each second. In the United States, approximately 100,000 thunderstorms occur each year, and every one of those storms generates lightning. It is not uncommon for a single thunderstorm to produce hundreds or even thousands of lightning strikes. However, to the majority of the general public, lightning is perceived as a minor hazard. That perception lingers despite the fact that lightning damages many structures and kills and injures more people in the United States per year, on average, than tornadoes or hurricanes. Many lightning deaths and injuries could be avoided if people would have more respect for the threat lightning presents to their safety.

Lightning deaths are usually caused by the electrical force shocking the heart into cardiac arrest or throwing the heartbeat out of its usual rhythm. Lightning can also cut off breathing by paralyzing the chest muscles or damaging the respiratory center in the brain stem. It takes only about one-hundredth of an ampere of electric current to stop the human heartbeat or send it into ventricular fibrillation. Lightning can also cause severe skin burns that can lead to death if complications from infection set in.

As an indicator of the circumstances involving lightning fatalities, injuries and damage in the United States, consider the following statistics compiled by the National Oceanic and Atmospheric Administration (NOAA) and the National Lightning Safety Institute (NLSI) for the period of 1959-1994:

Location of Lightning Strikes

- 40% are at unspecified locations
- 27% occur in open fields and recreation areas (not including golf courses)
- 14% occur to someone under a tree (not including golf courses)
- 8% are water-related (boating, fishing, swimming, etc.)
- 5% are golf-related (on golf course or under tree on golf course)
- 3% are related to heavy equipment and machinery
- 2.4% are telephone-related
- 0.7% are radio, transmitter and antenna-related

Gender of Victims

- 84% are male; 16% are female

Months of Most Strikes

- July (30%); August (22%); June (21%)

Most Likely Time Period of Reported Strikes

- 2:00 PM – 6:00 PM

Number of Victims

- One victim (91%); two or more victims (9%)

The NLSI has estimated that 85% of lightning victims are children and young men (ages 10-35) engaged in recreation or work-related activities. Approximately 20% of lightning strike victims die, and 70% of survivors suffer serious long-term after-effects such as memory and attention deficits, sleep disturbance, fatigue, dizziness, and numbness.

Lightning can be especially damaging for electrical infrastructure, causing localized power outages and damage to phone lines and communication systems. Computers are also especially vulnerable to lightning strikes. In terms of property losses from lightning, statistics vary widely according to source. The Insurance Information Institute (a national clearinghouse of insurance industry information) estimates that lightning damage amounts to nearly 5% of all paid insurance claims, with residential claims alone exceeding $1 billion. Information from insurance companies shows one homeowner's damage claim for every 57 lightning strikes. The NLSI has estimated that lightning causes more than 26,000 fires annually, with damage to property exceeding $5-6 billion. Electric utility companies across the country estimate as much as $1 billion per year in damaged equipment and lost revenue from lightning. The Federal Aviation Administration (FAA) reports approximately $2 billion per year in airline industry operating costs and passenger delays from lightning. Because lightning-related damage information is compiled by so many different sources, using widely varying collection methods and criteria, it is difficult to determine a collective damage figure for the U.S. from lightning. However, annual lightning-related property damages are conservatively estimated at several billion dollars per year, and those losses are expected to continue to grow as the use of computers and other lightning-sensitive electronic components becomes more prevalent.

Lightning-Related Impacts on Michigan

Unfortunately, lightning has taken a tremendous toll on Michigan's citizens in terms of injury and loss of life. According to National Weather Service records through the mid-2000s, Michigan had incurred 101 lightning deaths, 711 lightning injuries, and 810 lightning casualties (deaths and injuries combined) – consistently ranking it near the top of the nation in all three categories. During the period 1959-1995 (the last period for which composite statistics were available), Michigan was ranked 2nd nationally (behind Florida) in lightning injuries, 12th nationally in lightning deaths, and 2nd nationally (again, behind Florida) in lightning casualties. Undoubtedly, the fact that Michigan is an outdoor recreation-oriented state contributes heavily to its high lightning death and injury tolls. As the following tables indicate, Michigan's lightning deaths and injuries were fairly consistent with the national trends in terms of the location of deadly or injury-causing strikes. More recent data suggests some improvement in Michigan's statistics, ranking it #13 in number of lightning deaths (11) between the years 1998 and 2008.

Lightning-Related Deaths in Michigan: 1959-July 2005

	LIGHTNING DEATHS: 101	
Number of Deaths	**Location**	**Percent of Total**
29	Open fields, ball fields	29%
26	Under trees (not golf)	26%
11	Boats / water-related	11%
10	Golf course	10%
4	Near tractors / heavy equipment	4%
2	At telephone	2%
19	Other location / unknown	19%

Source: Storm Data, National Climatic Data Center

Although Michigan's counties experience from about 20 to 40 thunderstorm days per year, there are a smaller number of known damaging lightning events per year (estimated to be at least 13 such events on average, annually). The average Michigan deaths from lightning are approximately 1.5 per year, and about 10.7 injuries per year. Property damage from major events totals over $20 million since 1990 – approximately $1.4 million per year. (Note: these calculations should be considered conservative, with the actual totals likely to be higher were a more extensive study able to be performed from a comprehensive array of sources. In these estimates, data from the National Climatic Data Center have primarily been used.) In terms of lightning risk around the state, Southwestern Michigan has the highest rate of lightning strikes, according to Global Atmospherics, Inc., with a strike ratio of 4.0 flashes/km²/yr. Locations south of Midland have strike ratios of 3.0 flashes/km²/yr, and areas north of Midland have strike ratios of 2.0 flashes/km²/yr, including the Upper Peninsula.

Lightning-Related Injuries in Michigan: 1959-July 2005

	LIGHTNING INJURIES: 711	
Number of Injuries	**Location**	**Percent of Total**
243	Open fields, ball fields	34%
104	Under trees (not golf)	15%
35	Golf course	5%
26	Boats / water-related	4%
19	At telephone	3%
20	Near tractors / heavy equipment	3%
264	Other location / unknown	37%

Source: Storm Data, National Climatic Data Center

Because it is virtually impossible to provide complete protection to individuals and structures from lightning, this hazard will continue to be a problem for Michigan's residents and communities. However, lightning deaths, injuries, and property damage can be reduced through a combination of public education, human vigilance, technology, proper building safety provisions, and simple common sense.

Large outdoor gatherings (e.g., sporting events, concerts, campgrounds, fairs, festivals, etc.) are particularly vulnerable to lightning strikes that could result in many deaths and injuries. This vulnerability underscores the importance of developing site-specific emergency procedures for these types of events, with particular emphasis on adequate early detection, monitoring, and warning of approaching thunderstorms. Early detection, monitoring, and warning of lightning hazards, combined with prudent protective actions, can greatly reduce the likelihood of lightning injuries and deaths. In addition, close coordination between event organizers, local emergency management officials, and response agencies (i.e., police, fire, emergency medical care) can help prevent unnecessary (and often tragic) delays and mistakes in rendering care should a lightning incident occur.

Impact on the Public
Lightning has a discouraging effect on outdoor activities, and has also caused casualties (including death) and severe property damage, including the ignition of structural fires and wildfires, which in turn present serious additional risks and harm to the public and its property. Electrical and communications infrastructure can be affected by lightning strikes, causing widespread inconvenience and, in some cases, life-threatening impairment of needed medical equipment and emergency response.

Impact on Public Confidence in State Governance
When lightning causes infrastructure failure, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders
Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from lightning. This makes the use of various equipment more difficult and inhibits the ability of responders to work safely outdoors.

Impact on the Environment

Trees can be blown apart completely if struck by lightning, or have branches and bark broken off that can scar and even kill them. Lightning can cause trees and natural vegetation to catch fire, and large wildfires (q.v.) can be devastating upon an area's short-term ecological condition. Dry lightning is lightning that occurs with no precipitation at ground level, and this type of lightning is the most common natural cause of wildfires. Humans and wildlife can both be killed or injured when struck by lightning, and smoke from wildfires is unhealthy to breathe.

Severe Winter Weather Hazards

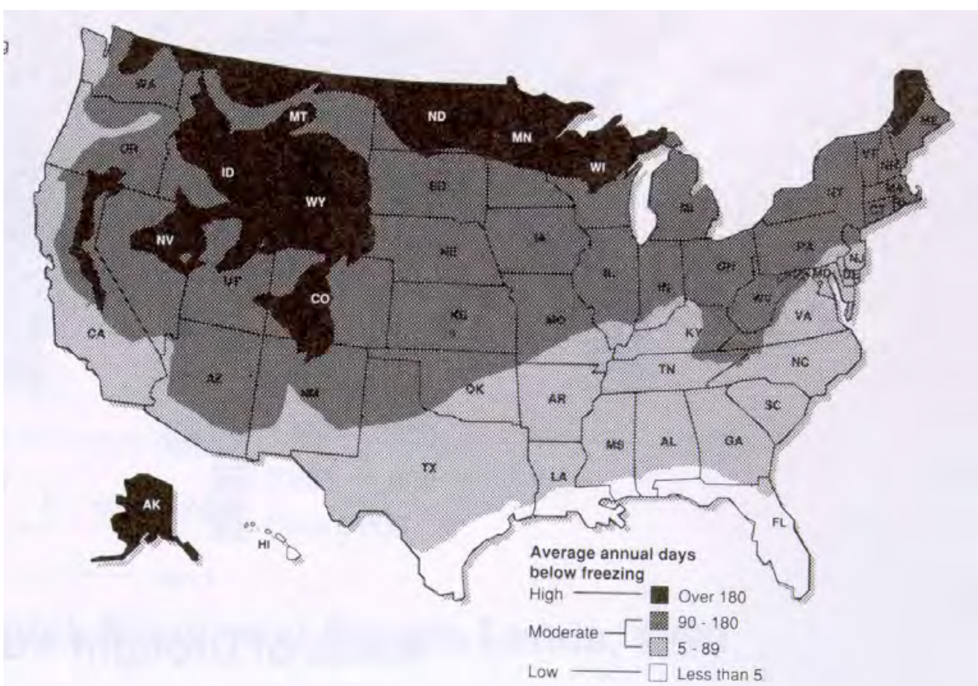
Severe winter weather hazards include snowstorms, blizzards, extreme cold, and ice and sleet storms. As a northern state, Michigan is vulnerable to all of these winter hazards. Most of the severe winter weather events that occur in Michigan have their origin as Canadian and Arctic cold fronts that move across the state from the west or northwest, although some of the most significant winter storms have their origins from the southwest, in combination with Arctic air masses. As the maps on the following pages show, Michigan averages moderate to heavy snowfall and extreme cold, averaging 90-180 days per year below freezing in the Lower Peninsula, and over 180 days below freezing in most of the Upper Peninsula. (For record snowfall amounts and a description of Michigan's three general "regions," please refer to the relevant table and text in the Introduction to the Weather Hazards section in this plan.)

The snowstorms and ice and sleet storms sections that follow provide greater detail on those particular severe winter weather hazards. The extreme temperatures section provides a more detailed overview of the severe cold temperatures hazard.

Winter storm hazards plague Michigan annually from November to March, with the state being vulnerable to snowstorms and ice and sleet storms. No area of the state is immune to severe winter conditions that can clog or paralyze the transportation network, cause widespread power outages, and slow normal daily activities to a standstill. Each community should be prepared for the harsh landscape created by snow and ice extremes. One way to understand the approaching risks of winter weather comes in the form of daily forecasts, and winter watches and warnings from the National Weather Service. The website for the NWS is www.crh.noaa.gov, which covers all regions in Michigan. To obtain recent county-level historical data since 1993 for both severe snowstorms and ice and sleet storms, visit the National Climatic Data Center's Storm Event website, http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms

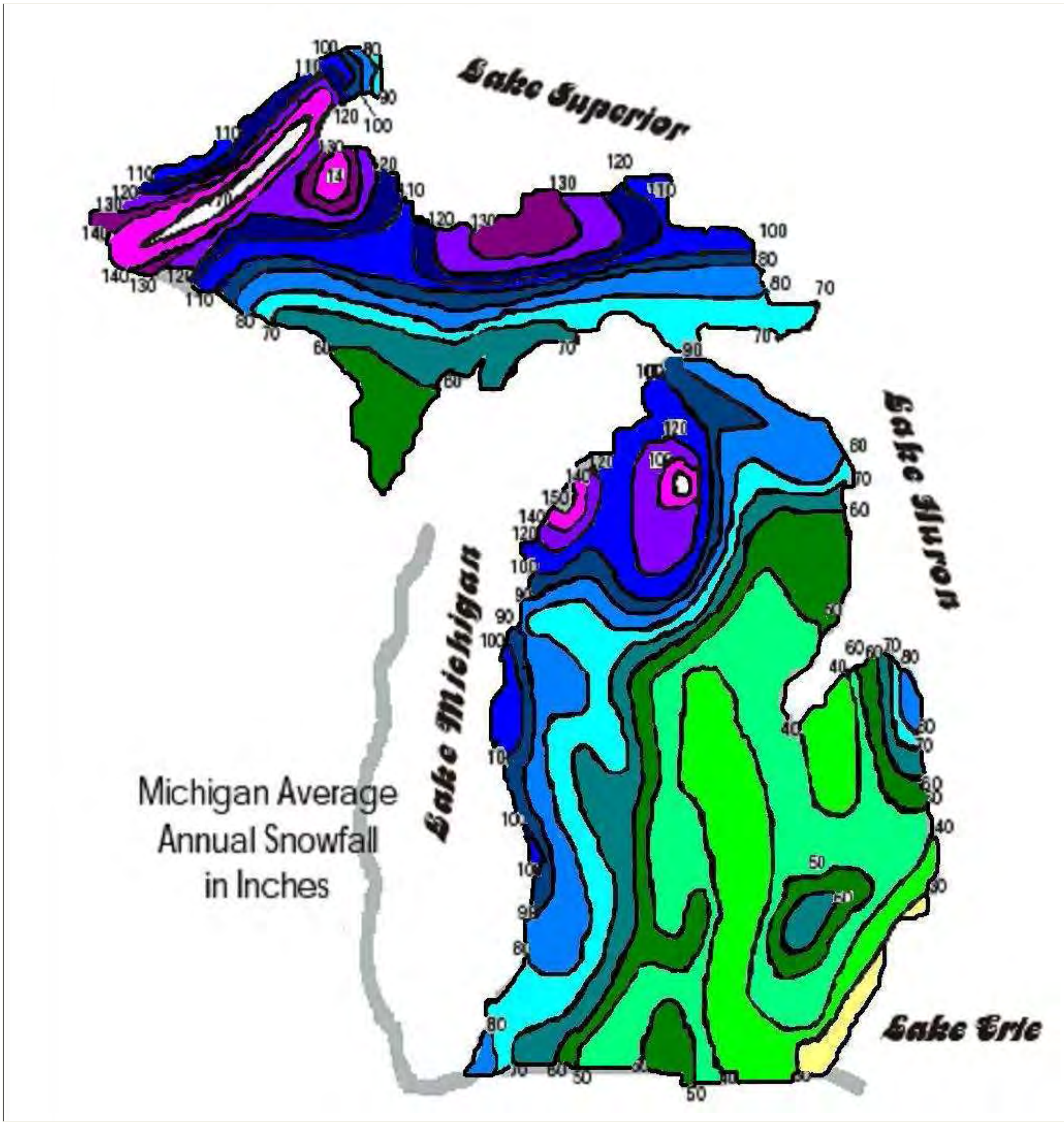
Average Annual Days Below Freezing in the U.S.

Source: Council of State Governments; Federal Emergency Management Agency



Michigan Average Annual Snowfall

Source: Michigan Committee for Severe Weather Awareness



Ice and Sleet Storms

A storm that generates sufficient quantities of ice or sleet to result in hazardous conditions and/or property damage.

Hazard Description

Ice storms are sometimes incorrectly referred to as sleet storms. Sleet is small frozen rain drops (ice pellets) that bounce when hitting the ground or other objects. Sleet does not stick to trees and wires, but sleet in sufficient depth does cause hazardous driving conditions. Ice storms are the result of cold rain that freezes on contact with a surface, coating the ground, trees, buildings, overhead wires and other exposed objects with ice, sometimes causing extensive damage. When electric lines are downed, power may be out for several days, resulting in significant economic losses and the disruption of essential services in affected communities. Often times, ice storms are accompanied by snowfall, in which the ice is camouflaged and covered up by snow, creating treacherous transportation conditions. Both storms occur when the temperature is close to 32°F, but are far more severe when the temperature is in the 20s.

Hazard Analysis

The table below illustrates the frequency distribution of ice and sleet storms in Michigan for the period 1970-July 2007. Approximately 81% of those storms occurred during the months of January, February, March and April, when conditions are most conducive for the development of ice and sleet. One-quarter of all ice and sleet storms in the period occurred during the month of March, and more than a quarter occurred in January.

By observing winter storm watches and warnings, adequate preparations can usually be made to reduce the impacts of ice and sleet conditions on Michigan communities. Providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear broken tree limbs from roadways, are the primary challenges facing community officials. Severe ice and sleet storms can affect every Michigan community. Ice storms usually have a regional effect and groups of communities are usually affected instead of just one community. Therefore, every community should plan and prepare for these emergencies. MSP/EMHSD staff has not yet found specific documentation on sleet and ice storms in the state to verify different vulnerabilities in different areas of the state. The southern parts of the state have annual winter temperatures closer to 32°F, so the prevalence for ice and sleet storms seems more likely there than in the northern areas of the state. Planning and preparedness efforts should include the identification of mass care facilities and necessary resources such as cots, blankets, food supplies and generators, as well as debris removal equipment and services. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the tree and other storm-related debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

Frequency Distribution of Ice and Sleet Storms

in Michigan: 1970 – July 2007

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
17	**10**	**14**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**9**	**59**
29%	**17%**	**24%**	**10%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**5%**	**15%**	**100%**

Source: National Weather Service; Storm Data, National Climatic Data Center (percentages are rounded off)

There is an average of about 1.6 major storm events in Michigan each year. Many ice storm deaths are actually caused by automobile accidents, heart attacks from overexertion, downed power lines, carbon monoxide poisoning, and other secondary effects that may be difficult to distinguish from other causes. In terms of property damage, major ice storm events have, according to NCDC records, caused more than $200 million in damages since 1993 (averaging $16.4 million per year), and the April 2003 ice storm was particularly severe, reportedly causing $161 million in damage. Due to this type of occasional major incident, a better estimate of annual risks would only come as a longer time-frame of data is accumulated and assessed.

Impact on the Public

Ice and sleet storms tend to cause power or other infrastructure failures that interfere with residents' activities, comfort, and safety (often through the impact of infrastructure failures on needed medical and emergency response capabilities). Direct physical effects may include frostbite, hypothermia, and other medical conditions, and thus require some citizens to be provided with warm clothing and shelter. Certain types of building designs are susceptible to structural failure from the accumulation of ice or snow on their roofs. Traffic efficiency and road capacity tends to be impeded by these weather events, which cause a large increase in the risks involved in all modes of travel. Injurious accidents may include simple pedestrian falls (due to the difficulty of balancing and walking on ice-coated surfaces), or large-scale transportation accidents (such as multi-car interstate pileups).

Impact on Public Confidence in State Governance

For this hazard, the main issues regarding public confidence in government predominantly involve: (1) the ability of the infrastructure of the impacted area to withstand the ice or sleet event and continue to serve area residents, and (2) the ability of the government(s) to efficiently clear away ice and sleet from areas that are most vitally needed for transportation and other shared public uses (e.g. schools, hospitals). If any shortcomings or failures in one or both of these functions are too evident to citizens (or mass media providers), then the capacity, efficiency, and adequacy of government(s) may be called into question. In many areas, the State and different forms of local governments and agencies will have different types of responsibilities, and where problems arise in the coordination or clarity of these governments' actions and responsibilities, discontent can reasonably be expected to be expressed by citizens.

Impact on Responders

Responders are asked to be outdoors during winter weather events in which most citizens prefer to take shelter. In addition to the risks from winds, obscured vision, impaired control of vehicles, power failures and blocked roadways, winter storm events also expose responders to extremely cold temperatures for long periods of time, and may thus compound the difficulties, risks, and expenses of response. Fatigue can more easily become a problem under extreme temperature conditions, either during winter weather emergencies or during extreme summer heat and humidity. Icy conditions make various travel and outdoor operations treacherous.

Impact on the Environment

Freezing rain drops (sleet) and dangerous ice storms coat surfaces with layers of ice and can also affect the environment. Ice storms can damage trees, as the weight of accumulated ice brings down limbs and branches, or even entire trees. When soil is not frozen, ice loads can cause root damage to forest trees. An ice coating over widespread forest lands can destroy natural forest vegetation and disrupt species' habitats, species composition, and forest land diversity. Dried dead trees may be more prone to fire, contributing to wildfires in other seasons if not removed properly. Dead trees can become breeding areas for beetles and other pests that can harm the healthy green trees. Floods often occur when ice melts, and can cause environmental effects (as described in the flooding section).

Snowstorms

A period of rapid accumulation of snow often accompanied by high winds, cold temperatures, and low visibility.

Hazard Description

As a result of being surrounded by the Great Lakes, Michigan experiences large differences in snowfall over relatively short geographic distances. The average annual snowfall accumulation in different areas ranges from 30 to 200 inches of snow. The highest accumulations are in the northern and western parts of the Upper Peninsula, as some areas of Baraga and Houghton Counties receive over 200 inches of snow per year. In Lower Michigan, the highest snowfall accumulations occur near Lake Michigan and in the higher elevations of northern Lower Michigan. Areas in the northwest portion of the Lower Peninsula average greater than 120 inches of snow annually. On the low end of snowfall totals, areas in the east central and southeastern portions of the state receive less than 50 inches of snow per year. Communities in West Michigan typically receive 60-100 inches of snow.

Blizzards are the most dramatic and perilous of all snowstorms, characterized by low temperatures and strong winds (35+ miles per hour) bearing enormous amounts of snow. Most of the snow accompanying a blizzard is in the form of fine, powdery particles that are wind-blown in such great quantities that, at times, visibility is reduced to only a few feet. Blizzards have the potential to result in property damage and loss of life. Just the cost of clearing the snow can be enormous.

Hazard Analysis

The snowfall map before the preceding section shows that the western Upper Peninsula experiences the most snowstorms and snowfall in Michigan each year. The western half of the Lower Peninsula also experiences heavy snowfall and a relatively large number of snowstorms. One reason for this is the "lake effect," a process by which cold winter air moving across Lakes Michigan and Superior picks up moisture from the warmer lake waters, resulting in larger snowfall amounts in the western part of the state.

Please refer to the table in the Introduction to the Weather Hazards section to find a table of record snowfall amounts at various locations across Michigan, and for a description and comparison of the state's three general "regions," as defined in this document. In general, the snowstorm season of the Southern Lower Peninsula runs from November to April each year. (Although snow occasionally does fall outside of this "season," such snowfall would be comparatively light, rather than the sort of snowstorm event that is here being considered as a hazard.) The snowstorm season in the Northern Lower Peninsula runs from October to May. The snowstorm season for the Upper Peninsula runs from late September to May. This does not mean that all of these months necessarily receive significant snowfall each year. Instead, the "season" denotes the part of each year when a significant snowstorm may occur. A significant snowstorm is here defined as at least several inches of snow accumulation in a single event.

By observing winter storm watches and warnings, adequate preparation can usually be made to reduce the impact of snowstorms on Michigan communities. Providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear blocked roads, are the primary challenges facing community officials. Severe snowstorms can affect every Michigan community. Therefore, every community should plan and prepare for severe snowstorm emergencies. That planning and preparedness effort should include the identification of mass care facilities and necessary resources such as cots, blankets, food supplies and generators, as well as snow clearance and removal equipment and services. Pre-planning for snow storage areas will be helpful. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the tree and other storm-related debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

Michigan sees a major regional or statewide snowstorm approximately every 5 years. Local events are more frequent. Casualties are difficult to assess because many deaths are caused by automobile accidents, heart attacks from overexertion, and other secondary impacts that may be difficult to distinguish as weather-related.

Heavy snows can shut down towns and cities for a period of a few days if snow is persistent and cannot be cleared in a timely fashion. Roof failures may occur as the weight and volume of snow cause damage to homes and buildings. Urban areas are especially susceptible to outages and problems with snow removal, while rural areas may have inaccessible roads for some time but have residents that are more prepared to handle power outages and temporary isolation. Motorists and passengers in cars can be stranded in rural areas and die of exposure because of inadequate preparation for conditions.

Impact on the Public

Snowstorms present hazards that are similar to ice storms, but occur much more frequently. Transportation impairments tend to be of longer duration and require the clearance of snowy "debris" out of the areas needed for transportation or other useful functions. The work required to move accumulated snow (which may "drift" to significant heights or be blown back in place by wintry winds) can often overwhelm the capacities of both individual residents as well as public workers and local budgets.

Impact on Public Confidence in State Governance

For this hazard, the main issues regarding public confidence in government predominantly involve: (1) the ability of the infrastructure of the impacted area to withstand the winter storm event and continue to serve area residents, and (2) the ability of the government(s) to efficiently clear away snow and ice from areas that are most vitally needed for transportation and other shared public uses (e.g. schools, hospitals). If any shortcomings or failures in one or both of these functions are too evident to citizens (or mass media providers), then the capacity, efficiency, and adequacy of government(s) may be called into question. In many areas, the State and different forms of local governments and agencies will have different types of responsibilities, and where problems arise in the coordination or clarity of these governments' actions and responsibilities, discontent can reasonably be expected to be expressed by citizens.

Impact on Responders

Responders are asked to be outdoors during winter weather events in which most citizens prefer to take shelter. In addition to the risks from winds, obscured vision, impaired control of vehicles, power failures and blocked roadways, winter storm events also expose responders to extremely cold temperatures for long periods of time, and may thus compound the difficulties, risks, and expenses of response. Fatigue can more easily become a problem under extreme temperature conditions, either during winter weather emergencies or during extreme summer heat and humidity. Snow can impede facility access and make travel and outdoor activities treacherously slippery.

Impact on the Environment

Heavy snowstorms and severe blizzards can cause environmental impacts. Snowstorms can damage trees, with the weight of heavy snow accumulations bringing down limbs, branches, or entire trees. Dried dead trees more readily catch fire, contributing to wildfires in other seasons if not removed properly. Dead trees can become a breeding ground for beetles or other pests that can harm healthy green trees in non winter seasons. Animal deaths can occur as a result of immobility, injury, infections, frost bite, hypothermia, etc. Floods often occur when snow melts, and can cause environmental effects (as described in the flooding section). Erosion from melted snow can occur, affecting beaches and soils, and harming vegetation.

Snow can function as a significant source of water pollution since it accumulates a variety of contaminants from the atmosphere and roadways. The removal of snow from roadways can damage the physical and biological environment with contaminants that include salts and salt additives, sediments, metals/emissions, asbestos, petroleum products, bacteria, organic chemicals, soil materials and litter. Those materials that accumulate in roadway-removed snow affect streams, rivers, ground water resources, and lakes, causing harm to fish species and destruction of bottom-dwelling fish fodder. The contamination of soil and groundwater can also result in vegetative stress and decreased productivity. The contamination in sediments can accumulate in the tissues of plants and animals and cause harm.

Climate Change Considerations

According to meteorologist Paul Gross, author of “Extreme Michigan Weather” (2010), the likely effects of climate change upon Michigan’s winters will involve more severe snowfall events, even though the length of Michigan’s winter season may shrink.

Severe Winds

Non-tornadic winds of 58 miles per hour or greater.

Hazard Description
Severe winds spawned by thunderstorms or other storm events have had devastating effects on Michigan, resulting in 122 deaths, nearly 700 injuries, and hundreds of millions of dollars in damage to public and private property and agricultural crops since 1970. Severe wind events are characterized by wind velocities of 58 miles per hour or greater, with gusts sometimes exceeding 74 miles per hour (hurricane velocity), but do not include tornadoes. (Please refer to the Tornadoes section which follows, for more information on that hazard.)

Hazard Analysis
Figures from the National Weather Service indicate that severe winds occur more frequently in the southern-half of the Lower Peninsula than any other area of the state. On average, severe wind events can be expected 2-3 times per year in the Upper Peninsula, 3-4 times per year in the northern Lower Peninsula, and 5-7 times per year in the southern Lower Peninsula. It must be emphasized that this refers to winds from thunderstorms and other forms of severe weather, but **not** tornadoes.

The property damage from straight line winds can be just as extreme as that of a tornado, since the damage from straight line winds is more widespread and usually affects multiple counties. In addition to property damage to buildings (especially less sturdy structures such as storage sheds, outbuildings, etc.), there is a risk for infrastructure damage from downed power lines due to falling limbs and trees. Large-scale power failures, with hundreds of thousands of customers affected, are common during straight-line wind events.

Another dangerous aspect of straight line winds is that they occur more frequently beyond the April to September time frame than is seen with the other thunderstorm hazards. It is not rare to see severe winds ravage parts of the state in October and November. Stark temperature contrasts seen in colliding air masses along swift-moving cold fronts occur regularly during those months.

National Weather Service forecasts of severe winds usually give sufficient warning time to allow residents to take appropriate action to reduce, at least to some degree, the effects of wind on structures and property. Little can be done to prevent damage from flying objects. However, proper structural bracing techniques can help minimize or even eliminate major damage due to the loss of a roof or movement of a building off its foundation.

In terms of response to a severe wind event, providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear and dispose of downed tree limbs and other debris from roadways, are the primary challenges facing Michigan communities. In addition, downed power lines present a public safety threat that requires close coordination of response efforts between local agencies and utility companies. Thunderstorms and severe winds can affect every Michigan community. Therefore, every community should adequately plan and prepare for this type of emergency. That planning and preparedness effort should include the identification of necessary resources such as cots, blankets, food supplies, generators, and debris removal equipment and services. In addition, each community should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the stream of tree and construction debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

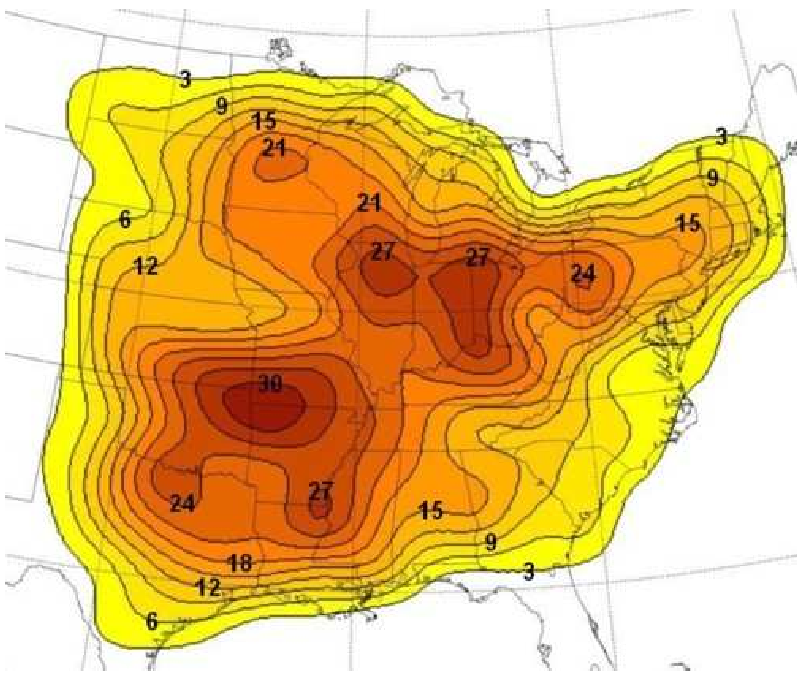
To mitigate the effects of severe winds, communities can: 1) institute a comprehensive urban forestry program, 2) properly brace and strengthen vulnerable public facilities, 3) ensure compliance with manufactured home anchoring regulations, 4) coordinate with utility companies on local restoration priorities and procedures, 5) improve local warning systems, and 6) amend local codes to require structural bracing, where appropriate, in all new residential and commercial construction.

Derecho
A Derecho, also called a bow echo, is a widespread and long-lived windstorm that is associated with a fast-moving band of severe thunderstorms. Derechos are usually not associated with a cold front, but instead with a stationary front. They occur mostly in July, but can occur at anytime during the spring or summer. The following map gives an indication of the pattern of Derecho frequency across the Midwest.

There are three types of Derechos:

- Serial Derecho - Multiple bow echoes embedded in a massive line typically around 250 miles long. This type of Derecho is usually associated with a very deep low pressure system. Also because of embedded supercells, tornadoes can easily spin out of these types of Derechos.
- Progressive Derecho - A small line of thunderstorms take a bow-shape and can travel for hundreds of miles.
- Hybrid Derecho - Has characteristics of a serial and progressive Derecho. These types of Derechos are associated with a deep low pressure system like serial Derechos, but are relatively small in size like progressive Derechos.

Moderate and High Intensity Derechos
1980-2001



Note: Numbers on map indicate the number of Derechos that occurred during the period.
Source: National Oceanic and Atmospheric Administration

On average, severe wind events can be expected 2 to 3 times per year in the Upper Peninsula, 3 to 4 times per year in the northern Lower Peninsula, and 5 to 7 times per year in the southern Lower Peninsula. Based upon an analysis of NCDC records (kept since 1990), an average of two deaths and 20 injuries occur each year from severe winds. Property damage from major events averages about $25 million per year.

Impact on the Public
Severe winds tend to impede transportation, causing slowed traffic and impaired control on roadways, and delays in the flight schedules for airlines. In addition, their physical impact can be comparable to that of a weak tornado, judged in terms of the severity of the resulting property damage, but with a more widespread area of effect. Structural collapse, and damages caused by falling trees/limbs, can cause injury and impairment of the residential and commercial use of the

affected properties. It is very common for winds to cause trees and their limbs to break communication and power lines, causing the types of impacts described for the lightning hazard (and in the section on infrastructure failures).

Impact on Public Confidence in State Governance

When winds cause infrastructure failures, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impacts of severe winds. Some winds, such as the most extreme gusts from severe straight-line winds (microbursts), can be brief, but can still be surprising and harmful to those caught in them. Strong winds can also persist for many hours and exacerbate the existing difficulties and challenges involved in emergency response—impeding traffic, causing power loss and road closures, and making the use of equipment more difficult.

Impact on the Environment

Non-tornadic winds of at least 58 mph are classified as severe winds and/or derechos. Some of the harmful effects of wind on the environment include full-grown trees being completely uprooted and knocked down, or large acreage of forest land being destroyed. Large amounts of debris, elements from collapsed structures, and destroyed natural vegetation can result from severe winds. Wildlife species can be harmed. Collapsed structures can contain combustible building materials, debris, chemicals, machinery, smoke, sewage, or other elements that can damage the environment. Lakeshore beach erosion can occur, along with rip currents in the water, as a result of severe winds. Winds can stir up sediments in waterways that can also disrupt the ecosystem.

Tornadoes

An intense rotating column of wind that extends from the base of a severe thunderstorm to the ground.

Hazard Description

Tornadoes in Michigan are most frequent in the spring and early summer when warm, moist air from the Gulf of Mexico collides with cold air from the polar regions to generate severe thunderstorms. These thunderstorms often produce the violently rotating columns of wind known as funnel clouds. Michigan lies at the northeastern edge of the nation's primary tornado belt, which extends from Texas and Oklahoma through Missouri, Illinois, Indiana, and Ohio. Most of a tornado's destructive force is exerted by the powerful winds that knock down walls and lift roofs from buildings in the storm's path. The violently rotating winds then carry debris aloft that can be blown through the air as dangerous missiles.

A tornado may have winds up to 300+ miles per hour and an interior air pressure that is 10-20% below that of the surrounding atmosphere. The typical length of a tornado path is approximately 16 miles, but tracks much longer than that – even up to 200 miles – have been reported. Tornado path widths are generally less than one-quarter mile wide. Typically, tornadoes last only a few minutes on the ground, but those few minutes can result in tremendous damage and devastation. Historically, tornadoes have resulted in tremendous loss of life, with the mean national annual death toll being 87 persons. Property damage from tornadoes is in the hundreds of millions of dollars every year.

Hazard Analysis

Tornado intensity is measured on the Enhanced Fujita Scale, which examines the damage caused by a tornado on homes, commercial buildings, and other man-made structures. The Enhanced Fujita Scale rates the intensity of a tornado based on damaged caused, not by its size. It is important to remember that the size of a tornado is not necessarily an indication of its intensity. Large tornadoes can be weak, and small tornadoes can be extremely strong, and vice versa. It is very difficult to judge the intensity and power of a tornado while it is occurring. Generally, that can only be done after the tornado has passed, using the Enhanced Fujita Scale as the measuring stick. The Enhanced Fujita Scale is presented in the table below.

The Enhanced Fujita Scale of Tornado Intensity

EF-Scale Number	Intensity Descriptor	Wind Speed (mph)	Type/Intensity of Damage
EF0	Gale tornado	65-85	Light damage. Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
EF1	Weak tornado	86-110	Moderate damage. The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
EF2	Strong tornado	111-135	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	Severe tornado	136-165	Severe damage. Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
EF4	Devastating tornado	166-200	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
EF5	Incredible tornado	Over 200	Incredible damage. Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged; incredible phenomena will occur.

NOTE: When describing tornadoes, meteorologists often classify the storms as follows:

EF0 and EF1 = weak tornado; EF2 and EF3 = strong tornado; EF4 and EF5 = violent tornado

(Source: The Tornado Project; Storm Data, National Climatic Data Center)

According to the National Weather Service (NWS), since 1950 the vast majority of tornadoes that occurred in the United States (approximately 74%) were classified as weak tornadoes (EF0 or EF1 intensity). Approximately 24% were classified as strong tornadoes (EF2 or EF3 intensity), and only 3% were classified as violent tornadoes (EF4 or EF5 intensity). Unfortunately, those violent tornadoes, while few in number, caused about 65% of all tornado-related deaths nationally. Strong tornadoes accounted for another 33% of tornado-related deaths, while weak tornadoes caused only 1% of tornado-related deaths. If the data prior to 1950 is examined, the percentage of deaths attributable to violent tornadoes climbs drastically. That is largely due to the fact that tornado forecasting and awareness programs were not yet established. As a result, it was much more likely for death tolls from a single tornado to reach several hundred.

The map and table at the end of this section show the breakdown of tornadoes by county for the period from 1950-2009. A close examination of the map indicates that tornadoes occur more frequently in the southern-half of the Lower Peninsula than any other area of the state. This area could be referred to as Michigan's "tornado alley." Most tornadoes in Michigan come from the southwest and travel northeast, with many passing through the most densely populated areas of the state.

Records indicate that tornadoes in Michigan have been more deadly than in many other tornado-prone states. Part of that is influenced by the high death toll associated with the June 8, 1953 and April 11, 1965 tornadoes. However, part is also due to the fact that several tornadoes have hit relatively densely populated areas of Michigan, increasing the fatalities. As for when those deaths occurred, the table below provides a good indicator, based upon about 55 years of events, and reveals that 96% of the state's tornado-related deaths have occurred in the months of April, May and June. June has been Michigan's most deadly tornado month, with 54% of all deaths. If the June 8, 1953 tornado death toll of 115 people is excluded, April becomes the most deadly tornado month with 77 deaths (32% of the total).

Tornado-Related Deaths in Michigan, by Month: 1950-May 2005

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
0	**0**	**3**	**77**	**23**	**130**	**3**	**1**	**1**	**0**	**1**	**0**	**239**

Source: National Climatic Data Center

Although tornadoes cannot be predicted, prevented or contained, their potential impacts on Michigan's citizens and communities can certainly be reduced. In general, improved surveillance and warning systems implemented by the National Weather Service and emergency management agencies, coupled with extensive public education campaigns, have been very effective in keeping the death toll down in recent years. However, this is not to say that a major death toll could not occur again if a strong tornado should strike a highly populated area. History has clearly shown that tornadoes must always be treated with the utmost respect and caution. Other initiatives, such as structural bracing, urban forestry practices, manufactured home anchoring, and strengthening electrical system components, can help to reduce public and private property damage.

Like severe straight-line wind events, tornado disasters require that communities plan and prepare for the mass care of residents left without electrical power and the clearance and disposal of tree and construction debris from roadways. Those are the two primary challenges facing Michigan communities. The planning and preparedness effort should include the identification of necessary mass care facilities and supplies, as well as debris removal equipment and services. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the debris stream can be handled in the most expedient, efficient, and environmentally safe manner possible.

National Weather Service data indicates that Michigan has experienced 923 tornadoes and 242 related deaths during the period from 1950 to 2009, an average of 15 tornadoes and 4 tornado-related deaths per year. The greatest number of tornadoes per year during that period occurred in 1974, with 39 tornadoes (8 of which occurred on April 3). The least number occurred in 1959, with only 2 tornadoes. From 1950 to March 2005, Michigan experienced 508 "tornado days" (defined as days in which tornadoes are observed), an average of 9 days per year.

The map and table at the end of this section list the number of tornadoes experienced in each Michigan county for the period 1950-2009. (Note: these totals do not correct for boundary-crossing tornadoes; therefore, a tornado that crosses a county boundary will be "double counted" in the totals for each county.)

All counties south of Kent and Genesee Counties have had at least 14 tornadoes touch down in their boundaries from 1950-2009 (with the exception of St. Joseph County, having only 9 tornadoes). Genesee (41), Lenawee, Kent and Oakland Counties (31 each) have had the highest total of tornadoes in the state. When adjusting for the size of the county, the highest-risk counties on a per-land area basis become Genesee (10.5 tornadoes per 10,000 square miles), Monroe (8.4), and Ingham and Berrien (8.0 each). North of Flint and Grand Rapids, only Saginaw County has had a relatively high occurrence of tornadoes, with 21. The extreme northern portion of the Lower Peninsula and the Upper Peninsula overall have a lower risk of tornadoes, with almost all counties having 11 or fewer tornadoes (although Alpena and Ogemaw had 14) over the 60-year time span. Nevertheless, the tornado impact can be disastrous for any Michigan county.

In terms of intensity, Michigan's tornado experience since 1950 has essentially mirrored the national experience. Approximately 67% of all Michigan tornadoes have been weak tornadoes (EF0 or EF1 intensity), while 29% have been strong tornadoes (EF2 or EF3 intensity) and 4% have been classified as violent tornadoes (EF4 or EF5 intensity). However, those few violent tornadoes have been responsible for 88% of Michigan's tornado-related deaths. Strong tornadoes (EF2 or EF3 intensity) have accounted for approximately 11% of the deaths, while weak tornadoes (EF0 or EF1 intensity) have caused only 1% of all tornado-related deaths. Those patterns are fairly consistent with the national averages, although Michigan has had more strong and violent tornadoes (approximately 33% in Michigan vs. 27% nationally), and its death toll from violent tornadoes is slightly higher than the national average (67% in Michigan vs. 65% nationally). Michigan's higher than average death toll from violent tornadoes is largely due to the tragic storm events that occurred in Flint in 1953 and across southern Michigan in 1965 (see the Significant Tornadoes section for more details). Unfortunately, Michigan's tornado experience to date has been more deadly than in many other tornado-prone states across the country. Michigan's tornado events have earned it a top ten ranking in three national tornado statistical categories: (1) single killer tornadoes, (2) deaths per 10,000 square miles, and (3) killer tornadoes as a percent of all tornadoes.

Killer Tornadoes: Selected Top Ten Lists

Rank	Single Killer Tornadoes (Date, State, # Deaths, F-Scale)	Tornado Deaths Per 10,000 Sq. Miles	Killer Tornadoes as % of all Tornadoes
1	March 18, 1925, MO-IL-IN, 695 deaths, F5	Massachusetts	Tennessee
2	May 7, 1840, LA-MS, 317 deaths, F?	Mississippi	Kentucky
3	May 27, 1896, MO-IL, 255 deaths, F4	Indiana	Arkansas
4	April 5, 1936, MS, 216 deaths, F5	Alabama	Ohio
5	April 6, 1936, GA, 203 deaths, F4	Ohio	Alabama
6	April 9, 1947, TX-OK-KS, 181 deaths, F5	**Michigan**	Mississippi
7	May 22, 2011, MO, 161 deaths, F5	Arkansas	North Carolina
8	April 24, 1908, LA-MS, 143 deaths, F4	Illinois	**Michigan**
9	June 12, 1899, WI, 117 deaths, F5	Oklahoma	New York
10	**June 8, 1953, MI, 115 deaths, F5**	Kentucky	Massachusetts

Source: The Tornado Project / National Weather Service

Michigan's tornado death toll is significantly influenced by two disasters: one in Flint on June 8, 1953 that caused 115 deaths and $19 million in damage, and a series of tornadoes in southern Michigan on April 11, 1965 (Palm Sunday) that caused 53 deaths and $51 million in damage. (See the tables below and on the following pages for more information on these and other significant tornadoes in Michigan.) Fortunately, the trend over time has generally been toward a lesser number of tornado deaths. During the 1950s, 153 deaths occurred, when the total number of tornadoes recorded was 109. In the 1960s, the number of deaths dropped to 66 although the number of tornadoes went up a bit, to 123. In the 1970s, despite a whopping 251 tornadoes, only 8 deaths resulted, and the trend has stayed quite low ever since. The 1980s saw 10 tornado deaths and 212 tornado events, but the 1990s saw only 2 deaths among 173 events. During the 2000s, a total of 3 deaths occurred, and the total number of events numbered 160.

According to the National Climatic Data Center, tornadoes in 2001 alone caused $28 million in property damage and $490,000 in crop damages in the state, while tornadoes in 1999 and 2000 only produced $2.4 million in property damage around the state.

Michigan has averaged about 17 tornadoes per year. At the end of this section are maps that provide information about each county's risks. An average of about 4 tornado deaths and 60 injuries takes place each year, in Michigan. Property damage averages more than $15 million per year. (NOTE: As with other weather events, these figures are conservative, actual totals are likely to be higher.) Higher-risk regions of Michigan are illustrated in the maps at the end of this section. Vulnerabilities tend to vary by the engineering of each particular type of structure.

Impact on the Public

Tornadoes are rightfully dreaded as the most severe windstorms to which most of Michigan is vulnerable. Ordinary public activities must be curtailed in order to avoid extreme danger of injury and death either from the force of the winds themselves (which have the capacity to lift persons, heavy objects, or even structures and throw them great distances), or from the impact of objects that are being thrown forcefully around by the storm. Sheltering needs are compounded by the danger of broken and flying glass—to best ensure residents' safety, it is necessary to find the most secure area possible within a structure or affected area. An underground or specially reinforced, window-free room is usually required to guarantee personal safety (sometimes at considerable economic expense). The effects of a strong tornado may disrupt normal community functions for some time, or even cause a small community to be practically destroyed. Tornadoes cause more annual injuries, on average, than any other Michigan hazard except for structural fires.

Impact on Public Confidence in State Governance

When infrastructure failures occur, as from the impact of tornadic winds, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. For example, an assumption might be made by some that the burying of power lines should be undertaken (or required by legislation), even if it involves considerable expense, whereas a full consideration of the tradeoffs involved in such burial (e.g. greater difficulty in locating and repairing a broken line) may not have been considered. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impact of winds. Fortunately, tornado events tend to be rather brief, but their unpredictability, and their difficulty of detection and avoidance, exacerbates the existing challenges involved in emergency response. Impeded traffic, power failures, debris, and road closures often make responses and the use of equipment much more difficult.

Impact on the Environment

Tornadoes are dangerous violent rotating columns of winds that can produce wind speeds from 73 to more than 300 miles per hour, and can cause severe environmental damage. Damage to the environment includes debris, fires, and chemicals from damaged and destroyed structures, vehicles, and infrastructure, which can be scattered for miles. Building materials, chemicals, smoke, sewage, and machinery can land in and cause harm to forests, valleys, streams, lakes, rivers, and wildlife species. Animals (including domesticated livestock) and other organisms can be killed or injured in the event of a tornado. Trees can easily be uprooted, branches broken off, and entire woodlands can be destroyed by tornado impacts. Rural settings can be damaged and plants can be carried to different parts of land for seeding where they otherwise would not have been. There is also an increased threat of fire in areas where dead trees are not removed in a timely matter.

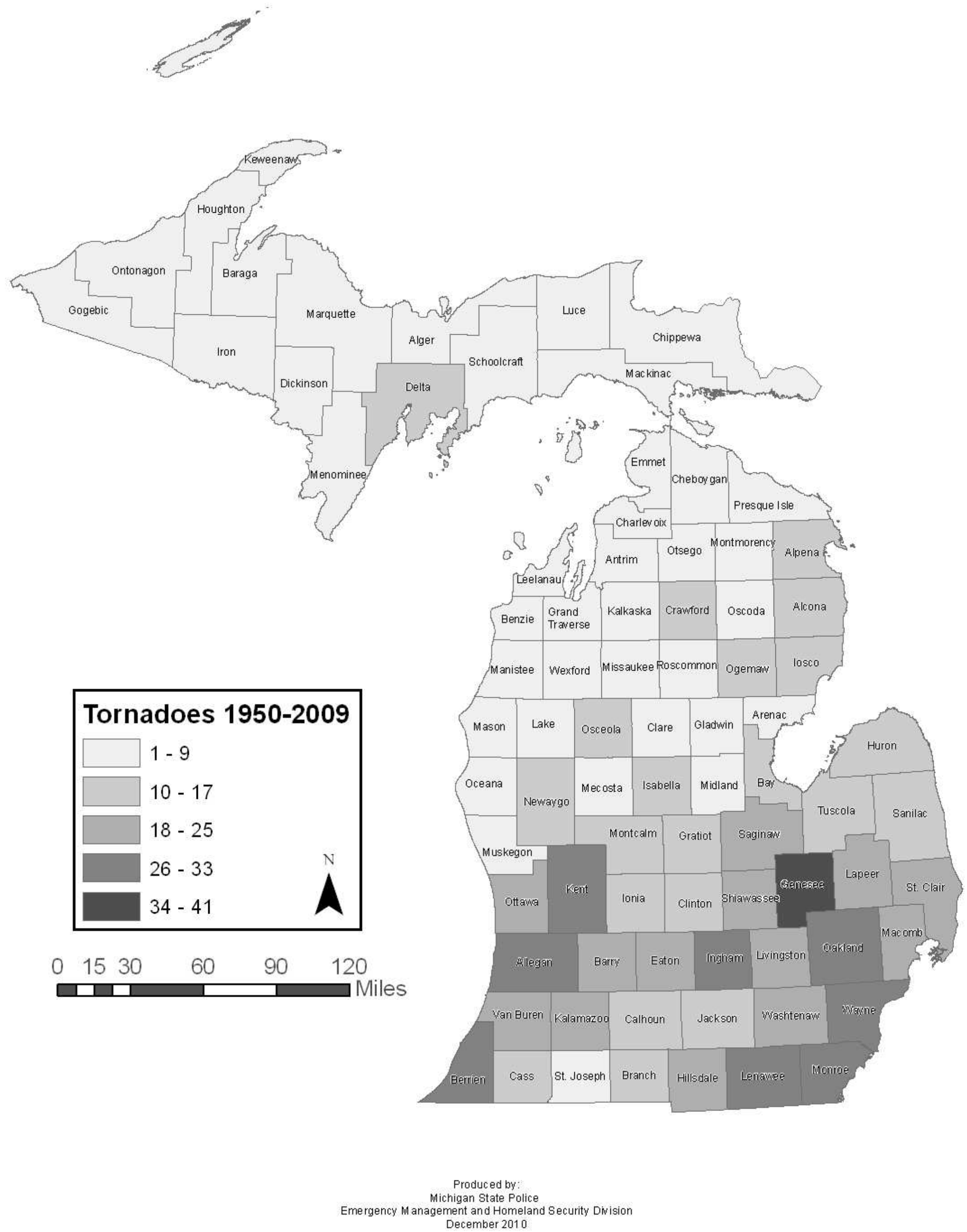
The most dangerous type of environmental impact would be when a tornado strikes a facility that contains potentially hazardous or toxic materials, farm chemicals, trash in a local landfill, medical waste awaiting disposal, or radioactive materials. Not only can material be spread around the immediate site where the tornado strikes, a small (but important) fraction can be carried aloft and transported a great distance down streams or rivers. There is also a possibility that tornadoes can cause the spread of diseases, or fungi found in certain soils. Gas lines can also be ruptured and harm local air quality as well as cause environmental damage by seeping into the soil, rivers, lakes, and streams.

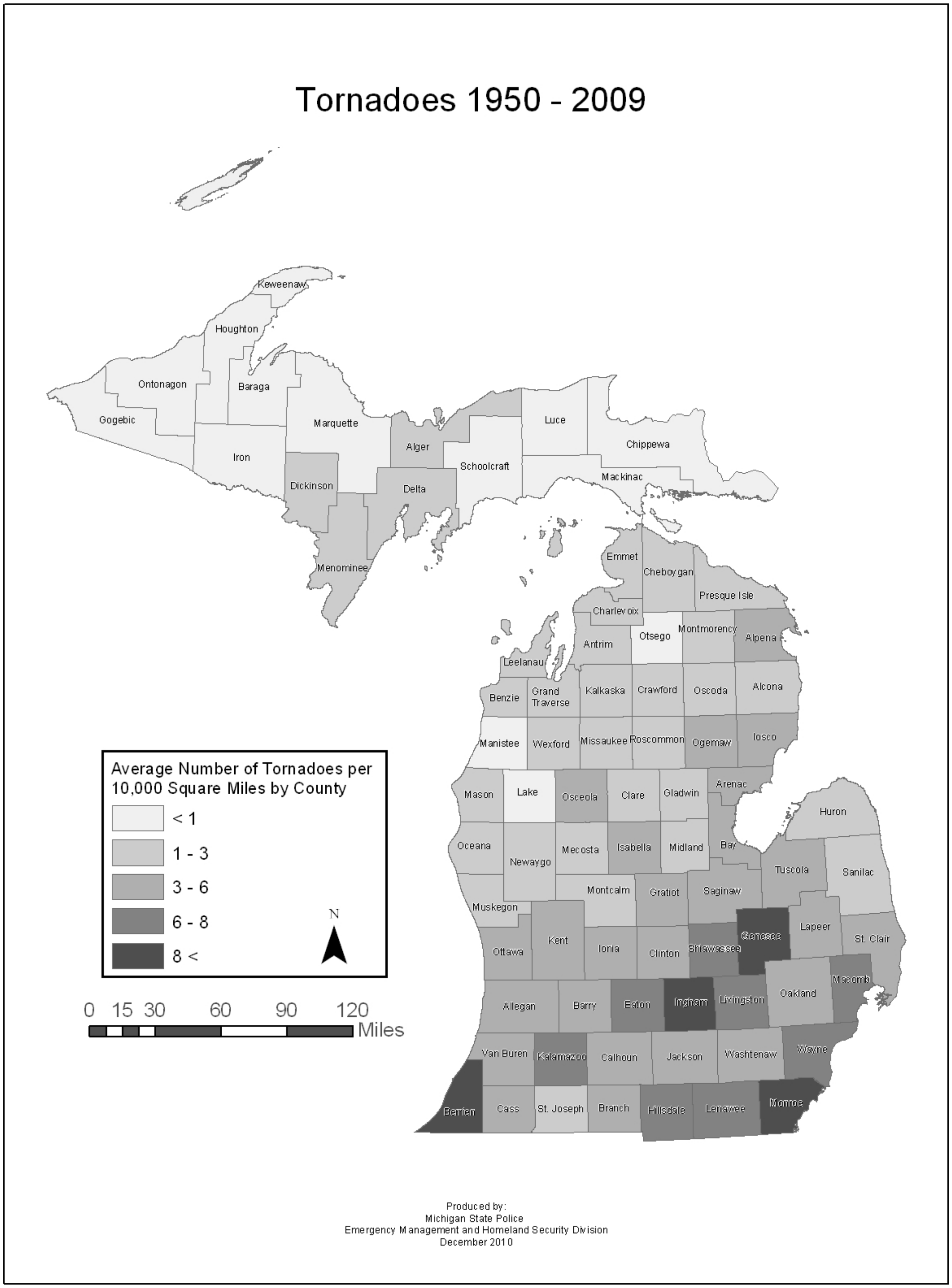
Number of Tornadoes in Michigan, by County: 1950- 2009

County (A-K)	Tornadoes: 1950-2009	County (L-Z)	Tornadoes: 1950-2009
Alcona	11	Lake	2
Alger	6	Lapeer	20
Allegan	26	Leelanau	3
Alpena	14	Lenawee	31
Antrim	9	Livingston	24
Arenac	7	Luce	2
Baraga	2	Mackinac	5
Barry	18	Macomb	18
Bay	12	Manistee	2
Benzie	4	Marquette	6
Berrien	28	Mason	5
Branch	15	Mecosta	9
Calhoun	15	Menominee	7
Cass	14	Midland	8
Charlevoix	4	Missaukee	8
Cheboygan	6	Monroe	28
Chippewa	6	Montcalm	11
Clare	8	Montmorency	6
Clinton	17	Muskegon	7
Crawford	10	Newaygo	12
Delta	11	Oakland	31
Dickinson	7	Oceana	5
Eaton	25	Ogemaw	14
Emmet	5	Ontonagon	2
Genesee	41	Osceola	16
Gladwin	9	Oscoda	5
Gogebic	3	Otsego	3
Gd. Traverse	4	Ottawa	18
Gratiot	12	Presque Isle	6
Hillsdale	23	Roscommon	8
Houghton	1	Saginaw	21
Huron	12	Sanilac	14
Ingham	27	Schoolcraft	3
Ionia	17	Shiawassee	25
Iosco	11	St. Clair	20
Iron	5	St. Joseph	9
Isabella	13	Tuscola	17
Jackson	17	Van Buren	18
Kalamazoo	25	Washtenaw	24
Kalkaska	7	Wayne	28
Kent	31	Wexford	7
Keweenaw	2	STATEWIDE:	923

IMPORTANT NOTE: Tornadoes that crossed county lines are counted more than once in this table.
Therefore, the statewide total is less than the sum of the individual county totals.
Source: National Weather Service

Historic Tornadoes per County





Tornado Frequency, by land area (per 10,000 square miles)

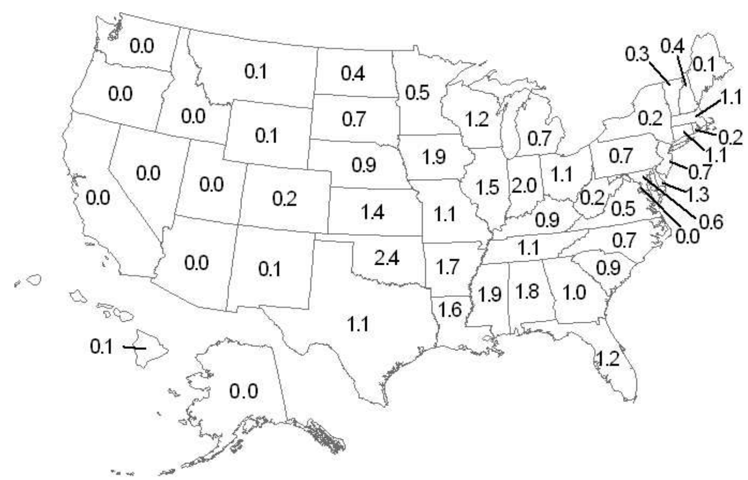
Comparative National Tornado Statistics

Source: National Weather Service

Annual Average Number of Strong-Violent (F2-F5) Tornadoes by State

* Theses maps use data for the years 1950 to 2009 for the State of Michigan only, but the rest of the states show data only for the years 1950 to 1995. Although updated national maps were not available from the National Weather Service for use in this plan, new information for Michigan was readily provided upon request, and these maps were then revised by MSP/EMHSD staff to reflect this new data

Average Annual Number of Strong-Violent (F2-F5) Tornadoes per 10,000 Square Miles by State



Michigan State Police
Emergency Management & Homeland Security Division
January 2011

Extreme Temperatures

Prolonged periods of very high or very low temperatures, often accompanied by other extreme meteorological conditions.

Hazard Description

Prolonged periods of extreme temperatures, whether extreme summer heat or extreme winter cold, can pose severe and life-threatening problems for Michigan's citizens. Although they differ in their initiating conditions, the two hazards share a commonality in that they both tend to have a special impact on the most vulnerable segments of the population—the elderly, young children and infants, impoverished individuals, and persons who are in poor health. Due to their different characteristics, extreme summer heat and extreme winter cold hazards will mostly be discussed separately in this section. For both types of temperature extremes, however, a longer hot or cold spell makes the temperature effects much more severe on vulnerable populations—a longer duration tends to produce more severe effects.

Hazard Analysis

Extreme Summer Heat is characterized by a combination of very high temperatures and humid conditions. When persisting over a long period of time, this phenomenon is commonly called a heat wave. The major threats of extreme summer heat are heat exhaustion and heatstroke (a major medical emergency). **Heat exhaustion** is a less severe condition than heatstroke, but it causes problems involving dizziness, weakness and fatigue. Heat exhaustion is often the result of fluid imbalance due to increased perspiration in response to the intense heat. Treatment generally consists of restoring fluids and staying indoors in a cooler environment until the body returns to normal. If heat exhaustion is not addressed and treated, it can advance to heatstroke, so medical attention should be sought immediately.

Heatstroke symptoms include a high body temperature (it can be 106 degrees or higher), dry skin, inadequate perspiration, paleness or reddening, confusion or irritability, and seizures. The victim may become delirious, stuporous, unconscious, or even comatose. Cooling is essential to preventing permanent neurological damage or death. Other, less serious risks associated with extreme summer heat are often exercise-related and include **heat cramps** (an imbalance of fluids that occurs when people unaccustomed to heat exercise outdoors) and **heat syncope** (a loss of consciousness by persons not acclimated to hot weather). Periods of hot weather also entail risks of dehydration, even for those who are not engaged in demanding physical activities. Non-caffeinated fluids should be consumed to maintain adequate hydration.

A useful set of general principles to recognize is that evaporation is a cooling mechanism for our bodies. Evaporation of moisture (i.e. perspiration) doesn't occur as rapidly when the surrounding air already has a relatively high moisture content (humidity). Thus, humidity inhibits evaporation and produces a feeling of greater heat, while winds assist the evaporation of perspiration from skin and thus tend to produce a feeling of greater coolness. It can therefore be difficult for the body to precisely gauge actual outdoor temperatures—it rather senses the potential for heat gain or loss. A period of extreme heat is more debilitating when the air humidity is high, and a period of extreme cold is similarly more dangerous when coupled with strong winds. For these reasons, temperature alone is usually only a limited indicator of the weather's likely threat to human health, and additional factors should also be considered. The additional factors of humidity and wind speed have provided the basis for two additional means of describing the extent of extreme temperatures' impact—the **Heat Index** (HI) and the **Wind Chill Temperature Index** (WCT).

The following tables indicate the way that temperature, humidity, and wind speed probably feels to the human body, and suggest the types of temperature effects relevant to Michigan's climate. Although some of the resulting heat numbers may at first seem outrageous to describe Michigan temperatures, some of the extremes are actually comparable to what is felt in a sauna, which is often set at more than 140 degrees. Like saunas, such heat should not be felt by the body for more than brief periods of time, and since one of the body's cooling reactions is to increase the rate of blood circulation, this also adds to the burden placed on the heart muscle, and can be too much strain for some persons to bear.

HEAT INDEX	Actual Temperature (degrees Fahrenheit)									
Rel. Humidity	**90**	**92**	**94**	**96**	**98**	**100**	**102**	**104**	**106**	**108**
40%	91	94	97	101	105	109	114	119	124	130
45%	92	96	100	104	109	114	119	124	130	137
50%	95	99	103	108	113	118	124	131	137	144
55%	97	101	106	112	117	124	130	137	145	
60%	100	105	110	116	123	129	137	145		
65%	103	108	114	121	128	136	144			
70%	106	112	119	126	134	143				
75%	109	116	124	132	141					
80%	113	121	129	138						
85%	117	126	135	145						
90%	122	131	141							
95%	127	137								

Source: formulas obtained from the National Climatic Data Center

TECHNICAL NOTE: The two indices can also be summarized by the following mathematical formulas, in which T means temperature (in degrees Fahrenheit), H means relative humidity (%), W means wind speed (in miles per hour), and E denotes a shorthand for scientific notation (times 10 raised to the power of the number that follows the E):

$HI = -42.38 + 2.049T + 10.14H - 0.2248HT - (6.838E\text{-}3)T^2 - (5.482E\text{-}2)H^2 + (1.229E\text{-}3)HT^2 + (8.528E\text{-}4)H^2T - (1.99E\text{-}6)H^2T^2$

$WCT = 35.74 + 0.6215T - 35.75(W^{0.16}) + 0.4275T(W^{0.16})$

WIND CHILL	Actual Temperature (degrees Fahrenheit)									
Wind speed (mph)	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**
5	36	25	13	1	-11	-22	-34	-46	-57	-69
10	34	21	9	-4	-16	-28	-41	-53	-66	-78
15	32	19	6	-7	-19	-32	-45	-58	-71	-83
20	30	17	4	-9	-22	-35	-48	-61	-74	-88
25	29	16	3	-11	-24	-37	-51	-64	-78	-91
30	28	15	1	-12	-26	-39	-53	-67	-80	-94
35	28	14	0	-14	-27	-41	-55	-69	-82	-96
40	27	13	-1	-15	-29	-43	-57	-71	-84	-98
45	26	12	-2	-16	-30	-44	-58	-72	-86	-100
50	26	12	-3	-17	-31	-45	-60	-74	-88	-102
55	25	11	-3	-18	-32	-46	-61	-75	-89	-104
60	25	10	-4	-19	-33	-48	-62	-76	-91	-105

Other tables and calculators can be found online, such as the tables for a heat index at http://www.ncdc.noaa.gov/oa/climate/conversion/heatindexchart.html, or the tables and calculator for wind chill at http://www.nws.noaa.gov/om/windchill/.

Heat Index above 130 degrees:
Extreme Danger (Heat stroke or sunstroke is highly likely with prolonged exposure and/or physical activity)

Heat Index in the 105 to 129 degree range:
Danger (Sunstroke, muscle cramps, heat exhaustion is likely with prolonged exposure and physical activity)

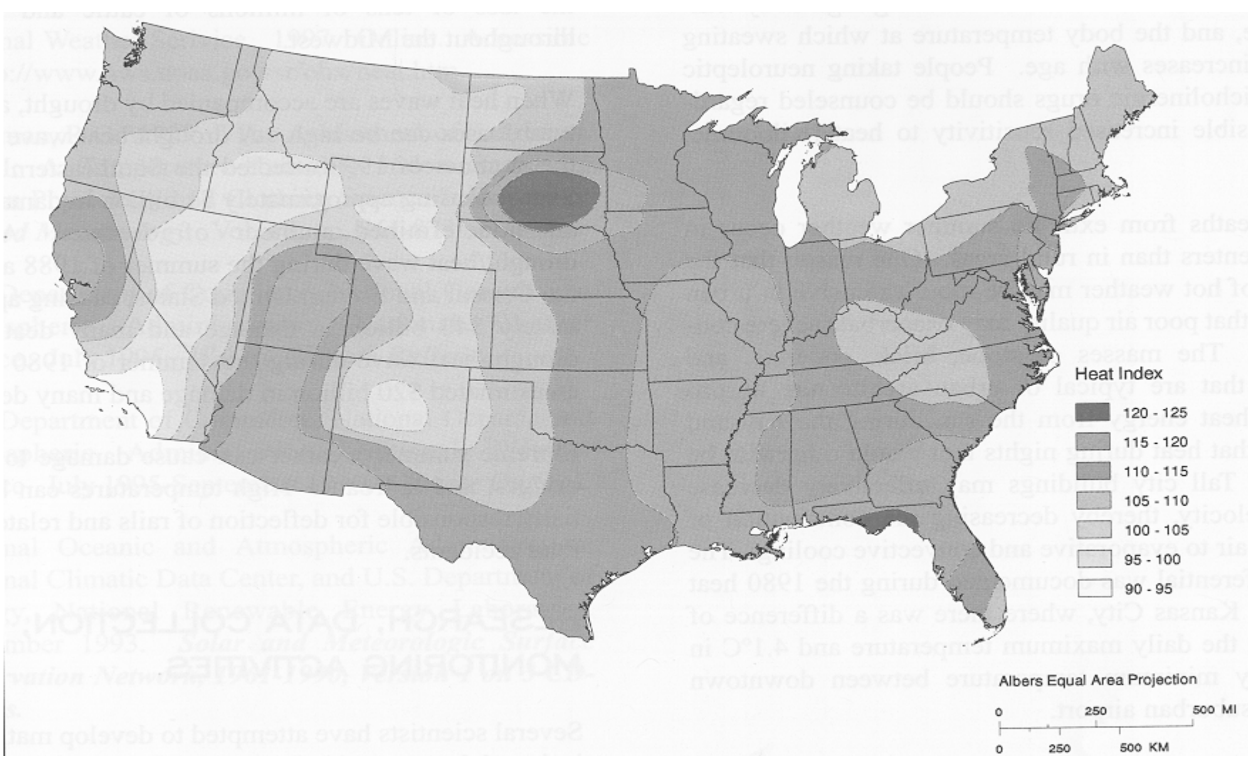
Heat Index in the 90 to 104 degree range:
Extreme Caution (Sunstroke, muscle cramps and/or heat exhaustion possible with prolonged exposure/activity)

Heat Index up through 89 degrees:
Caution (Fatigue possible with prolonged exposure and/or physical activity)

Although these indices involve a fairly straightforward means of expressing the "feel" of the weather in terms of a temperature equivalent, conditions for each individual will still vary with the duration and type of weather exposure, personal health, extent of acclimation, and the type of clothing worn. For example, exposure to full sunshine can increase heat index values by up to 15%. Also, cooler air holds less moisture, and dryer air readily allows the cooling evaporation of perspiration from skin. In other words, the heat index and wind chill index only involve a consideration of two important factors, but they are still more useful than a consideration of temperature alone. The Heat Index table assumes shady conditions with a light wind. Actual indoor conditions may vary, trapping heat and/or humidity in some locations and making them potentially much more dangerous. Prolonged exposure, physical activity, and age all tend to increase the risks associated with heat. Conditions that might cause heat cramps in a teenager could be experienced as heat exhaustion by a middle-aged person, and as heat stroke by a senior citizen. Young infants, however, are also vulnerable to heat effects.

Extremely high numbers are not shown in the table, since there are limits on the extent to which both humidity and heat would be experienced as a part of Michigan's weather (shown on the map below). However, the following guidelines are recommended, to make better use of the raw numbers:

**Severity and Extent of Extreme Summer
Heat in the United States**



Source: U.S. Department of Commerce; *Multi-Hazard Identification and Risk Assessment*, 1999, FEMA

In Michigan, heat advisories will tend to be announced when the heat index is calculated to exceed 105 degrees in an area for a period of at least 3 hours in duration. It should be noted, however, that the temperature inside of vehicles without air conditioning can be dozens of degrees hotter than the outdoor temperature—an outdoor temperature might be "only" 100 degrees Fahrenheit, but people may then get into a car that exceeds 130 degrees. People vary in the conditions in which they operate (and in their capacity to tolerate extreme temperatures), and can find themselves in circumstances that threaten their health even if no official temperature advisory has been issued.

Heat waves tend to have stagnant atmospheric conditions that trap pollutants in urban areas and thus compound the health effects faced by urban residents. Because the combined effects of high temperatures, high humidity, and trapped pollution are focused more intensely in urban centers, heatstroke and heat exhaustion are a greater problem in sizeable cities than in suburban or rural areas. Nationwide, approximately 135 deaths per year are attributable to extreme heat (a total of 3,311 over the 24 year period from 1986 to 2009, according to http://www.nws.noaa.gov/om/hazstats/images/70-years.pdf). Extreme summer heat is also hazardous to livestock and agricultural crops, and it can cause water shortages, exacerbate fire hazards, and prompt excessive demands for energy. Roads, bridges, railroad tracks and other infrastructure are susceptible to damage from extreme heat (due to the effects of thermal expansion of materials). Scorching weather also puts a strain on the energy demands for an area, as the use of air conditioning increases greatly. Possible shutdowns of schools, colleges, and industries can occur during these times.

Air conditioning is probably the most effective measure for mitigating the effects of extreme summer heat on people. Unfortunately, many of those most vulnerable to this hazard do not live or work in air-conditioned environments, especially in major urban centers where the vulnerability is highest. The use of fans to move air may help some persons feel more comfortable, but when the temperature reaches the high 90s, fans will not prevent heat-related illness. Bathing with cool water is more effective, but moving to a cooler environment (a basement or air-conditioned location) is most effective—even if only for a few hours per day.

To mitigate the extreme heat of summer, communities should have a contingency plan in place to protect those people who are most vulnerable to the heat. These contingency plans should include: setting up "cooling stations" where people can go to get out of the heat; a hierarchy of closings for industries, businesses, and schools during shutdown periods; and a means of explaining the dangers of heat conditions, such as pamphlets and local broadcast and print media. Monitoring of dangerous conditions can also be done through the National Weather Service website. A risk assessment should calculate the likelihood of such incidents and the number of days of extreme temperatures likely to be experienced in your community each year. It should also take account of past losses and harm caused by such events, and determine who or what is still vulnerable to such conditions today.

Heat waves severe enough to threaten health do not occur every year, and several relatively mild summers may intervene between major heat waves. The problem is complicated by the fact that long-term weather forecasts cannot reliably predict prolonged periods of extreme summer heat. Short-term forecasts of hot weather are more accurate, but often leave little time for mobilizing to effectively combat the hazard. Nevertheless, planning and preparedness activities can occur to mitigate the effects of this weather hazard.

Because of its geographic location in relation to the Great Lakes, Michigan is somewhat less susceptible to prolonged periods of extreme hot temperatures than are many other states. However, the Upper Midwest, in which Michigan is located, is definitely vulnerable to extreme temperature events. As a result, Michigan communities (and particularly urban centers) must always be prepared to respond to heat events in an organized, coordinated and expedient manner. Extreme summer heat poses the greatest danger to urban residents—especially the elderly, children, outdoor laborers, people with poor health, and people residing in homes without air conditioning. Michigan's urban communities must address extreme summer heat in their emergency preparedness efforts. Human service agencies, voluntary organizations, health departments, medical and health care facilities, and schools may have a role in response to a heat wave. The Michigan Department of Community Health, together with local health departments, medical and health care facilities, may have to establish specialized medical surge facilities to assist in the care of a large number of persons who may be affected in such events. In addition, the local media could be tapped to assist in information dissemination and community outreach efforts.

In an average year, Michigan has many days above 90° Fahrenheit. MDCH and NWS estimate about 5 deaths per year, on average, due to extreme heat. Although larger cities have been noted as having more risk from extreme heat, it should also be noted that residents in isolated rural locations may have trouble accessing air-conditioned places, or reaching designated cooling shelters. Such access may be easier for urban residents.

Extreme Winter Cold periods can, like heat waves, result in a significant number of temperature-related deaths. Each year in the United States, approximately 700 persons die as a result of severe cold temperature-related causes. This is substantially higher than the average of 175 heat-related deaths each year. It should be noted that a significant number of cold-related deaths are not the direct result of "freezing" conditions. Rather, many deaths are the result of illnesses and diseases that are negatively impacted by severe cold weather, such as stroke, heart disease and pneumonia. It could convincingly be argued that, were it not for the extreme cold temperatures, death would not have occurred at the time that it did due to the illness or disease alone. There are, in various parts of Michigan, an average of between 3 and 50 (or more) days per year at or below 0° Fahrenheit. Michigan also tends to have between 90 and 180 (or more) days per year in which the temperature is below the freezing point.

Hypothermia (the unintentional lowering of core body temperature), and **frostbite** (damage from tissue being frozen) are probably the two conditions most closely associated with cold temperature-related injury and death. Hypothermia is usually the result of over-exposure to the cold, and is generally thought to be clinically significant when core body temperature reaches 95 degrees or less. As body temperature drops, the victim may slip in and out of consciousness, and appear confused or disoriented. Treatment normally involves warming the victim (preferably performed by trained medical personnel) but frostbitten areas should not be rubbed. Although frostbite damage itself rarely results in death (which may occur due to hypothermia instead), in extreme cases it can result in the amputation of the affected body tissue.

Periods of extreme cold are risky for those in both rural and in urban areas. Frostbite and hypothermia is common in rural areas where people are trapped outdoors and do not adjust properly to the temperatures. Even indoors, hypothermia is a concern for individuals living in inadequately heated apartments or rooms. Loss of life can occur with either of these situations. Damage to buildings and pipelines can also occur in bitter cold conditions, resulting in expensive repairs and potential days of business and school shutdowns.

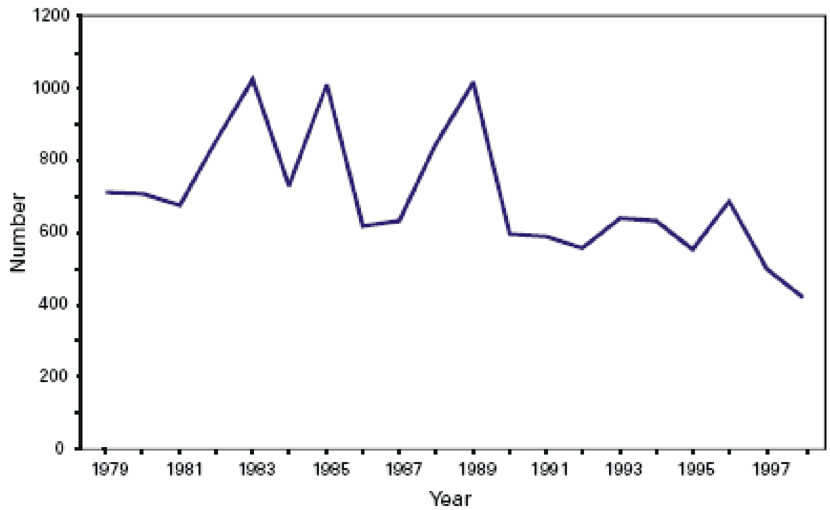
To mitigate the effects of the unfavorable cold temperatures, communities should make sure that housing codes are appropriate and that adequate furnaces are in place in apartment dwellings. Inspections of vulnerable and outdated infrastructure should be made in the fall season, before winter sets in. In addition, proper insulation of piped areas can prevent water main breaks.

In the wind chill chart, extremely low apparent temperatures can also be associated with an amount of exposure time that it takes to cause frostbite. Cells of the table that have darker shadings denote wind chill temperatures that can produce frostbite in 10 minutes or less. Cells with lighter shadings are associated with frostbite times of 30 minutes or less. Unshaded cells in the table should require longer exposure times to cause frostbite. Again, the chart displays only two factors that contribute heavily to risk, but risk can be increased for an individual in particular circumstances. For example, people should be aware that the drier air (common to winter weather) also allows a more rapid drop in temperature than is the case with warm summer air. As a cold front moves in, or as daytime high temperatures for the day change to nighttime low temperatures, the corresponding drop in temperature can be much greater when the humidity is low. Persons who are outdoors can rapidly find themselves in danger of hypothermia.

Hypothermia usually occurs in one of two sets of circumstances. One situation involves hypothermia associated with prolonged exposure to cold while participating in outdoor sports such as skiing, hiking or camping. Most victims of this form of hypothermia tend to be young, generally healthy individuals who may lack experience in dealing with extreme cold temperatures. The second situation involves a particularly vulnerable person who is subjected to only a moderate, indoor cold stress. A common example would be that of an elderly person living in an inadequately heated home. In such circumstances, hypothermia may not occur until days or perhaps weeks after the cold stress begins. Isolated rural locations may involve difficulties in reaching a heated space, or a designated warming shelter.

Deaths due to extreme winter cold are often not associated with a particular weather event. Rather, they are the result of a one-time over-exposure to severe cold weather (a hiker lost in the woods, or car failure in a rural area), or more commonly from continuous exposure to moderate cold temperatures by vulnerable persons (such as the elderly). In some cases, hypothermia deaths can be linked to severe winter weather such as snowstorms or blizzards, where the victim is caught unprepared for the extreme cold temperatures. As mentioned earlier, many cold temperature-related deaths involve the exacerbation of an existing, serious medical condition such as heart disease or pneumonia. In Michigan, approximately 70% of weather-related fatalities (about 40 deaths per year) are attributed to exposure to the cold (according to the Michigan Department of Community Health and the National Weather Service). The following 20-year table gives an indicator for the nation as a whole.

Number of Hypothermia-Related Deaths in U.S.: 1979-1998



Source: CDC Morbidity and Mortality Weekly Report

The special vulnerability of elderly persons to hypothermia has become apparent. Over half of the hundreds who die each year due to cold exposure are 60 years of age or older, even though this age group only represents about 20% of the country's population. This remarkable statistic may be due, in part, to an impaired perception of cold as well as the voluntarily setting of thermostats to relatively low temperatures. In addition, high energy costs and the relative poverty among some elderly people may discourage their setting thermostats high enough to maintain adequate warmth (just as it may cause others to limit their use of fans and air conditioning during summer heat waves). Because many elderly people live alone and do not have regular visitors, the cold conditions may persist for several days or weeks, thus allowing hypothermia to set in.

Babies and very young children are also very vulnerable to hypothermia. In addition, statistics indicate that death due to cold is more frequent among males than females in virtually all age groups. Part of that may be explained by differences in risk factors, and part may be due to different rates of cold exposure between activities performed by different sexes. Cold weather also increases blood viscosity, narrows small blood vessels, and increases blood pressure, all of which increase the risk of cardiovascular problems (e.g. a heart attack).

As explained in the general introduction to the weather hazards section of this plan, there should be no presumption made that temperatures will automatically be higher or lower in a southern or northern part of the state, despite the existence of certain trends and correlations. All parts of Michigan experience temperature extremes that threaten health. In fact, Michigan's two most extreme temperatures on record did not occur either in the extreme north of the Upper Peninsula or at the extreme south of the Lower Peninsula, but rather at locations in between – in the Northern part of the Lower Peninsula. The record low temperature of -51 was measured at Vanderbilt (located in Otsego County) and the record high of 112 was at Mio (located in Oscoda County).

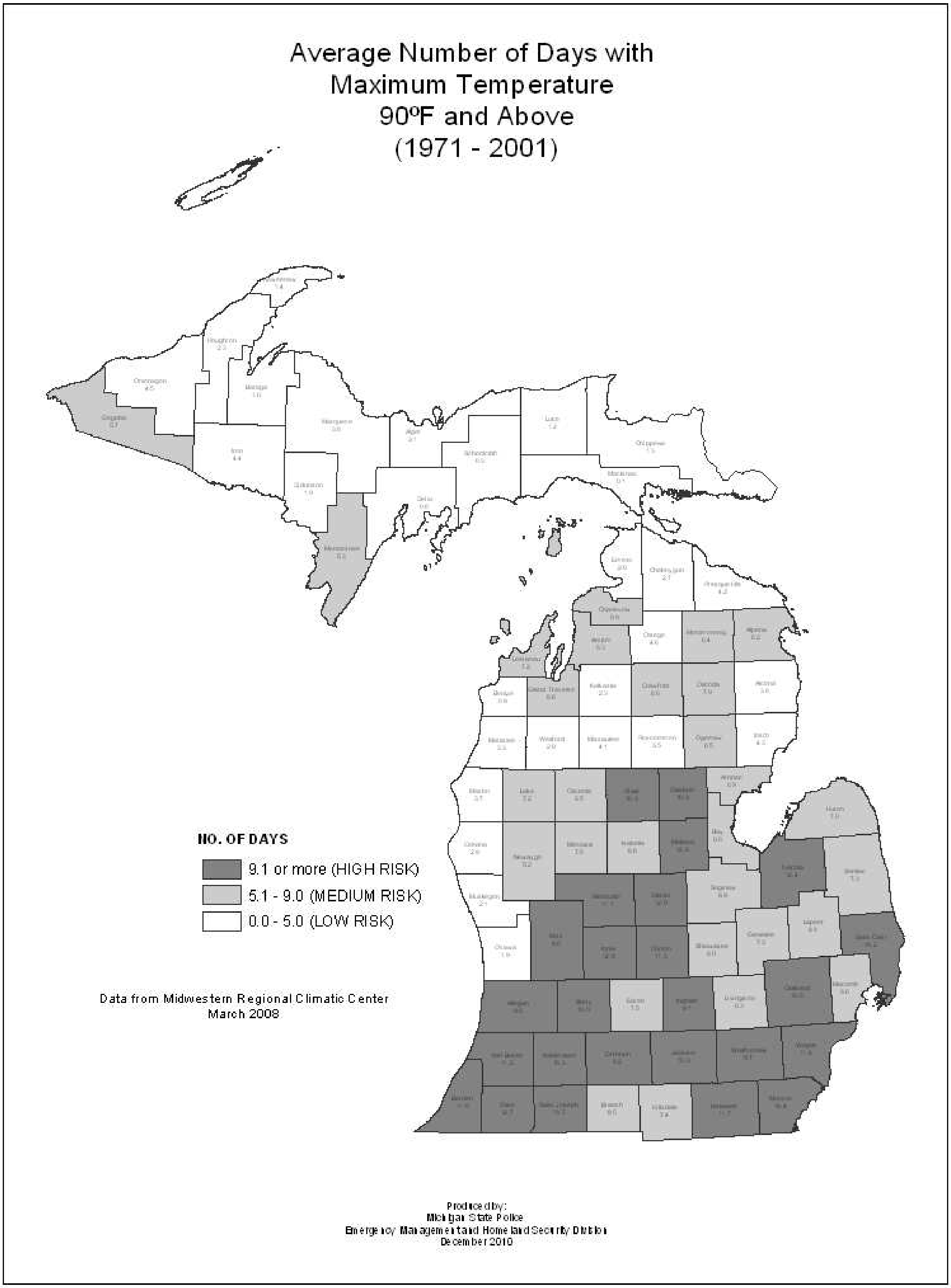
Nevertheless, there is some variation across Michigan in the conditions under which <u>wind chill advisories</u> are issued, since it is the case that the warm season is longer in the southern part of the Lower Peninsula and there is a different phase of that area's population becoming acclimated to each year's winter weather. For southern Michigan, wind chill advisories tend to be issued when the Wind Chill Temperature is within the -15 to -24 range. In northern Michigan and the Upper Peninsula, advisories tend to be issued when the WCT is within the -20 to -29 range. Wind chill warnings tend to be issued when the WCT gets down to -25 or below, in southern Michigan, or when it gets down to -30 or below, in northern Michigan.

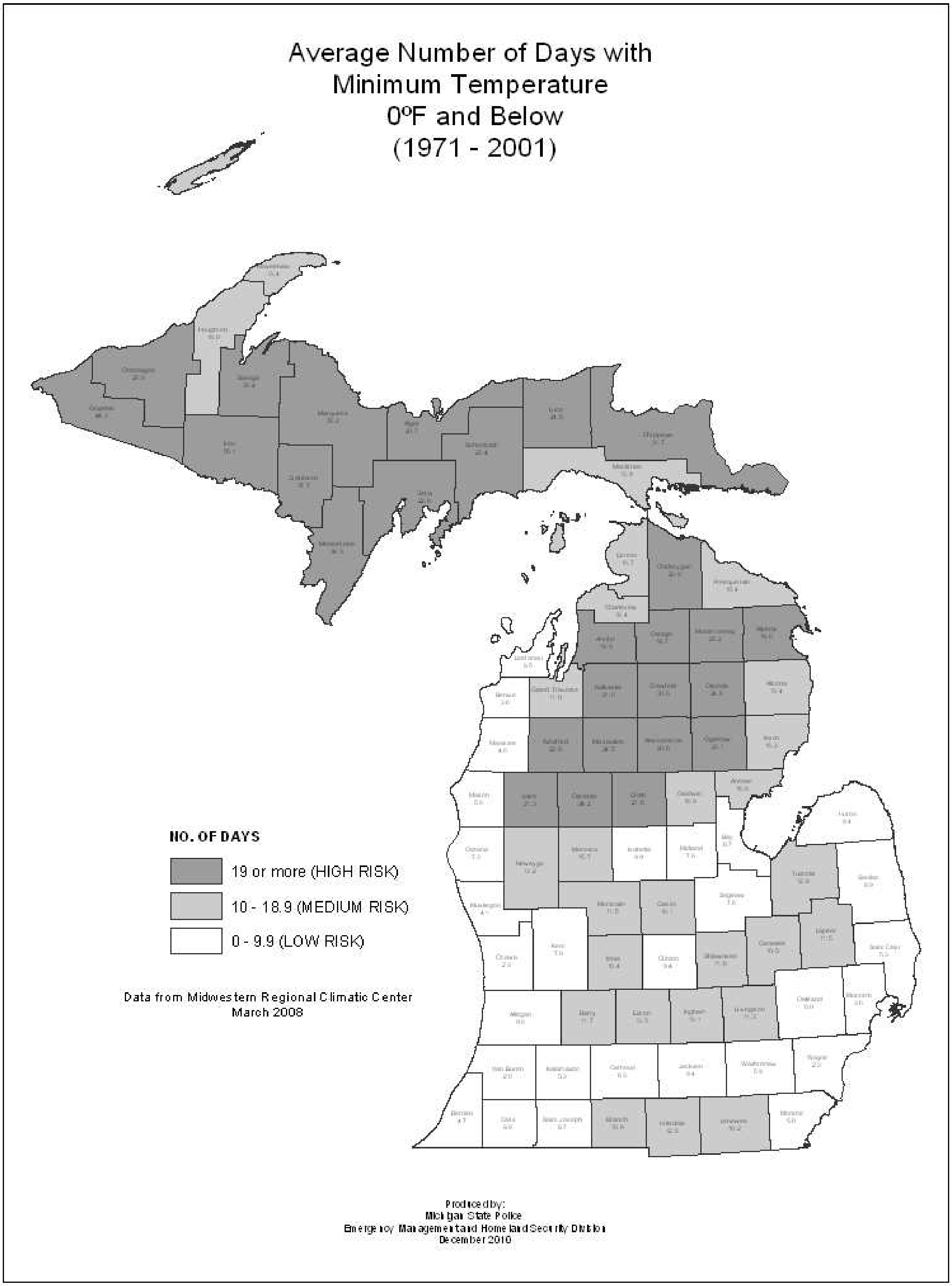
Maps on the following two pages illustrate the average number of days above 90 degrees and the average number of days below zero degrees, Fahrenheit. Although they are based on the three decades from 1971 to 2001, they give an excellent indication of the "typical" annual risk and exposure to Michigan summer and winter temperature extremes, for all of Michigan's counties.

A different type of risk indicator is provided in the subsequent table that lists record low and high temperatures for numerous weather stations across Michigan. For convenience, the listings are divided into three regions: the Southern Lower Peninsula, Northern Lower Peninsula, and Upper Peninsula. Note that these records are for specific stations, and do not necessarily represent all-time records for the counties or surrounding localities in that area. They should instead be taken as an indicator of the extremes to which various specific locations have experienced, across the state.

As already noted in the Introduction to the Weather Hazards section of this plan, although it makes sense to think in terms of three general Michigan regions for an analysis of trends and weather patterns, the extreme temperature hazard must be understood to be a significant one in every part of the state. This is true of both summer and winter temperature extremes. In general, however, "seasons" can be defined for these three regions, to denote when there is a serious risk of extreme temperature events. These "seasons" are based upon the historical occurrence of very high temperatures (above 90 degrees) and very low temperatures (near zero degrees, or below) and will here be generally defined:

	Extreme Heat Risk Season	**Extreme Cold Risk Season**
Southern Lower Peninsula	Early May to late September	Late November to early April
Northern Lower Peninsula	Late May to late September	Early November to April
Upper Peninsula	Late May to early September	Late September to May


Average Number of Days with
Maximum Temperature
90ºF and Above
(1971 - 2001)
NO. OF DAYS
9.1 or more (HIGH RISK)
5.1 - 9.0 (MEDIUM RISK)
0.0 - 5.0 (LOW RISK)
Data from Midwestern Regional Climatic Center
March 2008
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
December 2010


Average Number of Days with
Minimum Temperature
0ºF and Below
(1971 - 2001)
NO. OF DAYS
19 or more (HIGH RISK)
10 - 18.9 (MEDIUM RISK)
0 - 9.9 (LOW RISK)
Data from Midwestern Regional Climatic Center
March 2008
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
December 2010

Historic Temperature Records at Various Michigan Locations

Southern Lower Peninsula	**Record Low Temperature**	**Record High Temperature**
Adrian (Lenawee County)	-26° (Jan. 20)	108° (July 14 & 24)
Benton Harbor (Berrien County)	-21° (Jan. 12)	104° (June 1, July 21 & 30)
Coldwater (Branch County)	-23° (Jan. 4)	108° (July 24)
Ann Arbor (Washtenaw County)	-23° (Feb. 11)	105° (July 24)
Bloomingdale (Van Buren Co.)	-23° (Feb. 3)	105° (July 5 & 13)
Detroit (Wayne County)	-24° (Dec. 22)	105° (July 24)
Jackson (Jackson County)	-21° (Feb. 10)	105° (July 14)
Pontiac (Oakland County)	-22° (Feb. 5)	104° (July 6, 8, 16, 24)
Flint (Genesee County)	-25° (Jan. 18)	108° (July 8, 13)
Grand Rapids (Kent County)	-24° (Feb. 13 & 14)	108° (July 13)
Port Huron (St. Clair County)	-19° (Jan. 19)	103° (July 9)
Harbor Beach (Huron County)	-22° (Feb. 9)	105° (July 10)
Big Rapids (Mecosta County)	-36° (Feb. 11)	103° (July 13, 14 & 30)

The counties listed above start with the southernmost tier in Michigan, and proceed generally northward, tier by tier.
Big Rapids is situated on the very edge of the southern and northern regions, and its record low fits the northern region.

Northern Lower Peninsula	**Record Low Temperature**	**Record High Temperature**
Alpena (Alpena County)	-37° (Feb. 17)	106° (July 13)
East Tawas (Iosco County)	-29° (Feb. 1 & 20)	106° (July 8 & 9)
Gaylord (Otsego County)	-39° (Jan. 6)	101° (July 11 & 30)
Gladwin (Gladwin County)	-39° (Feb. 20)	105° (July 13)
Traverse City	-37° (Feb. 17)	105° (July 7)
Upper Peninsula	**Record Low Temperature**	**Record High Temperature**
Hancock (Houghton County)	-30° (Feb. 9 & 10)	102° (July 7)
Ironwood (Gogebic County)	-41° (Jan. 17, Feb. 12)	104° (July 13)
Munising (Alger County)	-33° (Feb. 25)	103° (July 7, 8, 9, Aug. 6)
Sault Ste. Marie (Chippewa Co.)	-37° (Feb. 8 & 10)	98° (July 3, 30, Aug 5, 6)
Statewide all-time records	-51° (Feb. 9) Vanderbilt (Otsego County)	112° (July 13) Mio (Oscoda Co.)

Source: Extreme Michigan Weather, by Paul Gross (2010, University of Michigan Press, Ann Arbor)

These tables show all the record low and high temperatures at various weather stations across Michigan. It can be noted that the majority of record low temperatures occurred in January and February, and the majority of record high temperatures took place in July. This pattern holds true across all of Michigan's regions. It should also be noted that lower-lying areas often experience colder temperatures, since colder air is denser and heavier and thus tends to sink to lower areas. Local variations of that type help to explain why the absolute coldest and hottest temperature extremes ever recorded in Michigan are more extreme than the various records listed for specific weather stations.

The tempering effects of the Great Lakes also help moderate the impact of the severe cold weather normally prevalent in the Midwest during the winter months. Even so, Michigan still endures many days of extremely cold temperatures in an average winter, and prolonged periods of extreme cold are not uncommon during the months of January and February. During those months especially, increased outreach to elderly persons - particularly those living alone - is certainly warranted. In addition, communities should be particularly cognizant of the vulnerability of elderly as well as very young persons when power outages occur due to ice and snowstorms. When outages are expected to last for several hours or more, consideration should be given to opening warming shelters. Once power is restored, outreach to the elderly may be necessary to ensure that furnaces have been re-started and are working properly.

Extreme cold temperatures are a universal hazard in Michigan. Whereas heat waves tend to impact urban centers more than suburban or rural areas, cold temperatures are an "equal opportunity" killer. Every community in Michigan is vulnerable, regardless of location or size. It must also be noted that many of the agricultural sectors of Michigan are vulnerable to crop losses because of extreme cold events.

Impact on the Public

Extreme temperatures can have direct impacts on personal health and productivity, which may collectively lead to reductions in economic activity and travel (e.g. tourism, shopping). Extreme temperature events tend to cause greater energy use, which can involve not only higher energy costs but can also result in infrastructure failures due to limitations in the capacity of the utility system. About 900 annual deaths nationwide have been attributed to extreme temperatures (mostly from extreme cold, involved in about 700 deaths), ranking this hazard as the second leading cause of fatalities (behind structural fires).

Impact on Public Confidence in State Governance

Questions may arise about the amount of utility assistance, provision/promotion of heating/cooling centers, etc. that governments are meant to provide, and whether there are identifiable and unjustified inequities in the extent and quality of resources and infrastructure provided to different groups and locations throughout the state. Inequities might be attributed to shortcomings in government efficacy and intentions, rather than to limited resources and the historical aspects of differential development patterns.

Impact on Responders

Heat and freezing conditions may directly impact the health and effectiveness of responders, including the potential for dealing with impacts on overwhelmed or failed infrastructure. Special clothing and equipment (and maintenance) tends to become necessary under conditions of extreme cold. Frozen pipes may inhibit or limit responders' access to water that is needed to fight fires, and extra activities and caution may be needed around wintry fire zones where water may have frozen and made footing treacherous for emergency workers (and others).

Impact on the Environment

Periods of extreme heat or cold can affect the environment in several ways. When the temperature rises, power consumption increases, as households and public buildings require more energy to run air conditioning. Agricultural areas also use more pumped water as irrigation is increased. More coal is burned to fulfill the rising demand and thus, more greenhouse gases and toxins are released into the air.

Long-term environmental damage includes greenhouse gas emissions that cause the earth's temperature to rise even further, in what may be described as a "vicious circle." The melting of glaciers in the arctic region will, along with the thermal expansion of ocean waters, increase the sea level, erode and flood coastal areas, and cause the extinction of many species.

Climate Change Considerations

Certain indicators of climate change in Michigan have already been observed. For example, in daily record temperature data, Michigan's new heat records outnumbered new cold records by 3 to 1 during the 1990s, and by 6 to 1 during the 2000s. Extreme heat problems are expected to increase in the future, and the MSP/EMHSD is coordinating with other agencies to assess the likely impacts of warming trends.

FOG

Fog: Condensed water vapor in cloudlike masses lying close to the ground and limiting visibility.

Hazard Description

Fog forms near the ground when water vapor condenses into tiny liquid water droplets that remain suspended in the air. Many different processes can lead to the formation of fog, but the main factor is saturated air. Two ways that air can become saturated are by cooling it to its dew point temperature or by evaporating moisture into it to increase its water vapor content. Although most fog, by itself, is not a hazard because it does not actually apply destructive forces, the interaction between humans and fog can be a dangerous situation, sometimes resulting in disastrous consequences. It must be noted, however, that **freezing fog** (a hazard for which the National Weather Service does issue special statements) can cause direct harm by causing slickness on roadways and thus leading to serious transportation accidents (examples are provided later in this chapter).

Haze and Smog

Haze occurs when dust, smoke and other pollutant particles obscure the normal clarity of the sky. It occurs when dust and smoke particles accumulate in relatively dry air. When weather conditions block the dispersal of smoke and other pollutants, they concentrate and form a usually low-hanging shroud that impairs visibility and may become a respiratory health threat, as well as make safe driving more difficult. Dense haze caused by industrial pollution is also known as smog. This hazard may cause public health problems, so it is mentioned in this subsection but is not given particular emphasis since this plan has more of an emergency management focus. It is noted here as an area of potential overlap and future coordination with other agencies. The Michigan Department of Community Health and the Michigan Department of Natural Resources may do more with this issue in the future, if the effects become severe enough. Since it may be possible that climate change issues cause this to be a more frequent and ongoing concern in Michigan, it is mentioned here. In general, however, air quality has generally improved since the effects of the Clean Air Act, other legislation, regulatory measures, and shifts away from heavy industry in Michigan's economy.

Hazard Analysis

In considering severe and high-impact meteorological events, attention can easily become focused on the more dramatic storms. Tornadoes and hurricanes for example, are readily recognized by the general public and the meteorological community alike for their devastating consequences. Fog, on the other hand, does not lend itself as readily to this categorization. Yet, both in cost and casualties, fog has consistently impacted society, and in particular the transportation sector - sometimes with deadly consequences. Fog has played a contributing role in several multi-vehicle accidents over the past several years. While statistics suggest that highway accidents and fatalities, in general, have fallen, that trend is not evident with respect to accidents and fatalities caused by fog.

Fog can be very dangerous because it reduces visibility. Although some forms of transport can penetrate fog using radar, road vehicles have to travel slowly and use more lights. Localized fog is especially dangerous, as drivers can be caught by surprise. Fog is particularly hazardous at airports, where some attempts have been made to develop methods (such as using heating or spraying salt particles) to aid fog dispersal. These methods have seen some success at temperatures below freezing.

One major fog event is estimated to occur in Michigan approximately every two years. Property damage can be significant for vehicles, although real property and structures are usually unaffected. Fog has not yet been identified as one of the most significant hazards in any of Michigan's local hazard mitigation plans.

Impact on the Public

The primary risks from fog involve the dangers of traveling under conditions of limited visibility. Although some modes of transportation, such as aircraft, are well-regulated, other modes, including simple pedestrian travel, may involve risks that have not been properly accounted for by those who are focused merely on reaching their destination as quickly as possible. The most substantial impacts have recently involved drivers whose bad habits (primarily that of not maintaining safe speeds and following distances) proved to be simply unsustainable under conditions of reduced visibility, resulting in severe crashes and subsequent roadway obstruction. In some circumstances, these conditions of reduced visibility can arise very quickly, although careless drivers, in their desire for fast travel conditions, may erroneously try to ignore the risks from reduced visibilities, in the hope that the condition will suddenly correct itself before any harm is caused.

Impact on Public Confidence in State Governance

This hazard is not expected to cause serious impacts upon public perception of the State's governance, so long as the cautionary messages issued by the National Weather Service and other agencies are received and understood. One reason for the estimated lack of impact on public confidence is that (1) the hazard is typically a localized one not presumed to be dealt with at a State level, (2) public announcements tend to be made when visibility gets too low, and (3) the airline industry operates under regulations (and also uses special equipment) to alleviate the risks from fog. The most serious incidents in Michigan, in which extensive chain-reaction car crashes have occurred on interstate highways, could arguably be connected with too lax of enforcement of fundamental traffic laws (primarily the infractions of following too closely and speeding), but a large proportion of the public, which persists in such unsafe and often unconscious driving habits, seems unlikely to perceive or understand any such hypothetical connection between these conditions.

Impact on Responders

In certain circumstances that require an emergency response, heavy fog may cause impediments and risks that would not normally be present. This is especially true in cases involving high-speed mechanized transportation that requires good visibility to maintain adequate and safe control and maneuvering ability, and for situations that involve search and rescue operations, for which visibility may be very important in locating and assisting victims. Response activities involving aircraft, for example, may be impaired or harmfully delayed by fog.

Impact on the Environment

Fog on its own does not directly impact the environment. However, fog may reduce visibility and can create dangerous traveling conditions. Transportation accidents involving a chemical release may cause great harm to the environment by releasing toxins into the soil, groundwater or air. (Please refer to the chapter on hazardous materials, in the Technological-Industrial Hazards section of this plan.)

I. Natural Hazards
B. Hydrological Hazards

The following outline summarizes the significant hydrological hazards covered in this section:

1. Flooding
    a. Riverine flooding
    b. Great Lakes Shoreline Hazards
    c. Dam failures
2. Drought

Most of the apparent impacts upon Michigan residents come from flooding. The section entitled Riverine flooding focuses upon inland areas and mapped floodplains, but consideration also needs to be given (where information allows) to urban flood hazards. Not all flooding occurs within recognized floodplain areas, or adjacent to rivers and lakes. In some cases, melting snow or other runoff waters pool in low-lying areas, damaging structures and inhibiting the function of roads and infrastructure. In other cases, some type of breakdown in an area's pumping or drainage infrastructure may result in a damaging flood. This type of flooding typically occurs in well-developed urban or suburban areas, and therefore is often called urban flooding. It tends to occur due to either (1) a breakdown in infrastructure or (2) inadequate planning and design standards on the part of builders, developers, engineers, architects, and planners.

One of Michigan's most heavily damaging federally-declared disasters (#1346) was the result of urban flooding, in September of 2000. A tremendous amount of damage had been caused by the entrance of water into basements throughout the densely developed central areas of the Metropolitan Detroit area. A historical problem with the development of many urban areas has involved the use of infrastructure whose original design was appropriate for the expected functions of the central city, but that has become overburdened with the effects of considerable "suburban" developments upstream, which send extra runoff into the system. In other cases, inadequate or deteriorating components exist at the connections between the drainage/sewage system and the structures they serve. Leaks, inadequate backflow preventers, drain openings clogged with leaves or other debris, the inadequacies of combined storm/sanitary sewer systems, and other problems can all cause water and sewer systems to experience problems under certain circumstances.

Fortunately, many important flood mitigation activities have taken place in recent decades, including the separation of combined sewer systems, the installation of backflow preventers in houses, and the dredging, expansion, and re-design of drainage systems. Numerous activities have demonstrated that municipalities and their utility providers have been able to learn from the hard lessons of the past. Nevertheless, a consideration of the types of flood events that have occurred in the past will help to keep such events from recurring in the future. Whether the urban flooding of September 2000, the basement flooding near Lake St. Clair in the early 1970s, or the channel changes and ice jams that caused flood problems to emerge in various other areas (such as Robinson Township, Ottawa County) over the past few decades, Michigan and its communities have learned lessons and taken many steps to mitigate flood impacts in the future. More importance is now placed on the preventive role of planners in coordinating their land development plans with the existing knowledge of local floodplains, wetlands, sewer capacity, and upstream development and hydrology. There has been an increased use of stormwater detention and retention areas, and a great deal of progress in the separation of combined sewer systems. However, drainage systems will always need to be maintained—to dredge out the sediment that would otherwise reduce stream capacities, to upgrade components of the infrastructure that have become worn or had their capacity exceeded, to identify and upgrade bridges that act as barriers to water flows, to remove dams that no longer provide a net benefit to nearby lands, to clear away clogging debris such as leaves and branches and logs, and to efficiently clear away ice jams that would similarly block and divert draining waters away from their intended, safe course.

Progress has also been made in collecting information that will help to identify and prioritize areas that are in need of flood mitigation activities. A system of stream gauges exists across Michigan and is linked with a real-time remote monitoring system through the internet (www.waterwatch.usgs.gov), allowing the assessment of risks and responses to both local flooding and regional drought conditions. A program of updated floodplain maps has also been proceeding (http://www.fema.gov/plan/prevent/fhm/mm_main.shtm), to not only update the boundaries of these maps, but also to enable these maps to be readily used in digital information processing. A developing database of natural hazard events has been online for several years now (http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms). Detailed aerial photos are now available at various sites on the internet, theoretically allowing a comparison between the identified at-risk areas and the actual structures and infrastructure that exist there. However, it will take years, plus adequate funding and staffing, for all of this new information to start to be adequately processed and incorporated into state and local plans.

Overlap Between Hydrological Hazards and Other Sections of the Hazard Analysis

Hydrological hazards stem from precipitation patterns, which are affected by the types of events described in the **Weather Hazards** sections on thunderstorms, severe winter weather, and extreme temperatures. Thunderstorms, snowstorms, and ice/sleet storms produce precipitation that can cause or exacerbate flooding—either immediately or when the frozen precipitation melts. In addition, ice can build up and block critical parts of drainage-ways and thus cause flooding. In the case of extreme temperatures, freeze events have caused flooding when pipes and water mains have broken, while heat waves may worsen the impacts of a drought. Severe winds and tornadoes tend to produce woody debris from the damage they do to trees, utility poles, etc., and this debris can, like ice, build up and jam streams or drains and thus cause flooding to occur. The same sort of debris might also arise from the **Ecological Hazards** of wildfires and invasive species (which can weaken and kill trees and thus cause them to fall).

Technological Hazards that inhibit the smooth functioning of drainage or water supply infrastructure may cause or exacerbate either the flooding or drought hazards. For example, sewer pumping and lift stations can go out of operation during a power failure (unless supplied with power by a back-up system or generators), and cause flooding to occur, or a reduction in water supply—especially in heavily developed urban areas. Transportation accidents also have the potential to cause power failures or even water main breaks, and thus produce flooding or exacerbate drought impacts.

Human-Related Hazards such as terrorism, sabotage, or civil disturbances, may cause water-related infrastructure to be disabled and thus cause or worsen flood or drought events. Public health emergencies may involve the contamination of already-limited water supplies during a drought and thus compound the human impacts of that hazard.

Examining the issue from a different direction, in terms of the effects that can be produced by flood or drought hazards, it can be seen that both flood and drought may, in their own different ways, reduce the quality of an area's water supply—possibly to the point of creating the risk of a public health emergency. Civil disturbances might result from a drought that involves a very limited supply of water for human consumption, or from some form of mismanagement, negligence, or culpability (real or imagined) on the part of some specific agency or actor. An example might be a damaging flood caused by a city's public works department, which might result in hostile protests and the destruction or sabotage of property.

It is also known that floods can cause hazardous materials incidents and transportation accidents, when facilities and transportation infrastructure is in the flooded area. Flood waters in urban or polluted areas tend to be contaminated with chemicals, debris from roadways and cars, and industrial residues. Flood waters can also carry the bodies of animals and humans, and exacerbate insect, snake, rodent, mold, and mildew problems that affect the public health of the area. Floods may hinder the response to emergency events (such as fires, accidents, or utility failures). Floodwaters may cause infrastructure failures, either due to physical impacts and erosion of roads and facilities, or by interfering with the functioning of equipment, electrical supply, etc. in the flooded area. Droughts increase the likelihood of wildfire events, and may also cause land subsidence.

Flood Hazards

Flood hazards in Michigan include dam failures, riverine flooding, and Great Lakes shoreline flooding and erosion. Flooding in Michigan can cause extensive property damage, reduced quality of life, and even injuries and deaths. The National Flood Insurance Program offers one form of security to communities that have flood-prone areas. As of December 2010, Michigan had 25,555 flood insurance policies in place. More information about this topic is provided in the Riverine Flooding section. Every year, flooding causes more than $2 billion of property damage in the U.S. In a high risk area, a home has at least a 26% chance of being damaged by a flood during the course of a 30-year mortgage, compared to a 9% chance of being damaged by fire. The map below shows the major rivers in Michigan and their watersheds (the area in which water runs off into the river and is then carried to one of the Great Lakes).

Riverine Flooding

The overflowing of rivers, streams, drains and lakes due to excessive rainfall, rapid snowmelt or ice.

Hazard Description

Flooding of land adjoining the normal course of a stream or river has been a natural occurrence since the beginning of recorded history. If these floodplain areas were left in their natural state, floods would not cause significant damage. Development has increased the potential for serious flooding because rainfall that used to soak into the ground or take several days to reach a river or stream via a natural drainage basin now quickly runs off streets, parking lots, and rooftops, and through man-made channels and pipes. Some developments have also encroached into flood plain areas and thus impeded the carrying capacity of the drainage area.

Hazard Analysis

Floods can damage or destroy public and private property, disable utilities, make roads and bridges impassable, destroy crops and agricultural lands, cause disruption to emergency services, and result in fatalities. People may be stranded in their homes for several days without power or heat, or they may be unable to reach their homes at all. Long-term collateral dangers include the outbreak of disease, widespread animal death, broken sewer lines causing water supply pollution, downed power lines, broken gas lines, fires, and the release of hazardous materials.

Floodprone areas are found throughout the state, as every lake, river, stream and open drain has a floodplain. The type of development that exists within the floodplain will determine whether or not flooding will cause damage. The Michigan Department of Environmental Quality (MDEQ) estimates that about 6% of Michigan's land – roughly the size of the southeast Michigan counties of Wayne, Oakland, Macomb, Washtenaw, and Monroe combined – is flood-prone, including about 200,000 buildings. The southern half of the Lower Peninsula contains the areas with the most flood damage potential.

The primary flooding sources include the Great Lakes and connecting waters (Detroit River, St. Clair River, and St. Marys River), thousands of miles of rivers and streams, and hundreds of inland lakes. Michigan is divided into 63 major watersheds, as shown in the map at the end of this section. All of these watersheds experience flooding, although the following watersheds have experienced the most extensive flooding problems or have significant damage potential: 1) Clinton River; 2) Ecorse River; 3) Grand River; 4) Huron River; 5) Kalamazoo River; 6) Muskegon River; 7) Saginaw River; 8) Rifle River; 9) River Raisin; 10) Rouge River; 11) St. Joseph River; and 12) Whitefish River. The flooding is not restricted to the main branches of these rivers.

Most riverine flooding occurs in early spring and is the result of excessive rainfall and/or the combination of rainfall and snowmelt. Ice jams are also a cause of flooding in winter and early spring. Log jams can also cause streams and rivers to be clogged up, and the backed-up waters to overflow the stream's banks. Either ice jams or log jams can cause dangerous flash flooding to occur if the makeshift dam-effect caused by the ice or logs suddenly gives way. Severe thunderstorms may cause flooding during the summer or fall, although these are normally localized and have more impact on watercourses with smaller drainage areas.

The map at the end of this section illustrates the major rivers and watersheds in the state. All of these rivers are susceptible to flooding. Although the flood hazard areas are spread throughout the state, the highest risk zones are in the populated areas of the southern two-thirds of the Lower Peninsula, including the glacial lake bed areas along Lake Erie, Lake St. Clair, and Saginaw Bay. As indicated earlier, the Michigan Department of Environmental Quality estimates that 6% of Michigan's land area, encompassing more than 200,000 buildings, is considered prone to flooding. Nationwide, annual flood losses amount to several billion dollars per year, along with over 140 fatalities on average. The monetary losses continue to rise. Michigan reflects this upward trend, with annual flood-related damages estimated to be between $60 and $100 million.

It is widely known that controlling floodplain development is the key to reducing flood-related damages. Although there are state and local programs to regulate new development or substantial improvements in flood-prone areas, floodplain development in many communities continues to increase, resulting in corresponding increases in potential future flood-related damages. The opportunity to mitigate flood hazards rests primarily with local government, since it controls the regulation or direction of land development. Proper land use management and strict enforcement of building codes can make communities safer from flood hazards and help reduce the high costs of flood losses.

Urban and Other Flooding

Flooding may not always be directly attributable to a river, stream or lake overflowing its banks. Rather, it may simply be the combination of excessive rainfall and/or snowmelt, saturated ground, and inadequate drainage. With no place to go, the water will find the lowest elevations – areas that are often not in a floodplain. That type of flooding is becoming increasingly common in Michigan, as development outstrips the ability of the drainage infrastructure to properly carry and disperse the water flow. Flooding also occurs due to combined storm and sanitary sewers that cannot handle the tremendous flow of water that often accompanies storm events. Typically, the result is water backing into basements, which damages mechanical systems and can create serious public health and safety concerns. Other cases involve the ponding of waters across roads or in other low-lying areas. These additional types of flooding have not been given a separate chapter in this plan, but instead have been included in the descriptions of the Riverine flood hazards within this section.

In Michigan, there tends to be a major flood event about every two years. (A long list of flood events that resulted in disaster declarations follows in this section.) Every year, there are various local flood events that do not rise to the level of a state or federally declared disaster. Occasional deaths and injuries are reported in connection with these events—about one death every two years (not counting shoreline and Great Lakes deaths, which are covered in a separate section that follows) and a slightly larger number of injuries. Property damage is extensive, averaging at least 60 to 100 million dollars per year from major events.

Impact on the Public

Riverine flooding has caused displacement, property damage, and impacts on the health of residents. In some cases, utility providers have had facilities located in floodplain areas, and these facilities have been negatively impacted by flooding. Floodwaters can also prevent normal access to structures and facilities. Flooding is a hazard whose risks are routinely underestimated by the public, who may be inclined to attempt to walk or drive through shallow waters, or to allow their children and pets to play in the water as if it were part of a beach or swimming pool. Public education is vital so that there is widespread knowledge of the contaminants and germs that floodwaters contain, and a greater awareness of the risks that floodwaters pose to drivers and pedestrians. Drivers need to know that roads and bridges are often weakened and degraded by flood impacts, and that the road they assume is still there under shallow waters may no longer be intact. Less than a foot of flowing water can cause travelers to end up in a ditch or sinkhole, where persons may find that it is impossible to escape from a submerged vehicle under the pressures exerted by flowing water. Those who are tempted to walk through floodwaters should be informed that the waters tend to conceal the presence of open manholes and dangerous debris, such as rusty nails and metal, or live electrical wires that can cause harmful shocks.

Impact on Public Confidence in State Governance

In cases where any type of flood impact causes negative effects on structures, utilities, or the ability to access them, doubts can arise about the appropriateness of the planning and development mechanisms that may have allowed these flood impacts to occur. Doubts may also arise about the adequacy of the area's drainage infrastructure, whether in the form of channels/drains at the surface or storm sewer systems underneath the ground. Especially controversial are cases in which sewer systems are perceived to have caused basement flooding, and when the original designs of some sewer systems have had their capacities exceeded because of subsequent urban development trends, or when outmoded designs have caused waters to be contaminated with sewage. Public health issues in these cases can thus compound the problems caused by flooding itself, in ways that can seem to be attributable to government.

Impact on Responders

"Ordinary" flood waters in known floodplain areas and riparian lands often contain "hidden" hazards that may not be evident at first. Roads and bridges are often weakened and degraded by flood impacts, and a previously intact roadway area may have been eroded away under a seemingly shallow water surface. Floodwaters tend to conceal the presence of open manholes, dangerous debris (such as rusty nails and metal), and live electrical wires that can cause harmful shocks. Responders in a large flood event therefore deal with numerous hidden hazards as well as floodwaters that are often unclean (containing carcasses, garbage, and filth) and contaminated with chemicals (from area roads, cars, industrial sites, storage facilities, etc.).

Impact on the Environment

Flooding is generally part of a natural cycle that has many important and beneficial functions for the environment. Flooding raises the water table in wetlands, maintains biodiversity, and replenishes nutrients back into the soil. Additionally, higher water tables allow fish and water plants to recolonize and may also help to control some invasive species. Flooding, however, becomes a problem in the built environment. Drainage systems and city sewers can become overwhelmed, causing raw sewage to back up in basements and onto roadways. Flooding in urban areas can also cause increased runoff, which may carry pollutants through storm sewers into rivers and lakes. Urban runoff can be toxic, as it may contain garbage, fertilizers, oil and other residues from city streets.

National Flood Insurance Program

For many years, the strategy for reducing flood damages followed a structural approach of building dams and levees and making channel modifications. However, this approach did not slow the rising cost of flood damage, and did not provide an affordable opportunity for individuals to purchase insurance to protect themselves from flood damage. It became apparent that a different approach was needed.

The National Flood Insurance Program (NFIP) was instituted in 1968 to make flood insurance available in communities that have agreed to regulate future floodplain development. As a participant in the NFIP, a community must adopt regulations that: 1) require any new residential construction within the 100-year floodplain to have the lowest floor, including the basement, elevated above the 100-year flood elevation; 2) require non-residential structures to be elevated or dry floodproofed (the floodproofing must be certified by a registered professional engineer or architect); and 3) require anchoring of manufactured homes in floodprone areas. The community must also maintain a record of all lowest floor elevations or the elevations to which buildings in flood hazard areas have been floodproofed. In return for adopting floodplain management regulations, the federal government makes flood insurance available to the citizens of the community. In 1973, the NFIP was amended to mandate the purchase of flood insurance, as a condition of any loan that is federally regulated, supervised or insured, for construction activities within the 100-year floodplain.

As of December 2010, there were 25,555 active flood insurance policies in Michigan. Officials from FEMA and the MDEQ estimate that only 15% of all flood-prone structures in Michigan eligible to purchase flood insurance actually have flood insurance. Furthermore, since only about 49% of the communities in Michigan participate in the NFIP, there are thousands of structures that are floodprone, but are not eligible to purchase flood insurance. (There were 867 participating communities as of December 22, 2010, and another 108 communities that were mapped but not participating—probably since the mapping was recently completed under FEMA's Map Modernization program.)

The following table provides listings of the 10 counties in Michigan which have the highest number of flood insurance policies in effect. The list is one indicator of the areas in Michigan that have the greatest potential for flood damage:

Top 10 Michigan Counties – Number of Flood Insurance Policies

County	Number of Policies
Wayne	3,975
Macomb	3,404
Monroe	2,452
St. Clair	2,085
Saginaw	1,828
Bay	1,368
Oakland	1,318
Ingham	957
Kent	721
Washtenaw	689

As of 12/31/2010; Source: Michigan Department of Environmental Quality

The top counties include the most urbanized areas of the state. The top counties are also located along the eastern shoreline of Michigan, along Lake Huron, Lake Erie, Lake St. Clair, and/or a connecting waterway such as the Detroit River or the St. Clair River.

The following table presents a slightly different ranking, in terms of the total amount of coverage, per county:

Top 10 Michigan Counties – Flood Insurance Coverage

County	Coverage (Thousand of Dollars)
Macomb	618,133
Wayne	586,507
Monroe	375,047
St. Clair	354,144
Oakland	286,764
Saginaw	201,381
Bay	189,667
Ingham	165,476
Kent	141,864
Washtenaw	129,390

As of 12/17/2010; Source: Michigan Department of Environmental Quality

Since 1978, about $45.1 million in claims have been paid due to flooding in Michigan. It should be remembered that officially claimed flood losses are only a small percentage of the total losses that are occurring from flood events. The flood insurance losses provide a good indication of where flooding problems currently exist, but they do not provide a good estimate of the total losses that are actually occurring. The following table lists the top ten Michigan counties in terms of highest amounts of flood insurance claims paid.

Top 10 Michigan Counties – Flood Insurance Claims Paid

County	Claims Paid (thousands of dollars)
Monroe	5,699
Wayne	4,094
Macomb	3,678
Kent	3,372
Bay	3,122
St. Clair	2,959
Berrien	2,654
Oakland	2,645
Saginaw	2,272
Ottawa	2,146

As of 12/31/2010; Source: Michigan Department of Environmental Quality

Since the Great Lakes experienced record high lake levels in 1985-86, and again in 1997-98, it is not surprising that seven of the ten communities showing the highest amount of flood insurance payouts occurred on the Great Lakes and connecting waterways. It should also be noted that the major riverine flood events that have occurred since 1978 have largely occurred in the inland and more rural areas of the state, which typically have lower flood damage potential.

The following tables present ranked lists of NFIP-participating communities, according to flood insurance coverage amounts, number of policies, and total claim amounts.

Top 10 Michigan Communities – Flood Insurance Coverage

Community	Coverage (Thousand of Dollars)
Harrison Township	243,621
Clay Township	190,730
St. Clair Shores, City of	177,661
Dearborn Heights, City of	154,184
Ann Arbor, City of	89,199
Gibraltar, City of	77,473
Lansing, City of	65,997
Chesterfield Township	64,277
Hamburg Township	50,400
Monroe Charter Township	49,957

As of 1/2011; Source: Michigan Department of Environmental Quality

Top 10 Michigan Communities – Number of Flood Insurance Policies

Community	Active Policies
Dearborn Heights, City of	1,343
Harrison Township	1,264
Clay Township	1,108
St. Clair Shores, City of	1,009
Frenchtown Charter Township	625
Gibraltar, City of	465
Lansing, City of	457
Bangor Township	438
Luna Pier, City of	352
Monroe Charter Township	315

As of 1/2011; Source: Michigan Department of Environmental Quality

Top 10 Michigan Communities – Flood Insurance Claims Paid

Community	Claims Paid (thousands of dollars)
Grand Rapids, City of	1,866
Midland, City of	1,823
Gibraltar, City of	1,807
Farmington Hills, City of	1,688
Luna Pier, City of	1,117
La Salle Township	1,109
Frenchtown Charter Township	1,097
Clay Township	1,080
Kalamazoo, City of	870
Castleton Township	863

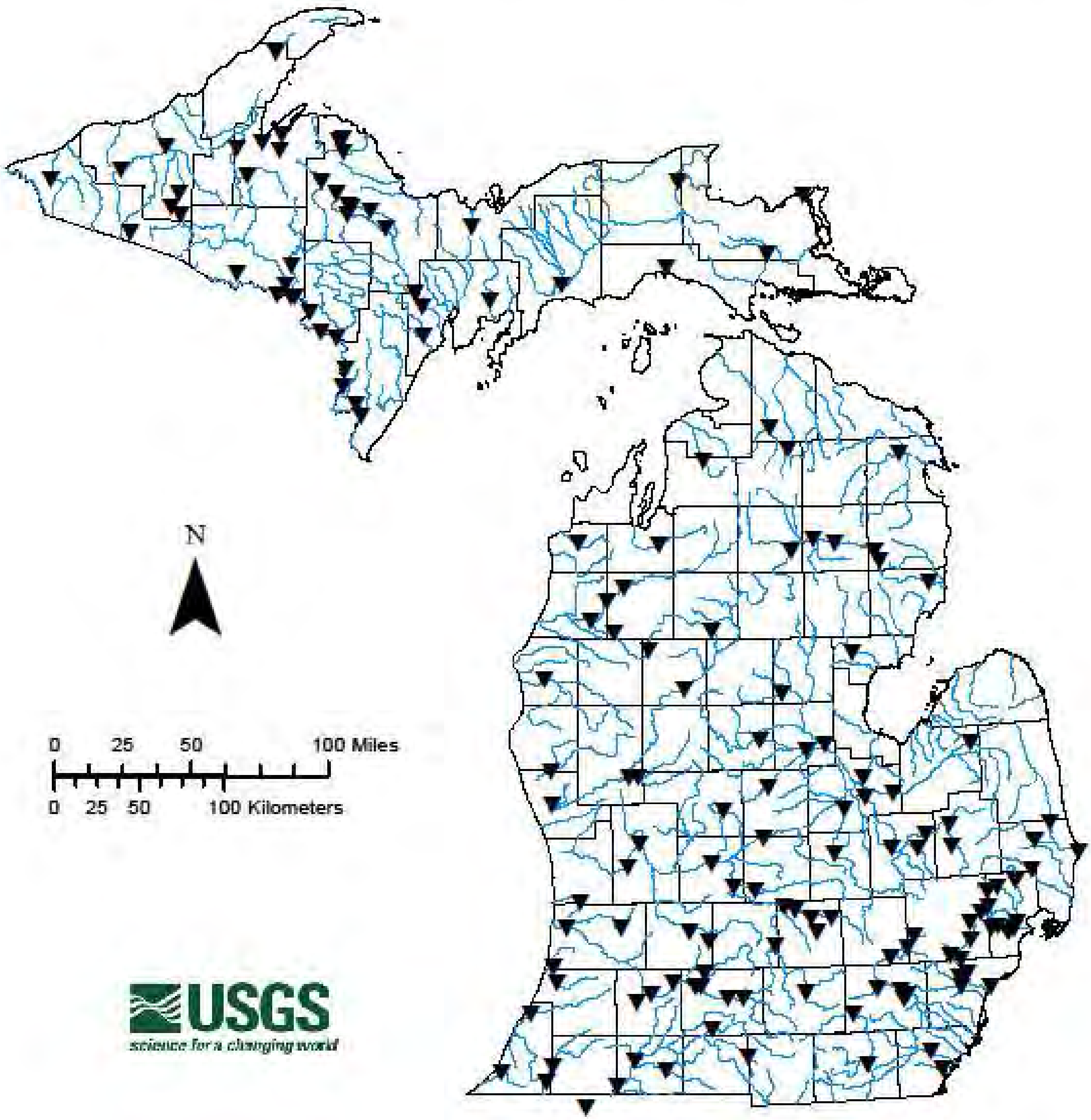
As of 1/2011; Source: Michigan Department of Environmental Quality

The “Community Rating System” allows participating communities to earn discounts for their residents’ flood insurance premiums. The following communities (as of October, 2010) are all CRS participants that have earned discounts of between 5% and 25% on the policy premiums for their NFIP-insured properties:

<u>CRS Class 9</u> (5% discounts earned on NFIP policy premiums): Fraser Township, Park Township, Plainfield Township
<u>CRS Class 8</u> (10% discounts earned): Bedford Township, Brooks Township, Commerce Township, Gibraltar City, Hamburg Township, Luna Pier City, Portage City, Richfield Township, Saginaw Township, Saugatuck City, Shelby Township, Taylor City, Taymouth Township, Zilwaukee City
<u>CRS Class 7</u> (15% discounts earned): Dearborn Heights City, Novi City, Sterling Heights City

<u>CRS Class 6</u> (20% discounts earned): Vassar City
<u>CRS Class 5</u> (25% discounts earned): Midland City

USGS Stream Gauge Locations in Michigan



Great Lakes Shoreline Hazards

High or low water levels that cause flooding or erosion, and other wave and current action that threatens life, health, and property in shoreline areas, including storm surges, rip currents, and the recession of shoreline areas.

Hazard Description

Michigan has over 3,200 miles of coastline (the longest freshwater coastline in the world), and about 4.7 million persons live in the state's 41 shoreline counties. Wind, waves, water levels, and human activities constantly affect the communities along the shores of the Great Lakes. Shoreline flooding and erosion are natural processes, occurring at high, average, and even low Great Lakes water levels. However, during periods of high water, flooding and erosion are more obvious, causing serious damage to homes and businesses, roads, water and wastewater treatment facilities, and other structures in coastal communities. Low lake levels can also pose a hazard, as cargo ships are more prone to running aground and the shorelines may also become more polluted from lake bottom debris. Long-term and seasonal variations in precipitation and evaporation rates primarily control the Great Lakes water levels and their fluctuations.

The Great Lakes occupy an area of 95,000 square miles and drain an amount of land twice that size. They hold nearly one-fifth of the world's fresh surface water. Because the land draining into the Great Lakes is so vast, changes in the amount of water running into the lakes from precipitation within the basin has an enormous effect on water levels. Following long periods of above-average yearly precipitation, there is an accompanying rise in water levels. This rise is not immediately evident because of the delay between the time precipitation falls within the drainage basin and the time that runoff waters enter the lakes. (The same holds true for below-average yearly precipitation. The reduced flow of runoff water eventually results in lower Great Lakes water levels.)

Hazard Analysis

Over one hundred years of record keeping have not indicated a simple, easily-predictable cycle of water levels on the Great Lakes. (However, geologic research has indicated quasi-periodic cycles of 33 years and 160 years for lake level fluctuations; e.g. Baedke and Thompson's article in the Journal of Great Lakes Research, v.26 p. 416-426, 2000.) The time between periods of high and low water levels can vary widely. Records indicate the maximum differences in levels have varied from nearly four feet on Lake Superior to over six and one-half feet on Lakes Michigan and Huron. Seasonal fluctuations caused by more water runoff can cause lake level fluctuations averaging about one foot on Lakes Superior, Michigan and Huron, and one and one-half feet on Lake Erie. The graphs at the end of this section show the average historical water levels of the Great Lakes up through 2009.

In addition to natural causes of water level fluctuation, there are four man-made factors that can also affect water levels to some degree: (1) diversion of water for power generation, municipal water supply, and navigation, (2) regulation of water levels via dams and other control structures, (3) dredging of connecting waterways for navigation purposes, and (4) covering land surfaces with impervious materials that cause storm runoff to be delivered to water bodies more quickly than the pre-development runoff rates. Although these man-made factors do impact water levels, natural factors such as precipitation, evaporation and winds have a far greater overall impact. The vast majority of shoreline flooding and erosion that occurs along the Great Lakes is caused by natural factors. However, it should be remembered that it is humans who place themselves in harm's way by building structures in dynamic coastal areas. If that did not occur, the natural processes of flooding and erosion would not be viewed as problems.

Generally, low-lying lands along the coastline are prone to shoreline flooding during both high and low lake water periods. The Michigan Department of Environmental Quality estimates that approximately 10% of Michigan's Great Lakes shoreline (30 counties encompassing greater than 45,000 acres) is floodprone.

The map at the end of this section indicates those townships that contain high-risk erosion areas as determined by the MDEQ under Part 323, Shorelands Protection and Management. A high-risk erosion area is defined by the MDEQ as an area where erosion studies have indicated that the erosion hazard line is receding at an average of one foot or more per year over a minimum 15-year period. The MDEQ has identified 121 township areas along the Great Lakes coast as containing one or more sections of high-risk erosion areas. Within those areas, any new permanent structure must comply with building setback regulations that require a minimum distance between the existing erosion hazard line and the structure. (The MDEQ also designated 41 communities on Michigan's shoreline as flood risk areas, meaning that they have floodplain-like areas with at least a 1% annual chance of a designated flood level being exceeded.)

The intent of these and other applicable building restrictions is to minimize the extent and magnitude of shoreline flooding and serious erosion problems along the Great Lakes shoreline. Although shoreline flooding and erosion is inevitable, severe damage can be avoided if prudent shoreland management practices are followed and adequate emergency procedures are implemented. Coordination of federal, state and local shoreland management and emergency preparedness efforts is vital to keeping Michigan's shoreline areas as safe and undamaged as possible. The recession of the Great Lakes water levels is also inevitable, but there is not much, other than dredging, that can be done to combat the negative effects. That is why it is important for all those involved in water transportation to be prepared for all types of water fluctuations.

Much of Michigan’s character is defined by the Great Lakes. The beaches provide numerous recreational opportunities and are considered prime real estate. Unfortunately, the inherent hazards of coastal areas are not always apparent. Development activities along the shoreline significantly alter the natural ebb and flow of coastal dynamics. Continuing and increasing development of coastal areas threatens to exacerbate the shoreline flooding and erosion problem. As more people and structures are put in harm’s way, the problem of shoreline flooding and erosion will continue to grow in frequency and significance.

The MDEQ administers programs aimed at balancing the impact of shoreline flooding and erosion with the development pressures facing the Great Lakes shoreline by implementing non-structural approaches, such as construction setbacks and lowest floor elevation requirements. These types of approaches do not interfere with the natural processes of erosion and flooding, but instead take what is known about the coastal hazard and develop construction standards to prevent the premature collision between homes and nature.

The MDEQ has the responsibility of administering the permitting programs that implement the coastal construction standards. However, under Part 323, local governments have the authority to take over the permitting programs for high-risk erosion and flood risk areas. In the area of floodplain management, permitting responsibility is handled at the local level due to the overlap of regulations found in Part 323, the NFIP, and the building codes. However, few communities have shown an interest in adding the regulatory responsibility of the erosion program to their already busy building and zoning departments. As with many regulatory programs that address private property development rights, the potential for conflict in these areas is high. This is especially true in the realm of expensive shoreline real estate where a view of the water can outweigh the threat of future flood or erosion damage. Political pressure can also come into play in some situations. Compliance with these regulations has best been achieved through cooperation between the State and local governments. Public understanding and support of these programs can be increased by improved communication with property owners regarding the natural hazards associated with the Great Lakes shoreline. About 10 major periods of flooding/erosion have occurred on the Great Lakes since 1918—about every 8.3 years.

Shoreline erosion hazards typically involve the loss of property as sand or soil is removed by water action and carried away over time. Erosion effects that are experienced along rivers may be included in this category of hazard. Worst case scenarios typically involve occupied structures that, over the years, have had adjacent lands eroded away and now stand perilously close to waters or cliffs. The foundation of a structure, or underground utility pipes in the area, may become fully exposed and vulnerable to weather, extreme temperatures, water damage, or other sources of risk.

Another frequent situation in Michigan involves shoreline roadways whose banks erode and cause the road surface to crack, become unstable, or more prone to deposits of sand, snow, water and ice from nearby beaches and water bodies. The costs of delayed traffic and detours can be counted as harmful shoreline effects.

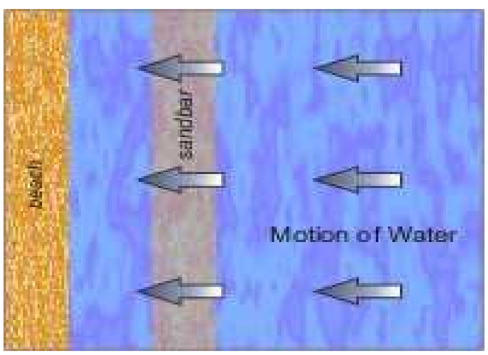
Storm Surges (Seiches)

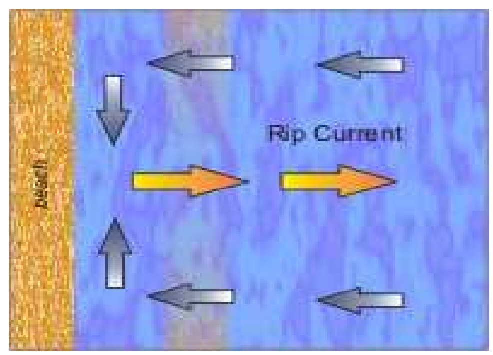
Weather-related events can also cause lake fluctuations that can last from several hours to several days. For example, windstorms combined with differences in barometric pressure can temporarily tilt the surface of a lake up at one end by as much as eight feet. This phenomenon is called a **storm surge** or **seiche** (typically pronounced as saysh) and can drive lake waters inland over large areas, cause weakening and erosion of shoreline areas, make water travel hazardous, and cause flood damages, deaths, and injuries to occur. The following list presents some of the most significant seiche events to have affected Michigan.

Rip Currents
A rip current is a strong flow of water returning seaward from the shore. When wind and waves push water towards the shore, the previous backwash is often pushed sideways. This water streams along the shoreline until it finds an exit back to the sea. The resulting rip current is usually narrow and located between sandbars, under piers or along jetties. The current is strongest at the surface, and can dampen incoming waves, leading to the illusion of a particularly calm area. Rip current speeds are typically 1-2 feet per second. However, speeds as high as 8 feet per second have been measured. Rip currents cause approximately 100 deaths annually in the United States, more than all other natural hazards except excessive heat. In the Great Lakes alone, the average over the last six years is 10 drownings per year caused by rip currents. About 80% of rescues by surf beach lifeguards are due to rip currents. A picture showing how rip currents are formed can be found below.

In recent years, rip current advisories have been announced by the National Weather Service, as a part of their weather warning information system. These warnings advise about dangerous swimming conditions, and that rip currents are more likely to exist near break walls, sandbars, jetties, and piers. Persons who are caught in a rip current should wade or swim sideways (parallel to the beach) so as to leave the rip current area before it pulls them too far away from shore. The most important action is to conserve one's strength so as to stay afloat (rather than expending one's strength in an over-desperate struggle to "fight the current"). Once out of the rip current's pull, head back to shore at a pace that is appropriate to one's strength. In some circumstances, a swimmer may have been observed by beach lifeguards while being pulled by the current, and in such a case, if waves and weather are not too severe to allow a rescue, a swimmer may simply need to stay afloat until the lifeguards can bring aid.

Rip Current Formation





According to the National Climatic Data Center, Michigan has experienced at least 17 deaths and 9 injuries caused by rip currents in just the past 10 years. Out of 17 events, 8 took place in the Lake Michigan waters off of Berrien County (a total of 7 dead and 8 injured). Problem locations included the waters south of Bridgman down to Harbart, and a couple of incidents off of Silver Beach (in the City of St. Joseph). Three events occurred in the waters north of Marquette County—one near Presque Isle, and off of Picnic Rocks. Other incidents occurred in waters off of Allegan County, Manistee County, Benzie County, and Mackinac County. One Alger County incident involved two drowning deaths in the Grand Marais Harbor.

Another Great Lakes hazard is the potential effect of severe winds upon boating activities. Although some description of marine accidents can be found in the Transportation Accidents section, it must be noted here that severe winds tend to be felt more strongly on open waters (winds from an approaching storm front often strike in advance of the storm itself, by 5 minutes or even more). Waterspouts (which are like a tornado, but involve contact with water instead of land) are a common occurrence posing a great threat to marine traffic. Seventeen Michigan waterspouts have been noted by NCDC between 1993 and 2001, including one that caused $200,000 in damage to a boat house and storage building at Drummond Island on July 3, 1999. Many additional events have occurred since, which NCDC has classified according to the corresponding lake location rather than as part of Michigan itself. Waterspouts are less frequent on Lake Superior (8 events since 2001) than on Lakes Huron (23 events) or Michigan (51 events).

Impact on the Public
Great Lakes shoreline flooding is similar to inland (riverine) flooding in some ways (such as having a probabilistically definable flood risk area), but the shoreline tends to have a much greater risk of allowing strong wave action as part of

a flood's impacts. Storm seiches can make the magnitude of shoreline flooding much greater than what is possible in most inland areas. In addition, patterns of Great Lakes shoreline erosion tend to be a larger issue than the erosion associated with Michigan's rivers, since the water effects are greater, and the topographic relief in Michigan's shoreline areas is sometimes considerable. For example, the erosion effects from a single severe thunderstorm have caused large sections of shoreline roadway to crumble and disappear into the crashing waters, involving a drop of dozens of feet on the southern coasts of Lake Michigan, and have encroached upon structures located nearby.

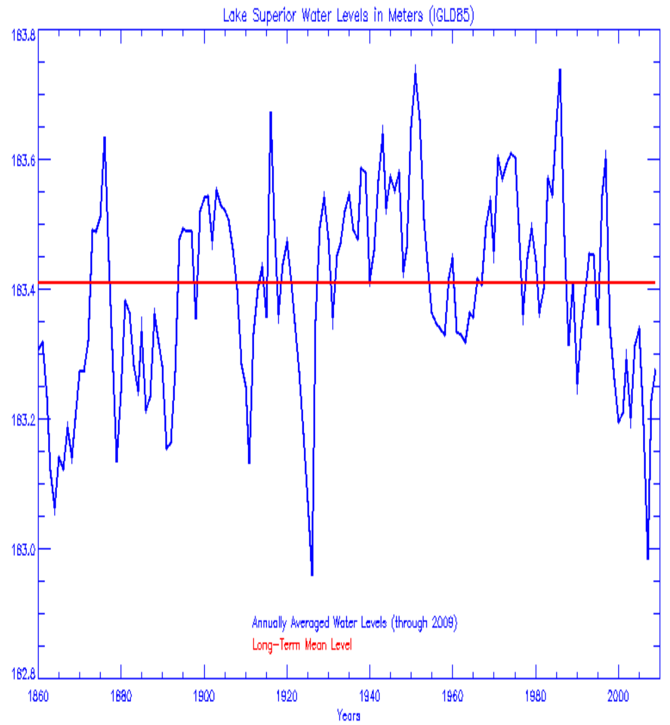
Impact on Public Confidence in State Governance
Great Lakes shoreline flooding and erosion impacts are probably similar to those of riverine flooding, except that shoreline impacts may seem to be less controllable than riparian impacts. Erosion severity is likely to be far greater along the shoreline, especially when involving substantial elevations in which the roads and homes are located along bluffs or cliffs and are thus clearly imperiled by any degradation in the solidity of the supporting land structure that is subjected to erosion and weakening. Thus, part of the public may be prone to question why structures were allowed to be built in an area at-risk from erosion effects, or whether some government-funded mitigation action may be undertaken to preserve the condition and value of such property, once it is recognized as being at-risk.

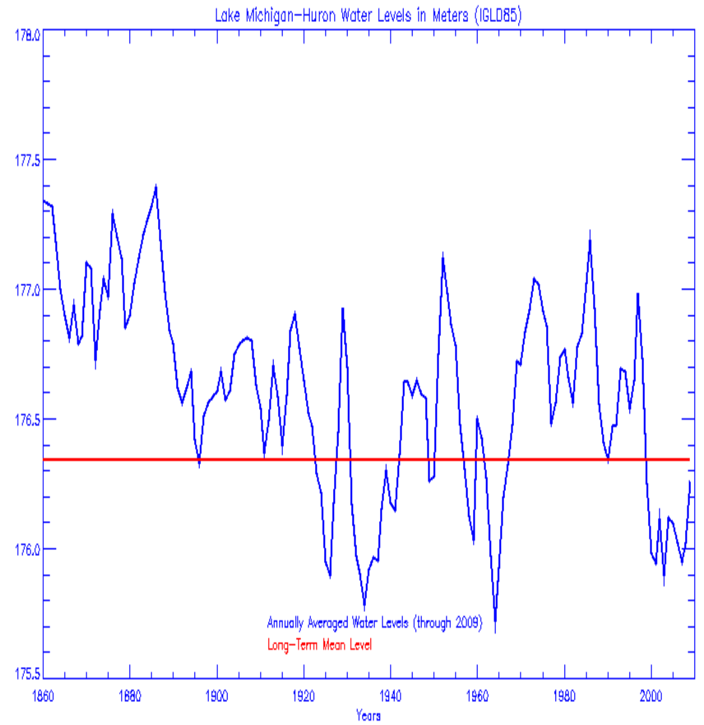
Impact on Responders
Compared to riverine flood events, the main additional risks posed by shoreline flooding and erosion hazards involve the generally greater topographic relief along certain shoreline areas, and the greater potential impact likely to be seen from a single event such as a storm or seiche that involves substantial wave action. The event may cause roadways and property to crumble and tumble dozens of feet into the waters of one of the Great Lakes. Thus, weakened shoreline roads may cause personnel, vehicles, or equipment to plummet down a steep incline, if erosion has been severe enough to cause such a collapse. Shoreline events may also require more extensive use of boats and marine equipment during response activities, with an associated increase in the variety of risks to responders.

Impact on the Environment
Great Lakes shoreline flooding and erosion does the greatest amount of harm to the built environment by destroying structures that are built too close to the shoreline. However, shoreline erosion can also affect the natural environment by altering the landscape, with the potential to permanently destroy wildlife habitat.

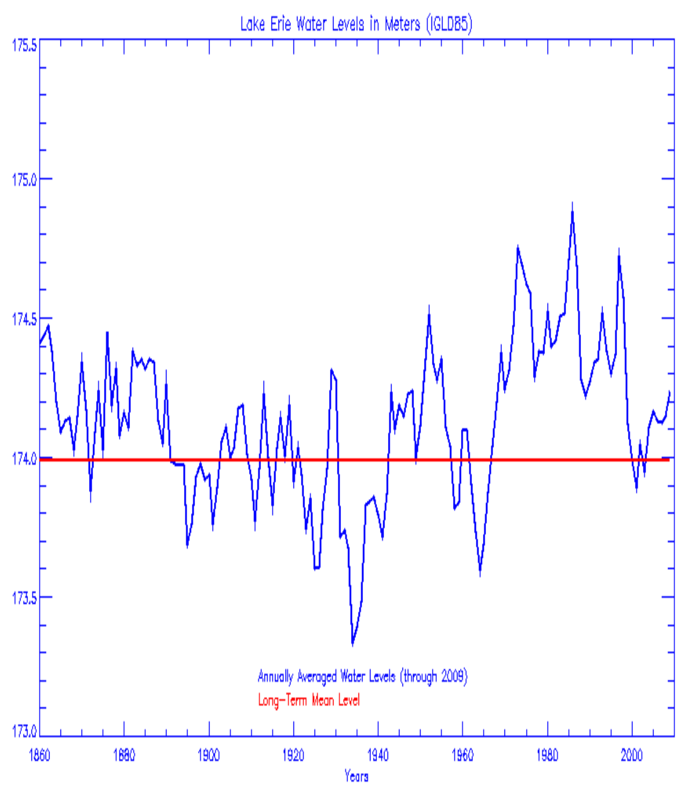
Great Lakes Water Levels Since 1860
(Plus Lake St. Clair Since 1900)
Measurements are in meters

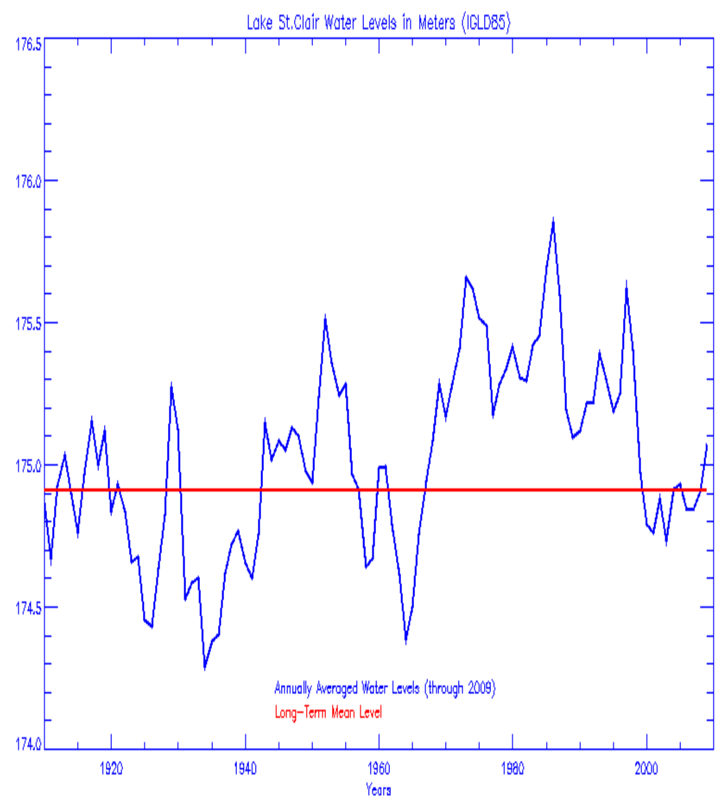
Superior	Michigan / Huron





Erie	(Lake St. Clair, 1900-2009)





Source: National Oceanic and Atmospheric Administration hydrographs from http://www.glerl.noaa.gov/data/now/wlevels/levels.html

Michigan Great Lakes Shoreline Erosion Hazard Areas

Source: Michigan Department of Environmental Quality web site at http://michigan.gov/deq/0,1607,7-135-3307_3331-107407--,00.html

Dam Failures

The collapse or failure of an impoundment that results in downstream flooding.

Hazard Description

A dam failure can result in loss of life, and in extensive property or natural resource damage for miles downstream from the dam. Dam failures occur not only during flood events, which may cause overtopping of a dam, but also as a result of poor operation, lack of maintenance and repair, and vandalism. Such failures can be catastrophic because they occur unexpectedly, with no time for evacuation. The Michigan Department of Environmental Quality (MDEQ) has documented approximately 287 dam failures in Michigan since 1888.

The federal levee database for the State of Michigan is provided on the map below. In addition, the following is a list of some areas known to the Water Resources Division of the MDEQ. This listing is for informational purposes only, to comply with federal recommendations for hazard analysis, and the listing of an area is not intended to suggest any specific risk or vulnerability in the vicinity at this time.

Information on dams with low hazard potential may be available from the National Inventory of Dams. The most recent information counted 927 dams in Michigan, with only 161 classified as “high hazard” (meaning there was at least some development downstream, in the dam’s “hydraulic shadow”) and 158 as “significant.” Development should be discouraged in areas that would increase the risks from potential dam failures. Effects from dam failures can be more severe than those from riverine flooding, due to the possibility of the extra effects of flash flooding and wave action from a catastrophic dam failure.

Hazard Analysis

The worst recorded dam failure in U.S. history occurred in Johnstown, Pennsylvania on the afternoon of May 31, 1889. More than 2,200 persons were killed when the South Fork Dam on the Conemaugh River upstream from Johnstown failed, sending 20 million tons of water downstream in a huge wall of water (at times 60-70 feet high) moving at 40 miles per hour. The wall of water, laden with debris, hit Johnstown within an hour, completely inundating the town and crushing everything in its path. The flood was over in 10 minutes, but the effects were felt for years to come. The cause of this catastrophic failure was later determined to be inadequate maintenance of the South Form Dam by the South Fork Fishing and Hunting Club – a private lake association who counted among its members wealthy Pittsburgh steel and coal industrialists such as Andrew Carnegie and Andrew Mellon. The Conemaugh Valley was again the site of dam failures in May of 1977 when nearly 12 inches of rain fell in a 10-hour period, causing six dams surrounding Johnstown to fail. These six failures poured more than 128 million gallons of water into the Conemaugh Valley, resulting in the deaths of 45 persons and heavy property losses. The storm event that caused the dam failures was said to be a once in a 5,000 to 10,000 year occurrence.

Some Michigan areas with levees, or similar structures:

Village of Clinton	Along the River Raisin in Lenawee County
City of Detroit	A series of “seawalls” may be providing some protection
East China Township (St. Clair Co.)	Several ring dikes are shown on the community’s map
City of Frankenmuth	USACE flood-control project on the Cass River
Cities of Grand Rapids and Walker	Floodwalls along the Grand River
City of Grosse Pointe Park	Sea wall along the Detroit River and Lake St. Clair
Hampton Township (Bay Co.)	Coastal levee
Kalamazoo City and Township	Levees surrounding waste disposal ponds
City of Manistique	One dam includes a flume that may have levee-like functions
Saginaw County	Low-level dikes along the Flint River in Albee, Spaulding, and Taymouth Townships
Saginaw County	Low-level dikes along the Cass River in Bridgeport and Spaulding Townships
Sebewaing (Huron Co.)	USACE flood-control project
Village of St. Charles (Saginaw Co.)	Levee
Wisner Township (Tuscola Co.)	Dikes

Dams are important components of the state's infrastructure and provide benefits to all citizens. However, as history has demonstrated, dams can fail with disastrous consequences, causing unfortunate loss of life and property and natural resources. Many existing dams are getting older, and new dams are sometimes built in developed areas. At the same time, development continues in potential inundation zones downstream from dams. More people are at risk from dam failure than ever before, despite better engineering and construction methods. As a result, continued loss of property can be expected to occur. The challenges facing local emergency management officials are: 1) minimize loss of life and property by working closely with dam owners in the development of the EAPs to ensure consistency with the Emergency Operations Plan (EOP) for the jurisdiction; 2) developing procedures in the EOP for responding to a dam failure (including a site-specific standard operating procedure for each dam site); 3) participating in dam site exercises; and 4) increasing public awareness of dam safety procedures.

The risk of dam failures should be calculated, where possible, from past occurrences. If a community has had no history of dam failures, the community may wish to examine the histories of similar types of dams (based on size, construction, ownership, maintenance schedules) and use that information to estimate the annual chance of a failure. Remember that not all failures result in damaging floods—many failures are caught in time to prevent flood damages, but still have costs associated with emergency response and repairs. It makes sense to calculate costs from different types of events. In most years, there will be no incident. If there is an incident, it may be relatively minor in its impact. The worst case scenario would involve catastrophic dam failure.

Although none of the 287 recorded dam failures in Michigan were truly catastrophic in terms of massive loss of life, property damage from major events has sometimes been very significant, particularly in terms of the related flooding that tends to follow a dam failure. Millions of dollars of damage resulted from the 2002 to 2004 events in the Upper Peninsula, which were the largest recent events of this type. Although dams vary widely in their significance and environmental context throughout Michigan, the historical record shows a frequency of about 2.3 failures per year, on average. Not all of these failures were damaging events, since most of Michigan's dams are small and located in rural areas.

Impact on the Public

No catastrophic dam failures have been reported in Michigan, of a type that actually had unanticipated flash-flood style impacts on anyone who might have been affected by them. However, significant dam failure events have occurred and caused displacement, infrastructure failure, road/bridge closures, and property damage. The impacts have generally been similar to those of riverine flooding (please see that chapter in this analysis), except that dam failures present the possibility for a faster release and inundation of the affected areas, and that failed dams may affect the area's hydrology and infrastructure. (For example, hydroelectric dams may need to be shut down in the event of a breach, causing impacts on the power supply of an area, or local economic effects.)

Impact on Public Confidence in State Governance

Recorded dam failures in Michigan have not been catastrophic, but still may cause problems in residents' perceptions of the reliability of government standards and policy regarding the engineering, inspection, and maintenance of such structures. The failure of levies in the New Orleans hurricane event may carry over into more general concerns about the adequacy of structural water containment infrastructure nationwide.

Impact on Responders

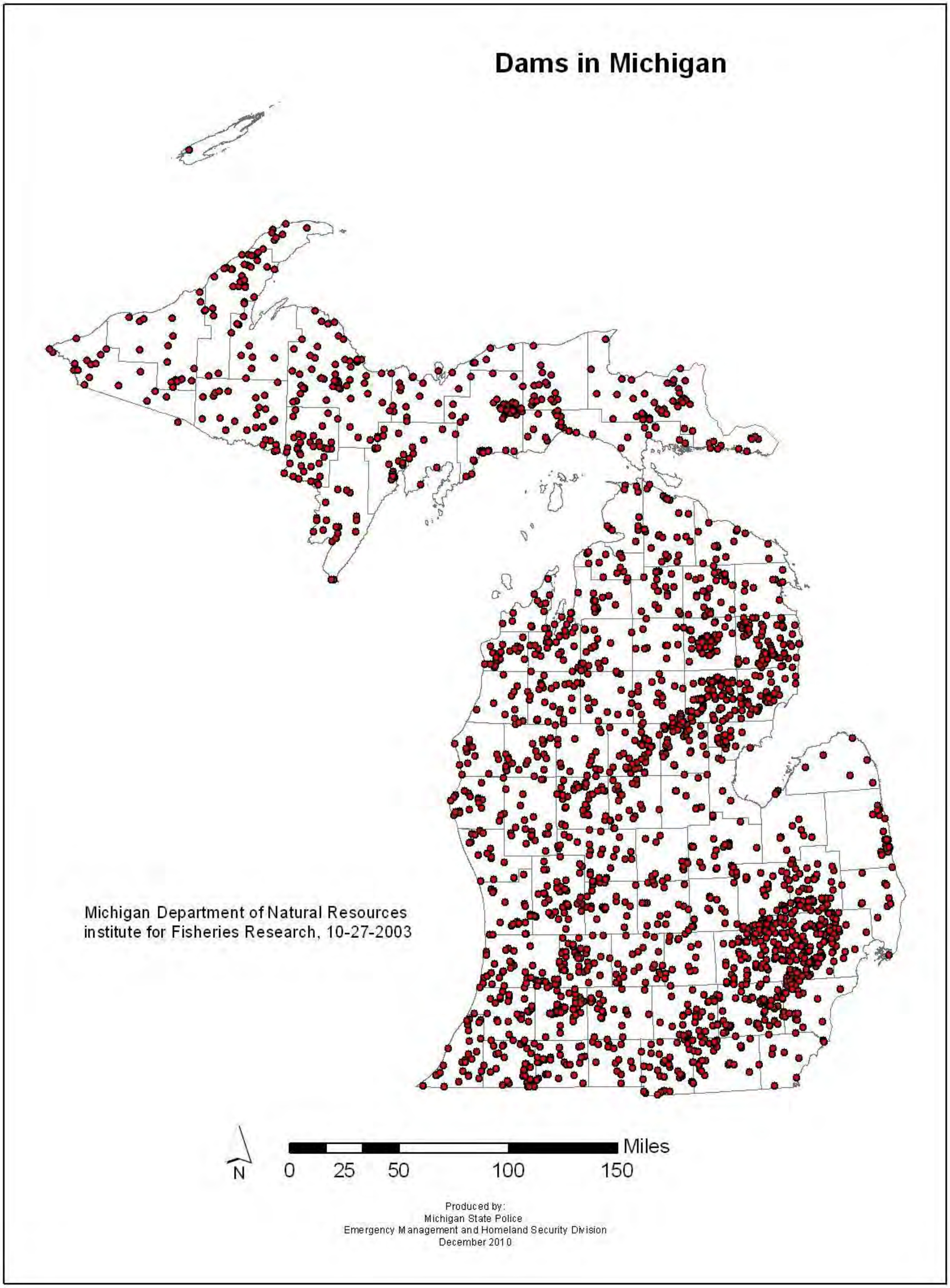
Some dam failures can cause catastrophic flash flooding to take place, which is especially dangerous to any who are near the floodway area, as responders often must be. In addition, access to dam areas is often made difficult by their remoteness, the presence of barbed wire, hunting areas, rugged terrain, etc.

Impact on the Environment

Dam failure has the potential to cause great harm to the natural ecosystem by pushing sedimentation throughout the floodplain. Dam failure can also push water onto agricultural land, which can then carry fertilizers and pesticides into other areas.

Potential Dam Hazards in Michigan
(as of December 2010)

County	High Hazard	Significant Hazard	Total	County	High Hazard	Significant Hazard	Total
Alcona	1		**1**	Lake		2	**2**
Alger	1		**1**	Lapeer	1	6	**7**
Allegan	7	2	**9**	Leelanau	2	1	**3**
Alpena	2	1	**3**	Lenawee	3	5	**8**
Antrim	2		**2**	Livingston	3	7	**10**
Arenac		1	**1**	Luce			**0**
Baraga	2		**2**	Mackinac	1		**1**
Barry		3	**3**	Macomb	2	1	**3**
Bay			**0**	Manistee	2		**2**
Benzie		1	**1**	Marquette	9	7	**16**
Berrien	2	2	**4**	Mason	2		**2**
Branch		1	**1**	Mecosta		4	**4**
Calhoun		3	**3**	Menominee	4	2	**6**
Cass	2	1	**3**	Midland	4		**4**
Charlevoix		3	**3**	Missaukee		1	**1**
Cheboygan	6	3	**9**	Monroe		2	**2**
Chippewa		1	**1**	Montcalm		2	**2**
Clare	3		**3**	Montmorency		2	**2**
Clinton		2	**2**	Muskegon	1	2	**3**
Crawford			**0**	Newaygo	3	1	**4**
Delta	1	1	**2**	Oakland	8	15	**23**
Dickinson	2	3	**5**	Oceana	2	2	**4**
Eaton	3		**3**	Ogemaw		3	**3**
Emmet		1	**1**	Ontonagon	2	2	**4**
Genesee	3	7	**10**	Osceola		1	**1**
Gladwin	5	1	**6**	Oscoda	1		**1**
Gogebic			**0**	Otsego			**0**
Grand Traverse	4	4	**8**	Ottawa	1	1	**2**
Gratiot		2	**2**	Presque Isle			**0**
Hillsdale		5	**5**	Roscommon	1	3	**4**
Houghton		2	**2**	Saginaw	1		**1**
Huron			**0**	St. Clair			**0**
Ingham	1	1	**2**	St. Joseph	5	3	**8**
Ionia	1	1	**2**	Sanilac			**0**
Iosco	4	1	**5**	Schoolcraft	1	1	**2**
Iron	3	2	**5**	Shiawassee		2	**2**
Isabella	1	3	**4**	Tuscola			**0**
Jackson	1	4	**5**	Van Buren	1	1	**2**
Kalamazoo	5	5	**10**	Washtenaw	8	6	**14**
Kalkaska	1		**1**	Wayne	8	1	**9**
Kent	2	5	**7**	Wexford		2	**2**
Keweenaw			**0**	**TOTAL**	**141**	**160**	**301**


Dams in Michigan
Michigan Department of Natural Resources
institute for Fisheries Research, 10-27-2003
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Miles
Produced by:
Michigan State Police
Emergency Management and Homeland Security Division
December 2010

Drought

A water shortage caused by a deficiency of rainfall, generally lasting for an extended period of time.

Hazard Description

Drought is the consequence of a natural reduction in the amount of precipitation received over an extended period of time, usually a season or more in length. Drought is a normal part of the climate of Michigan and of virtually all other climates around the world – including areas with high and low average rainfall. In low rainfall areas, drought differs from normal arid conditions in that the extent of aridity exceeds even that which is usual for the climate. The severity of a drought depends not only on its location, duration, and geographical extent, but also on the area's water supply needs for human activities and vegetation. This local variation of drought standards makes the hazard difficult to refer to and makes it difficult to assess when and where one is likely to occur.

Drought differs from other natural hazards in several ways. First, in the lack of an exact beginning and endpoint for a drought, whose effects may accumulate slowly and linger even after the event is generally thought of as being over. Second, the lack of a clear-cut definition of drought can make it difficult to confirm whether one actually exists, and if it does, its degree of severity. Third, drought impacts are often less obvious than other natural hazards, and they are typically spread over a much larger geographic area. Fourth, due primarily to the aforementioned reasons, most communities do not have in place any contingency plans for addressing drought. This lack of pre-planning can hinder support for drought mitigation capabilities that would otherwise effectively increase awareness and reduce drought impacts.

Hazard Analysis

Droughts can cause many severe impacts on communities and regions, including: 1) water shortages for human consumption, industrial, business and agricultural uses, power generation, recreation and navigation; 2) a drop in the quantity and quality of agricultural crops; 3) decline of water quality in lakes, streams and other natural bodies of water; 4) malnourishment of wildlife and livestock; 5) increase in wildfires and wildfire-related losses to timber, homes and other property; 6) declines in tourism in areas with water-related attractions and amenities; 7) declines in land values due to physical damage from the drought conditions and/or decreased economic or functional use of the property; 8) reduced tax revenue due to income losses in agriculture, retail, tourism and other economic sectors; 9) increases in insect infestations, plant disease, and wind erosion; and 10) possible loss of human life due to food shortages, extreme heat, fire, and other health-related problems such as diminished sewage flows and increased pollutant concentrations in surface water.

Although it is difficult to determine when a drought is actually occurring, once a drought is recognized it can be classified within four different categories - meteorological, hydrologic, agricultural, and socioeconomic. A **meteorological** drought is based on the degree of dryness, or the departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales. A **hydrologic** drought involves the effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels. An **agricultural** drought concerns soil moisture deficiencies relative to the water demands of plant life, usually crops. A **socioeconomic** drought is when the effective demand for water exceeds the supply, as a result of weather-related shortfalls.

The U.S. Drought Monitor (http://www.drought.unl.edu/dm/monitor.html) uses four classifications of severity, from the least intense category (D1) to the most intense (D4), with an additional (D0) category used to designate a "drought watch" area in which long-term impacts such as low reservoir levels are probably present. The Drought Monitor summary map is available online, identifying general drought areas and labeling their intensity. While not the only way to characterize droughts, the U.S. Drought Monitor is convenient and their classification levels have recently been used in various reports and assessments of drought conditions. Short-term indicators are on the level of 1-3 months, while long-term indicators focus on a duration of 6 to 60 months.

Palmer Drought Classification Categories

Category	Description	Possible Impacts	Palmer Drought Index	CPC Soil Moisture Model, USGS Weekly Streamflow, Objective Short & Long-term Drought Indicator Blends (Percentiles)	Standardized Precipitation Index (SPI)
D0	Abnormally Dry	Going into drought: short-term dryness that slows planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered.	-1.0 to -1.9	21-30	-0.5 to -0.7
D1	Moderate Drought	Some damage to crops, pastures, streams, reservoirs, or wells low; some water shortages developing or imminent; voluntary water-use restrictions requested.	-2.0 to -2.9	11-20	-0.8 to -1.2
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed.	-3.0 to -3.9	6-10	-1.3 to -1.5
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions.	-4.0 to -4.9	3-5	-1.6 to -1.9
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies.	-5.0 or less	0-2	-2.0 or less

Source: U.S. Drought Monitor web site http://drought.unl.edu/dm/classify.htm

In addition, the U.S. Drought Monitor uses two general drought categories in assessing an event—an A to denote agricultural effects on crops, pastures, and grasslands, and an H to denote hydrologic effects on water supplies such as rivers, groundwater, and reservoirs.

Despite the thousands of miles of rivers and streams in the state, Michigan has experienced occasional drought conditions. Most common are agricultural droughts, with severe soil-moisture deficits, which have had serious consequences for crop production, particularly when coupled with extreme summer temperatures. Also, various water bodies, both inland lakes and the Great Lakes themselves, cyclically go through periods of low-water levels. Michigan has been in such a period for a number of years now. (See the section on Flooding Hazards: Great Lakes Shoreline Flooding and Erosion for more information about these trends in water levels.)

Recent trends suggest that the pattern in Michigan will continue to be one of low water and lake levels, and even declared declarations of drought. The only exception appears to be the water levels in Lake Erie and Lake St. Clair, which are currently at or above their historically normal levels. (Updated graphs of Great Lakes water levels can be found in the Great Lakes Shoreline Hazards section.) In 2007, all 83 counties received drought disaster declarations from the U.S. Department of Agriculture due to crop losses from drought. In the Muskegon harbor, two freighters became stuck, with low water levels increasing the need for dredging activities and causing ships to unintentionally run aground on the sandy harbor bottom. These events occurred in August and September of 2007, at the same time that drought conditions were present in Michigan. At the beginning of August, three counties (Allegan, Kalamazoo, and Van Buren) were judged to be at D2 (severe drought) status. Twelve other counties in Southwest Michigan were evaluated as having D1 (moderate drought) conditions. Several others were considered to have abnormally dry (D0) status. Wildfire dangers were similarly escalated, due to these dry conditions, with fire danger levels in Southern Michigan ranging from “high” to “extreme.” (Usually fire dangers become less significant after a spring “green up,” but this year was an exception due to the drought effects.) Water flows in various rivers and creeks were far below normal—in many cases only about 60% of their usual rates. In addition to various Red Flag Warnings, by mid-August the Michigan Department of Natural Resources released a proclamation prohibiting the use of fire on or adjacent to forest lands for 75 counties in Michigan. In late August, drought conditions worsened, with 23 Northern Michigan counties at moderate (D1) drought status and two (Chippewa and Mackinac) at severe (D2) drought status. Although some rainfall in early September allowed the fire restriction proclamation to be rescinded in 23 southern Michigan counties, it remained in effect for 52 of the more northern counties. By late September, drought conditions had been alleviated somewhat by additional rainfall, except for the Upper Peninsula, which still had severe drought (D2) status in seven of its western counties, and moderate (D1) drought status for 5 of its eastern counties. (Source: Law Enforcement Information Network messages)

In the United States, drought conditions often exist in some region of the country, with some area likely to be experiencing drought conditions at a particular time.

Urbanized Areas

The entire state is subject to the impacts of drought. However, some areas are more vulnerable to certain drought-related impacts than others. Large urbanized areas can be more vulnerable to water shortages and business disruptions due to the sheer number of water users that are competing for the limited water resources. In those areas, water management strategies typically have to be implemented to deal with the water shortage problems. Public health and safety concerns are also numerous - everything from maintaining adequate water supply for firefighting to addressing the needs of the elderly, children, ill or impoverished individuals suffering from heat-related stress and illness. The latter is particularly problematic for densely urbanized, inner-city areas, because heat-related deaths occur much more frequently in those areas than in suburban and rural areas. (See the Extreme Temperatures section for more detailed information.)

Rural Areas

In rural agricultural areas and the heavily forested areas of Northern Michigan, drought brings on a host of other problems to address. The agricultural areas of southern Lower Michigan are highly vulnerable to drought conditions that impact the quantity or quality of crops, livestock, and other agricultural activities. These areas often depend heavily on agricultural production for their economic needs. A prolonged drought can seriously impact local and regional income, which in turn has a rippling effect on the other components of the economy. Drought can also cause long-term problems that can negatively affect the very viability of some agricultural operations.

In Northern Michigan's forested regions, drought can adversely impact timber production and some tourism and recreational enterprises. This can also cause a drop in income, which impacts other economic sectors. The biggest problem drought presents, however, is the increased threat of wildfire. Many Northern Michigan counties are heavily forested and are therefore highly vulnerable to drought-related wildfire threats. As the 1976 Seney fire proved, a drought-impacted landscape could quickly turn a small fire into a raging, out of control conflagration.

Statewide

Tourism is an important source of revenue for Michigan. The Great Lakes attract numerous boaters and vacationers each year. Many of the "nice weather" activities and attractions involve water-related swimming, boating, fishing, and resort activities, and these forms of recreational and tourist attractions can all be negatively impacted by the effects of drought conditions. Resort areas and boat docks have physical designs that tend to be based on particular water levels. In recent cases of moderate and severe drought, as described above, stream flows can fall below 50% of their normal levels, in many cases reducing the navigability of waterways and altering the relationship between water levels/locations and built facilities for recreational access to that water (boardwalks, docks, fishing sites, et cetera).

Drought Contingency Planning

Because of variations in the drought threat throughout the state, local communities should develop and maintain drought contingency plans (as part of their overall emergency preparedness effort) that address the primary threats that drought presents in their area. For urban jurisdictions, that threat is primarily related to water supply and use management, heat-related illnesses, and continuation of industrial and business operations. For rural jurisdictions, that threat is primarily agricultural and wildfire-related. Such preparedness efforts will not eliminate the negative effects of drought, but they can at least help minimize and manage the consequences of those effects on the population.

Because drought is a low-profile hazard, it does not receive as much attention as it probably should from the emergency management community, governmental agencies, or the public in general. As a result, drought contingency planning is typically a lower priority activity than is planning for other types of natural hazards. Because of the lack of pre-planning, historic responses to drought have been ad hoc and typically involve the creation of special task forces or interagency groups to address drought-related issues as they arise. Once the crisis is over, little is typically done in terms of time or resource commitment in order to ease the impacts of the next drought. Part of the problem stems from the fact that drought contingency planning faces many obstacles, including: 1) lack of a single definition of drought that works in all regions of the country; 2) lack of unified, consistent policies on natural resource management (including water) among states and regions in the U.S.; 3) lack of a lead, coordinating agency for drought mitigation and planning; 4) lack of "dramatic," high-profile impacts (i.e., property damage, casualties, debris, etc.) – which lessens the severity of drought in the minds of community decision-makers and the public; 5) the infrequent nature of drought makes it difficult to garner support for planning and mitigation actions; and 6) the widely-held perception that, because the problem is so enormous in scope and magnitude, there is little that can be done to prevent drought or lessen its impacts.

Having a Drought Contingency Plan for a community is quite important in the event that a severe drought impacts your area. Such a plan should be a separate document detailing what steps need to be taken in the event of a drought. The plan should cover the following questions:

1) Where are primary water sources for the general population?
2) Where are alternative sources for water if the primary sources are inadequate for the community's needs?
3) At what point of lessening water resources do local water restrictions go into place?
4) Are there incrementally strict water regulations related to drought severity?
5) At what point do water restrictions cease?
6) What are the costs of bringing outside water into the community?
7) What is the hierarchy of water distribution to residential, commercial, agricultural and industrial areas?
8) How will children, the elderly, the ill, and other vulnerable citizens be accounted for?

One thing is certain when it comes to drought. As the population increases (both in the U.S. and worldwide), so too does the need for water for drinking, growing food, and running businesses and homes. That increasing need greatly heightens vulnerability to future droughts.

Impact on the Public

Drought impacts may include limited or restricted access to water, and higher prices for water and agricultural goods. There is a threat to public health and safety, as water shortages and decreased water quality raise threats of illness, land subsidence, and wildfires. Conflicts between water users can arise, especially when a river or lake has competing uses among municipal, agricultural, industrial, and recreational users. Water restrictions and limitations among residents can also change daily lifestyle patterns and create social unrest in severe cases. There is also the possibility of a substantial economic impact on an area's agricultural sector, and that sector is very important for many of Michigan's rural areas, both in terms of the local area's economics (export value) as well as its employment (proportion of the labor force). Drought may also cause erosion of topsoil (with an associated loss of productivity and land value) and exacerbate other types of erosion, involving associated costs for property owners.

Impact on Public Confidence in State Governance

In some areas, the government is responsible for infrastructure maintenance and water supply planning and storage, and could be perceived as having failed during a major drought event. Actual responsibility for these issues varies with the specific jurisdiction(s) and agencies involved. Public expectations of government responsibility may be lower in areas with many natural water sources, and areas that make heavy use of individual rather than municipal supply sources. Some interesting cases emerge, however, in areas that have industries that commercially bottle area groundwater for profit. In cases of drought, or of lessened quantity or quality of local groundwater, there is likely to be popular discontent among segments of the public who hold local or state government responsible for "allowing" (or even "favoring") for-profit water bottling businesses to compete with the claimed interests of the area's residential water-users.

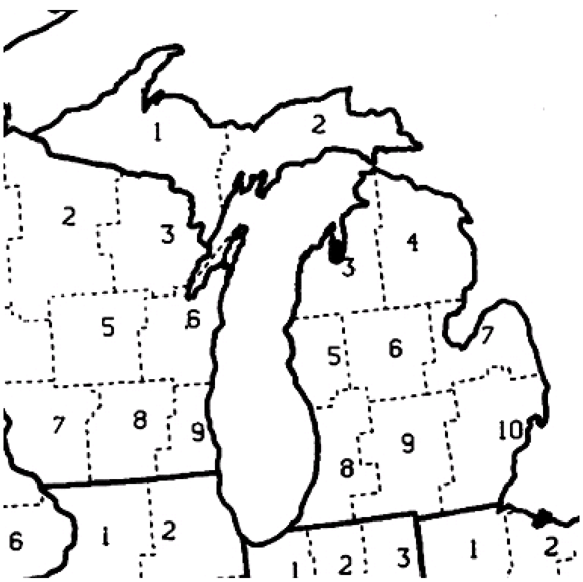
Impact on Responders

Droughts may be expected to affect a community's capacity to fight wildfires, and perhaps even major structural fires as well. There may be access issues involving egress into private property. For example, a water shortage may require access to a water pond on private property, to assist with efforts to fight a wildfire in the area. Otherwise, no particular responder issues should arise from a drought event.

Impact on the Environment

A drought can have serious consequences for the environment if the length and severity of the event is great enough. The hydrological effects of drought can include a loss of wetlands, and lower water levels in lakes, ponds and rivers that are used for irrigating agricultural crops. Additionally, a deficit in rain for an extended period of time may cause ground water depletion and a reduction in the water quality. Drought may also impact plant and animal life by a reduction in drinking water and loss of biodiversity. Drought is also the cause of many wildfires, which destroy wildlife habitats and alter an area's ecosystem. Air quality is reduced by an increase of dust and pollutants in the air. Soil quality and quantity is also diminished due to enhanced erosion, especially around freshly exposed areas near lowered lakes and streams.

Michigan's 10 climate divisions (for drought monitoring and analysis)



Information from the National Climatic Data Center is available for the current tracking and historical research of drought events in Michigan, but since dry conditions in one region may be balanced (in a statewide average) by wet conditions in another region, it is necessary to look at specific regions rather than the state as a whole, to assess the presence and severity of drought conditions from the historical data. For this plan, 126 years of data was analyzed (since 1895) for each of the 10 climate divisions illustrated in the map at left.

To assist with local planning efforts, the counties contained within these 10 climate divisions are hereby listed, and although historical data can at this time only be provided for the divisions as a whole, a summary of the most severe events from NCDC records have been included for each of the ten Climate Divisions. Following this is an overarching description of incidents and trends shown in historical drought records for Michigan.

Division 1: Baraga, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Marquette, Menominee, and Ontonagon Counties. The most extreme drought was in January 1977, when the Palmer index hit a record low of -6.67. Lengthy drought incidents took place in 1895-1896 (9 months), 1898-1899 (8 months), 1910-1911 (19 months), 1930-1931 (16 months), 1933-1934 (9 months), 1943-1944 (8 months), 1947-1949 (23 months), 1957-1958 (16 months), 1963-1964 (14 months), 1976-1977 (14 months), 1986-1987 (12 months), 1989-1990 (13 months), and 2006-2007 (16 months).

Division 2: Alger, Chippewa, Delta, Luce, Mackinac, and Schoolcraft Counties. The most extreme drought was in January 1931, when the Palmer index hit a record low of -7.18. Lengthy drought incidents took place in 1895-1896 (15 months), 1898-1899 (8 months), 1909-1911 (26 months), 1919-1920 (8 months), 1920-1922 (17 months), 1925-1926 (14 months), 1929-1931 (26 months), 1947-1949 (20 months), 1955-1956 (14 months), 1962-1964 (21 months), 1976-1977 (8 months), 1987 (8 months), 1989-1990 (9 months), 1997-1999 (21 months), 2000-2001 (14 months), and 2005-2007 (22 months).

Division 3: Antrim, Benzie, Charlevoix, Emmet, Grand Traverse, Kalkaska, Leelanau, Manistee, Missaukee, and Wexford Counties. The most extreme drought was in January 1931, when the Palmer index hit a record low of -8.07. Lengthy drought incidents took place in 1895-1896 (17 months), 1898-1899 (8 months), 1899-1901 (21 months), 1901-1902 (15 months), 1908-1911 (37 months), 1913-1914 (11 months), 1914-1915 (10 months), 1919-1920 (8 months), 1920-1922 (17 months), 1925-1926 (17 months), 1929-1931 (28 months), 1935-1936 (20 months), 1955-1956 (13 months), and 1976-1977 (13 months).

Division 4: Alcona, Alpena, Cheboygan, Crawford, Iosco, Montmorency, Ogemaw, Oscoda, Otsego, Presque Isle, and Roscommon Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -8.51 (the all-time record for Michigan). Lengthy drought incidents took place in 1895-1896 (17 months), 1898-1899 (8 months), 1899-1902 (37 months), 1909-1911 (28 months), 1913-1915 (26 months), 1919-1922 (33 months), 1924-1926 (19 months), 1929-1931 (28 months), 1948-1949 (9 months), 1955-1956 (12 months), 1963-1964 (11 months), 1976-1977 (13 months), 1981-1982 (12 months), 1989-1990 (8 months), and 1999-2000 (9 months).

Division 5: Lake, Mason, Muskegon, Newaygo, and Oceana Counties. The most extreme drought was in January 1931, when the Palmer drought severity index hit a record low of -7.20. Lengthy drought incidents took place in 1895-1896 (15 months), 1899-1900 (11 months), 1901-1902 (10 months), 1909-1911 (24 months), 1925-1926 (11 months), 1930-1931 (18 months), 1956-1957 (8 months), 1962-1963 (9 months), 1964-1965 (9 months), 1971-1972 (12 months), 1976-1977 (13 months), and 2002-2003 (12 months).

Division 6: Clare, Gladwin, Gratiot, Isabella, Mecosta, Midland, Montcalm, and Osceola Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -7.56. Lengthy drought incidents took place in 1895-1896 (15 months), 1899-1900 (13 months), 1900-1902 (20 months), 1910-1911 (19 months), 1913-1915 (23 months), 1919-1922 (30 months), 1924-1926 (16 months), 1930-1932 (25 months), 1934-1935 (10 months), 1936-1937 (13 months), 1944-1945 (8 months), 1963-1964 (10 months), 1971-1972 (12 months), and 1976-1977 (14 months).

Division 7: Arenac, Bay, Huron, Saginaw, Sanilac, and Tuscola Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -7.57. Lengthy drought incidents took place in 1895-1896 (15 months), 1899-1900 (13 months), 1900-1902 (20 months), 1909-1912 (33 months), 1913-1915 (24 months), 1919-1922 (32 months), 1924-1926 (17 months), 1930-1932 (28 months), 1934-1935 (16 months), 1936-1937 (14 months), 1938-1939 (8 months), 1939-1940 (13 months), 1946-1947 (8 months), 1963-1965 (18 months), 1971-1972 (9 months), 1976-1977 (8 months), and 1998-1999 (12 months).

Division 8: Allegan, Berrien, Cass, Kalamazoo, Kent, Ottawa, and Van Buren Counties. The most extreme drought was in February 1931, when the Palmer index hit a record low of -6.57. Lengthy drought incidents took place in 1895-1896 (8 months), 1901-1902 (10 months), 1914-1915 (8 months), 1925-1926 (11 months), 1930-1932 (29 months), 1934-1935 (9 months), 1946-1947 (9 months), 1953-1954 (8 months), 1956-1957 (9 months), 1962-1964 (31 months), 1999-2000 (10 months), and 2005-2006 (10 months).

Division 9: Barry, Branch, Calhoun, Clinton, Eaton, Hillsdale, Ingham, Ionia, Jackson, Shiawassee, and St. Joseph Counties. The most extreme drought was in April 1931, when the Palmer index hit a record low of -6.82. Lengthy drought incidents took place in 1895-1896 (13 months), 1899-1900 (11 months), 1901-1902 (14 months), 1913-1914 (9 months), 1914-1915 (10 months), 1924-1926 (15 months), 1930-1932 (22 months), 1934-1935 (12 months), 1946-1947 (8 months), 1953-1954 (11 months), 1962-1965 (30 months), and 2002-2003 (8 months).

Division 10: Genesee, Lapeer, Lenawee, Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne Counties. The most extreme drought was in March 1931, when the Palmer index hit a record low of -6.82. Lengthy drought incidents took place in 1895-1896 (8 months), 1900-1902 (24 months), 1913-1914 (12 months), 1914-1915 (12 months), 1925-1926 (13 months), 1930-1932 (24 months), 1933-1937 (42 months), 1939-1940 (12 months), 1952-1953 (8 months), 1953-1954 (17 months), 1963-1965 (35 months), 1971-1972 (15 months), and 1998-1999 (9 months).

The following two tables summarize 116 years of drought records in all 10 of Michigan's specified climate divisions. There are many possible ways of expressing this data and comparing Michigan's geographic areas. A consideration of the most severe Palmer drought index values has already been provided (which found that division number 4 had the most severe drought in Michigan, with a Palmer index of -8.51 for February of 1931), along with lists of lengthy drought periods (which numbered from 12 to 17 per division, during the period from 1895 to 2010). The first table below expresses the percentage of years that either had no drought months at all (with the Palmer Index always above a value of -2.0), or had drought months beyond a certain level of severity. Since a Palmer Index of -2.0 is considered to be a moderate drought (U.S. Drought Monitor category D1), this was the base criterion used to establish the presence of drought in the area during a given month. The percentage of years in which Palmer Index values fell below various cutpoints for drought severity are provided in the table. The annual figures suggest that climate division 4 is the most drought-prone within Michigan.

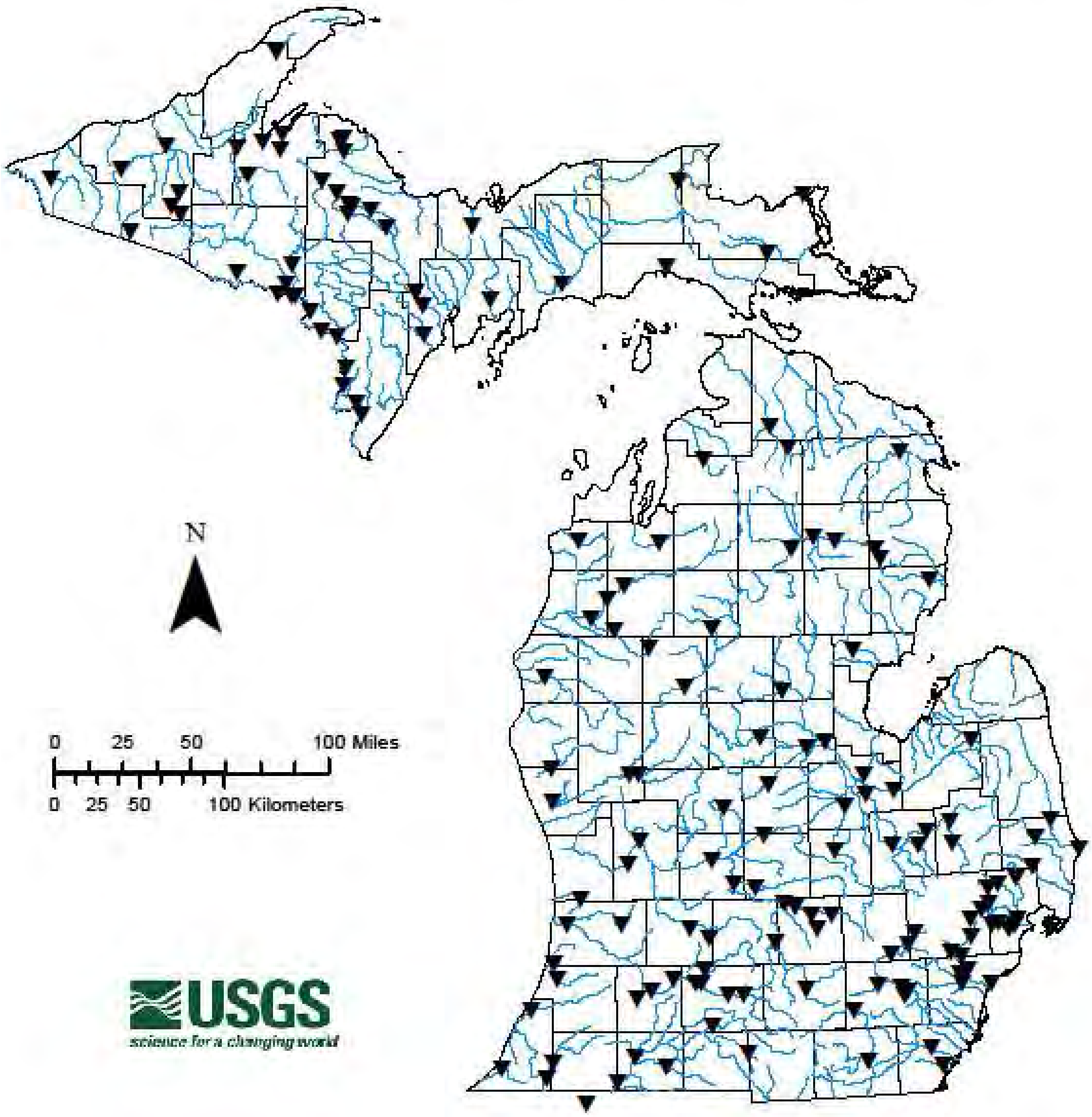
Drought Years in Michigan, by Climate Division
(covering the 116 years from 1895 to 2010)

Climate Division	Years without any drought months	With drought ≤ - 2.0 Palmer	With drought ≤ - 3.0 Palmer	With drought ≤ - 4.0 Palmer	With drought ≤ - 5.0 Palmer	With drought ≤ - 6.0 Palmer	With drought ≤ - 7.0 Palmer
1	50%	50%	28%	13%	9%	2%	0
2	41%	59%	39%	21%	**10%**	2%	1%
3	40%	60%	35%	20%	9%	2%	**2%**
4	**37%**	**63%**	39%	**23%**	**10%**	**3%**	**2%**
5	43%	57%	29%	12%	2%	2%	1%
6	39%	61%	31%	18%	3%	2%	**2%**
7	38%	62%	**40%**	20%	4%	2%	1%
8	44%	56%	30%	9%	2%	1%	0
9	43%	57%	29%	16%	4%	1%	0
10	46%	54%	34%	20%	6%	**3%**	0

An analysis by year tends to overstate Michigan's drought-susceptibility, because the presence of a single drought month may be counted the same as an entire year of sustained drought (although longer drought periods often will be distinguished by having more severe Palmer Index values). A single month's drought will not necessarily cause severe agricultural impacts, because the timing of the drought with regard to the crop cycle is also important for the extent of drought impact. Therefore, an analysis of the percentage of drought months is also provided here, as a different indicator of drought frequency. This table also suggests that Climate Division 4 is the most drought-prone area in Michigan. The listing (on the previous page) of lengthy drought incidents (lasting 8 months or longer) can also give a kind of indicator regarding the frequency of droughts that likely had a significant agricultural impact, although these are all summary indicators by climate division and may vary considerably from the actual performance of individual farms within a particular area. The differences between Michigan's climate divisions may be significant, but are not enormous. One reason for this is that drought is defined with respect to an area's precipitation norms. It may be noteworthy that Climate Division 4 was also the location of Michigan's highest and lowest recorded temperature extremes.

Drought Months in Michigan, by Climate Division
(covering the 1,392 months from January 1895 to December 2010)

Climate Division	**Months without any drought** (Palmer >-2)	**With drought ≤ - 2.0 Palmer**	**With drought ≤ - 3.0 Palmer**	**With drought ≤ - 4.0 Palmer**	**With drought ≤ - 5.0 Palmer**	**With drought ≤ - 6.0 Palmer**	**With drought ≤ - 7.0 Palmer**
1	79.1%	20.8%	9.4%	3.8%	1.3%	0.2%	0
2	73.3%	26.7%	13.7%	4.7%	1.5%	0.3%	0.1%
3	71.9%	28.1%	12.1%	5.2%	1.7%	0.7%	**0.4%**
4	**69.8%**	**30.2%**	**15.7%**	**6.8%**	1.9%	**0.8%**	**0.4%**
5	77.9%	22.1%	8.2%	2.5%	0.7%	0.4%	0.1%
6	73.7%	26.3%	10.8%	4.4%	1.1%	0.6%	**0.4%**
7	70.9%	29.1%	14.5%	5.6%	1.7%	0.6%	0.3%
8	79.7%	20.3%	8.0%	2.0%	0.8%	0.3%	0
9	79.2%	20.8%	8.6%	4.1%	1.3%	0.4%	0
10	75.6%	24.4%	12.1%	5.5%	**2.4%**	**0.8%**	0



USGS Stream Gauge Locations in Michigan

I. Natural Hazards
C. Ecological Hazards

The following outline summarizes the significant ecological hazards covered in this section:

1. Wildfires
2. Invasive species

These types of natural hazards deal with biological ecosystems, and their effects upon the human economy and built environment. The most well-known hazard of this type is that of major wildfires. Although wildfires, like floods, occur naturally, dangers exist because humans live in areas where the disaster event will periodically take place and cause damage and threats to human health and life. Ecological hazards must also be dealt with to maintain Michigan's environmental and recreational quality of life, as well as the important economic sectors that are closely connected with them (such as tourism, recreation, agriculture, and natural resource extraction).

Wildfires

An uncontrolled fire in grasslands, brushlands or forested areas.

Hazard Description

Forests cover approximately 49% (18.2 million acres) of Michigan's total land area. These vast forests provide Michigan with the largest state-owned forest system in the United States. In addition, Michigan has the fifth largest quantity of timberland acreage, with 4.2 million acres of softwoods and 13.1 million acres of hardwoods. That vast forest cover is a boon for both industry and recreation. However, it also makes many areas of Michigan highly vulnerable to wildfires.

Although Michigan's landscape has been shaped by wildfire, the nature and scope of the wildfire threat has changed. Michigan's landscape has changed substantially over the last several decades due to wildland development, and so the potential danger from wildfires has become more severe. Increased development in and around rural areas (more than a 60% increase in the number of rural homes since the 1980s) has increased the potential for loss of life and property from wildfires. (The map at the end of this section shows the wildland / urban interface areas of highest concern in Michigan.) There are simply not enough fire suppression forces available in rural areas to protect every structure from a disastrous wildfire.

Contrary to popular belief, lightning strikes are **not** the primary cause of wildfires in Michigan. Recently, only about 7% of all wildfires in Michigan were caused by lightning strikes, and most other causes have been attributed to human activity. Outdoor debris burning is the leading cause of wildfires in Michigan. Most Michigan wildfires occur close to where people live and recreate, which puts both people and property at risk. The immediate danger from wildfires is the destruction of property, timber, wildlife, and injury or loss of life to persons who live in the affected area or who are using recreational facilities in the area.

According to 2011 MDNR information, the leading causes of wildfires from 2001 to 2010 were:

1. Debris burning (32%)
2. Equipment (17%)
3. Miscellaneous (11%)
4. Unknown (10%)
5. Campfires (9%)
6. Lightning (7%)
7. Incendiary activity (5%)
8. Children (5%)
9. Railroads (3%)
10. Smoking (3%)

Areas of Greatest Vulnerability

The maps and tables at the end of this section show a breakdown of wildfires by county for the period since 1981, including both the number of fires and the number of acres burned. The maps indicate that the wildfire threat in Michigan is fairly widespread geographically. The large number of permanent and seasonal homes (especially in the northern Lower Peninsula), coupled with the increase in tourists during the most dry (and therefore most vulnerable) times of the year, greatly increase the risk from wildfires.

It should be noted that the figures shown on the maps do not include those wildfires suppressed by local volunteer fire departments or the U.S. Forest Service. If those records were readily available and broken down by county, the statistics would be significantly affected. For example, the 1976 Seney fire burned approximately 74,000 acres, which included federal, state and private lands. In addition, the statistics fail to show a major wildfire problem in the southern Lower Peninsula due to the small MDNR fire force presence in that area of the state. However, local fire departments in the southern Lower Peninsula respond to hundreds of wildfires per year, and are instrumental in keeping the wildfire threat in the southern Michigan counties in check.

In geographic terms, the percentage of forested land cover is the highest (more than 75% of the total land area) across the entire Upper Peninsula and in the Lower Peninsula counties of Cheboygan, Crawford, Kalkaska, Lake, Montmorency, Oscoda, Otsego, Presque Isle, and Roscommon (based upon a 2004 inventory by the USDA). The Michigan DNR has been involved in approximately 550 wildfire events per year, in recent decades. An average of about 4 deaths per year is estimated, from major events alone.

Role of Local Governments

Local governments can take a number of actions to reduce the risk from wildfires. One important action that can be taken at the local level is to adequately address wildfire vulnerability reduction in local zoning ordinances and comprehensive/land use plans. Most local zoning ordinances lack provisions for wildfire vulnerability reduction, and most comprehensive/land use plans are not prepared far enough in advance in rural areas to adequately direct development and institute mitigation measures in high-risk fire hazard areas. Communities are not adequately utilizing land use systems that recognize special fire problems and requirements related to vegetation, topography, weather, transportation and access, water supply, and density of development.

Local fire agencies, primarily due to lack of time and/or personnel, only sporadically review proposed lot splits, subdivisions, severances and other developments for fire protection needs. In general, communities are not requiring developers to project the fire vulnerability of their large-scale developments. These projections are also not required for most variances and special use permits. Builders seeking building permits for additions to homes do not have to retrofit the existing structure to meet wildfire safety and mitigation measures. These measures could include such actions as replacing an existing roof covering with a fire-resistant or non-combustible covering, installing smoke detectors and other fire safety controls, or maintaining a “Firewise” landscape by providing adequate vehicular access, signage streets, roads and buildings, and providing adequate emergency water supplies.

Additional measures that local governments can take to reduce wildfire vulnerability include restricting open burning of trash and yard debris (which causes nearly one-third of the wildfires in the state), and developing evacuation procedures for wildfires in the jurisdiction's Emergency Operations Plan (EOP) to minimize potential injury and loss of life.

Efforts of the MDNR Forest Management Division

The MDNR Forest Management Division is committed to a multi-jurisdictional, coordinated wildfire hazard mitigation effort. The Division is actively working toward reducing the State’s vulnerability to wildfires by: 1) participating in multi-state and interagency mitigation efforts; 2) aiding local communities in developing zoning and subdivision control ordinances that adequately address wildfire mitigation; 3) regulating the days and times people are granted permits to burn debris; 4) conducting research on wildfire prevention, containment and suppression activities; and 5) developing wildfire hazard assessments to aid community and property owners in determining their vulnerability to wildfires.

The MDNR is conducting a detailed statewide assessment to determine communities’ risks from wildfire, using Geographic Information System (GIS) technology. This assessment, which is expected to take several years to complete, will identify the areas of greatest concern for wildfires based on existing and projected land uses and population concentrations, as well as topography, hydrology, soils, vegetative cover, and other natural features. The assessment will provide the MDNR and other state agencies, local governments, builders and developers, and private citizens with information needed to make “Firewise” land use / development decisions and to facilitate the creation of community wildfire protection plans (CWPP), thereby reducing the wildfire threat to people and improved property. The risk map at the end of this section was the result of an early approximation using GIS and a basic model, but current mapping will result in products of far greater validity

Despite these ongoing initiatives of the MDNR Forest Management Division, wildfire prevention must be emphasized more at the local level if a meaningful reduction in vulnerability is to occur.

Wildfire Suppression

One trend involves wildfires outstripping the ability of firefighters to suppress them. Fire protection in wildland areas cannot be provided at the same level that it is provided in urban areas. Rural fire departments tend to be volunteer forces, the members of which may be widely geographically dispersed. That dispersion greatly increases the response time in rural and wildland areas. In addition, these forces also tend to be not as well equipped as their urban counterparts. These factors, coupled with the tremendous increases in development in wildland areas and the lack of readily available water from pressurized underground pipes, contribute to the possibility of wildfire disasters in many areas of Michigan.

Wildfire Analysis

FEMA (and others) have created fairly detailed methods for estimating wildfire risks. The information in this workbook summarizes that given in FEMA publication 386-2 ("Understanding Your Risks"). It primarily uses weather, topography, and land cover (fuel) data to estimate wildfire risks. The first activity is to map the "fuel model" categories in the community. This process currently sorts all areas into three "fuel model" categories based on the types of vegetative land covers that could act as fuels in a wildfire event. Here is a summary of the three fuel model categories described by FEMA:

LIGHT FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Predominantly marsh grasses and/or weeds.
2. Mosses, lichens, and low shrubs are the predominant ground fuels, but have no overstory and/or occupy less than one-third of the site.
3. Grasses and/or forbs predominate. Any woody shrubs will occupy less than one-third of the site. An open overstory of conifer and/or hardwood trees may be present.
4. Brush, shrubs, tree reproduction or dwarf tree species predominate, but this is only considered light fuel if the average height of woody plants is less than 6 feet, and they occupy less than one-third of the site.
5. Deciduous broadleaf tree species predominate and the area has not been thinned or partially cut (which would create a higher-risk fuel source called "slash.")
6. Conifer species predominate, but the primary ground fuels are grasses and forbs. If the primary ground fuels are duff and litter, branch wood, and tree boles, then the area can only be considered "light fuel" if pine needles are 2 or more inches in length, the overstory is not decadent, and there is only a nominal accumulation of debris.

MEDIUM FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Mosses, lichens, and low shrubs are the predominant ground fuels, and an overstory of conifers occupies more than one-third of the site.
2. Grasses and/or forbs predominate, with woody shrubs occupying between one-third and two-thirds of the site.
3. Brush, shrubs, tree reproduction or dwarf tree species predominate, and woody plants are either greater than 6 feet in height, or cover more than one-third of the site.
4. Conifer species predominate, and the understory is dominated by lichens, mosses, low shrubs, woody shrubs, and/or reproduction. (If the primary ground fuels are duff and litter, branch wood, and tree boles, and pine needles are less than 2 inches long, then the overstory must not be decadent, and there must be only a nominal accumulation of debris.)

HEAVY FUEL CATEGORY – Covers any of the following general descriptions of vegetation in an area:

1. Deciduous broadleaf tree species predominate in an area that has been thinned or partially cut, leaving slash as the major fuel component.
2. Conifer species predominate, with duff and litter, branch wood, and tree boles as the primary ground fuels, and an overstory that is overmature and decadent, with a heavy accumulation of dead tree debris.
3. Slash is the predominant fuel in the area. (Counts as heavy fuel at any level of loading, regardless of whether settling has been significant or slight, and whether foliage is attached or falling off.)

The United States Department of Agriculture has created a site with wildfire analysis resources, at http://www.fs.fed.us/fire/science/index.html. Since USDA assesses fire risks nationwide, local or state resources will probably be needed to supplement this source in order to accurately assess a community's specific fuel model areas in the local hazard mitigation plan.

FEMA's wildfire model then combines these fuel type areas with assessments of local topography and weather patterns, to identify overall risk categories (called "moderate hazard," "high hazard," and "extreme hazard.") Topographic information provides three land categories, based on the severity of slopes present in an area. Low slope areas have slopes less than or equal to 40%. Moderate slope areas contain slopes measuring from 40% to 60%. Steep slope areas contain slopes greater than 60%.

Weather information can produce estimates of the number of days per year with "critical fire weather" conditions. FEMA has stated that a local or state fire marshal, forestry department, or department of natural resources can help in determining the number of days per year that critical fire weather is experienced in an area.

Overall categories of wildfire risk (moderate, high, and extreme) are given by the following FEMA table:

	Frequency of Critical Fire Weather								
	1 day per year or less			2 to 7 days per year			8 or more days per year		
Fuel Classification	Slope ≤40%	Slope 41%-60%	Slope ≤60%	Slope ≤40%	Slope 41%-60%	Slope ≥60%	Slope ≤40%	Slope 41%-60%	Slope ≤60%
Light Fuel	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	High
Medium Fuel	Moderate	Moderate	High	High	High	High	Extreme	Extreme	Extreme
Heavy Fuel	High	High	High	High	Extreme	Extreme	Extreme	Extreme	Extreme

Additional factors that increase fire risk and may be included in a model include lightning and human factors such as the number of persons residing in, camping in, visiting, or traveling through an area. Such persons may increase fire risks through carelessness or ignorance, while other persons (including residents and fire spotters) may reduce risk of uncontrolled wildfire in an area, through their ongoing fire awareness, prevention, and response activities. It also makes sense to take into account the type of fire-fighting personnel, equipment, expertise, and related resources (such as water) that are available to a community, or lacking in adjacent communities (from which a fire might spread).

Vulnerable structures are those located in or near a potential wildfire area, unless they have taken special steps to become "Firewise" (as described previously). Nonflammable roof and patio materials, clearance of vegetation and maintenance of a defensible space around structures, available means to provide and facilitate site access by emergency responders, and so on, will make a structure potentially able to withstand wildfire events in its vicinity. Structures that are located in a wildland/urban interface area should be evaluated for these sorts of site features that will exacerbate or minimize their vulnerability. Certain design or landscaping features can render an at-risk structure completely vulnerable to any nearby wildfire event, and thus should be prioritized for wildfire mitigation strategies. Although risk-estimation models exist, FEMA has stated that there are no standardized methods for estimating the amount of damages and economic losses that a community will sustain from a wildfire event.

Impact on the Public

Wildfires can cause widespread concerns and disruptions even in cases where physical damages have been prevented. Smoke, closed roadways, and infrastructure impacts may interfere with ordinary life, as well as an area's economy and planned events (including tourism). Wildfires can also directly cause structural fires to occur. (Please refer to the preceding sections about structural and scrap tire fire events for more information about these potential impacts.)

Impact on Public Confidence in State Governance

The large scale of wildfires can cause widespread concerns and disruption, smoke, closed roadways, and infrastructure impacts. Since many wildfire locations involve state lands (especially the Michigan Department of Natural Resources), major wildfire events may raise public questions about the effectiveness of governmental policies toward the maintenance and monitoring of conditions on such lands.

Impact on Responders

Wildfires involve special training, equipment, and expertise, as well as a large-scale response and different types of risks for responders, including the large areas involved, the risks of extremely rapid fire spread, and locations that are often isolated and distant. These tend to present difficulties with responder equipment staging, transport, coordination, and communications.

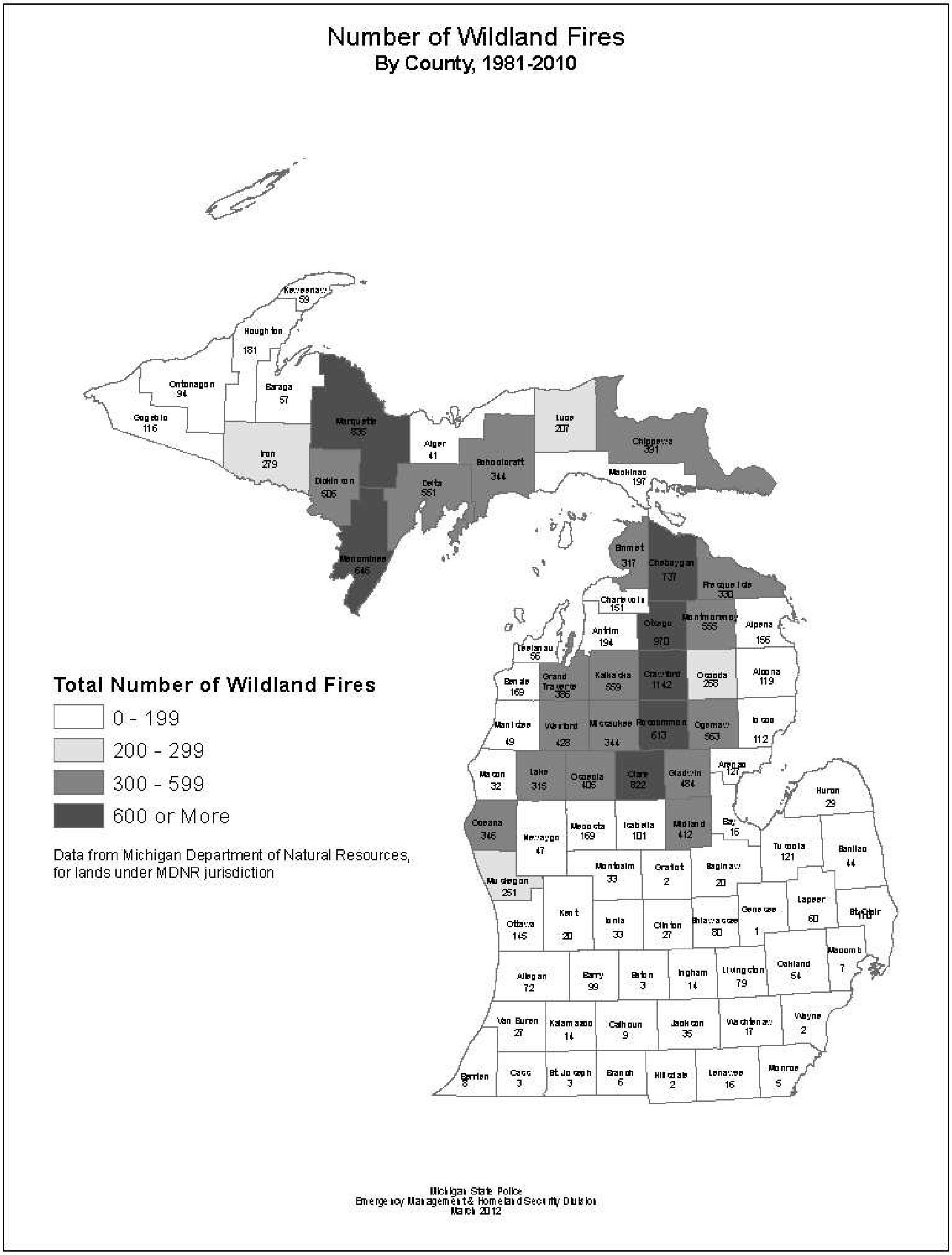
Impact on the Environment

Wildfire impacts on Michigan's environment can be considerable, due to the fact that Michigan has the largest state-owned forest system in the Eastern United States, as well as the fifth largest timber acreage in the country. Wildfires physically damage natural vegetation, forests, trees, shrubs, grasslands, native animals and insect species, etc, leaving black soot, deposits of peat, smolder, and charcoal-like ground cover that can contaminate the soil and underground water table. Wildfires can also cause dramatic and immediate changes or shock in vegetation, eliminating some species or causing others to appear where they were not present before the fire. Wildfires (depending on their size and burning time) are a significant source of gases and particulates in the atmosphere, including carbon dioxide, carbon monoxide, methane, non-methane hydrocarbons and oxides of nitrogen. Fire also produces large amounts of small, solid particles (particulate matter) that absorb and scatter solar radiation, exacerbating climate change conditions.

Even though many fires occur close to where human residences are located, they are a normal ecological phenomenon and serve long-term functions for vegetation and the natural environment. Wildfires burn excess brush, maintain large savannah-like openings, and restore wetlands by forcing out various unwanted brush and plants. The natural function of fires within the environment can be considered a renewal or “cleansing process” as long as the fire is not too severe.

Number of Wildfires, by County

(MDNR jurisdiction only)



Number of Wildfires and Acres Burned, by County: 1981-2010 (MDNR jurisdiction only)

County	Number of Wildfires	Number of Wildfires/Year* (over 30 year period)	Number of Acres Burned	Number of Acres Burned/Year* (over 30 year period)
Alcona	119	4	843.8	28
Alger	41	1	123.0	4
Allegan	72	2	312.0	10
Alpena	156	5	267.2	9
Antrim	194	6	194.1	6
Arenac	127	4	418.8	14
Baraga	57	2	1897.6	63
Barry	99	3	447.3	15
Bay	16	1	142.2	5
Benzie	169	6	279.3	9
Berrien	8	0	24.4	1
Branch	6	0	19.3	1
Calhoun	9	0	41.2	1
Cass	3	0	27.0	1
Charlevoix	151	5	492.3	16
Cheboygan	737	25	1424.0	47
Chippewa	391	13	5108.2	170
Clare	822	27	2385.6	80
Clinton	27	1	138.9	5
Crawford	1142	38	25861.5	862
Delta	551	18	3213.8	107
Dickinson	506	17	2411.0	80
Eaton	3	0	0.3	0
Emmet	317	11	543.5	18
Genesee	1	0	0.1	0
Gladwin	484	16	1938.9	65
Gogebic	116	4	245.4	8
Grand Traverse	386	13	1296.9	43
Gratiot	2	0	40.0	1
Hillsdale	2	0	23.0	1
Houghton	181	6	1200.1	40
Huron	29	1	725.5	24
Ingham	14	0	474.7	16
Ionia	33	1	728.4	24
Iosco	112	4	1630.3	54
Iron	279	9	1953.9	65
Isabella	101	3	931.8	31
Jackson	35	1	520.5	17
Kalamazoo	14	0	74.3	2
Kalkaska	559	19	2953.4	98
Kent	20	1	125.9	4
Keweenaw	59	2	375.6	13
Lake	315	11	1283.5	43
Lapeer	60	2	533.8	18
Leelanau	56	2	212.0	7
Lenawee	16	1	224.2	7
Livingston	79	3	651.4	22
Luce	207	7	18679.9	623
Mackinac	197	7	1610.6	54
Macomb	7	0	15.4	1
Manistee	49	2	1041.6	35
Marquette	835	28	16087.6	536
Mason	32	1	154.6	5
Mecosta	169	6	844.9	28
Menominee	646	22	2353.4	78
Midland	412	14	1414.9	47
Missaukee	344	11	1772.0	59
Monroe	5	0	233.3	8
Montcalm	33	1	567.6	19
Montmorency	555	19	1271.5	42
Muskegon	251	8	2675.7	89
Newaygo	47	2	404.2	13
Oakland	54	2	368.5	12
Oceana	346	12	1766.0	59
Ogemaw	563	19	8296.1	277
Ontonagon	94	3	1438.1	48
Osceola	405	14	1085.2	36
Oscoda	268	9	8765.3	292
Otsego	970	32	1924.9	64
Ottawa	145	5	469.9	16
Presque Isle	330	11	838.4	28
Roscommon	613	20	4551.9	152
Saginaw	20	1	474.7	16
Sanilac	44	1	427.3	14
Schoolcraft	344	11	3210.5	107
Shiawassee	80	3	576.7	19
St. Clair	110	4	1642.8	55
St. Joseph	3	0	7.7	0
Tuscola	121	4	930.9	31
Van Buren	27	1	249.2	8
Washtenaw	17	1	217.5	7
Wayne	2	0	42.2	1
Wexford	428	14	1057.4	35
Total DNR fire events	17449	582	152228.3	5074

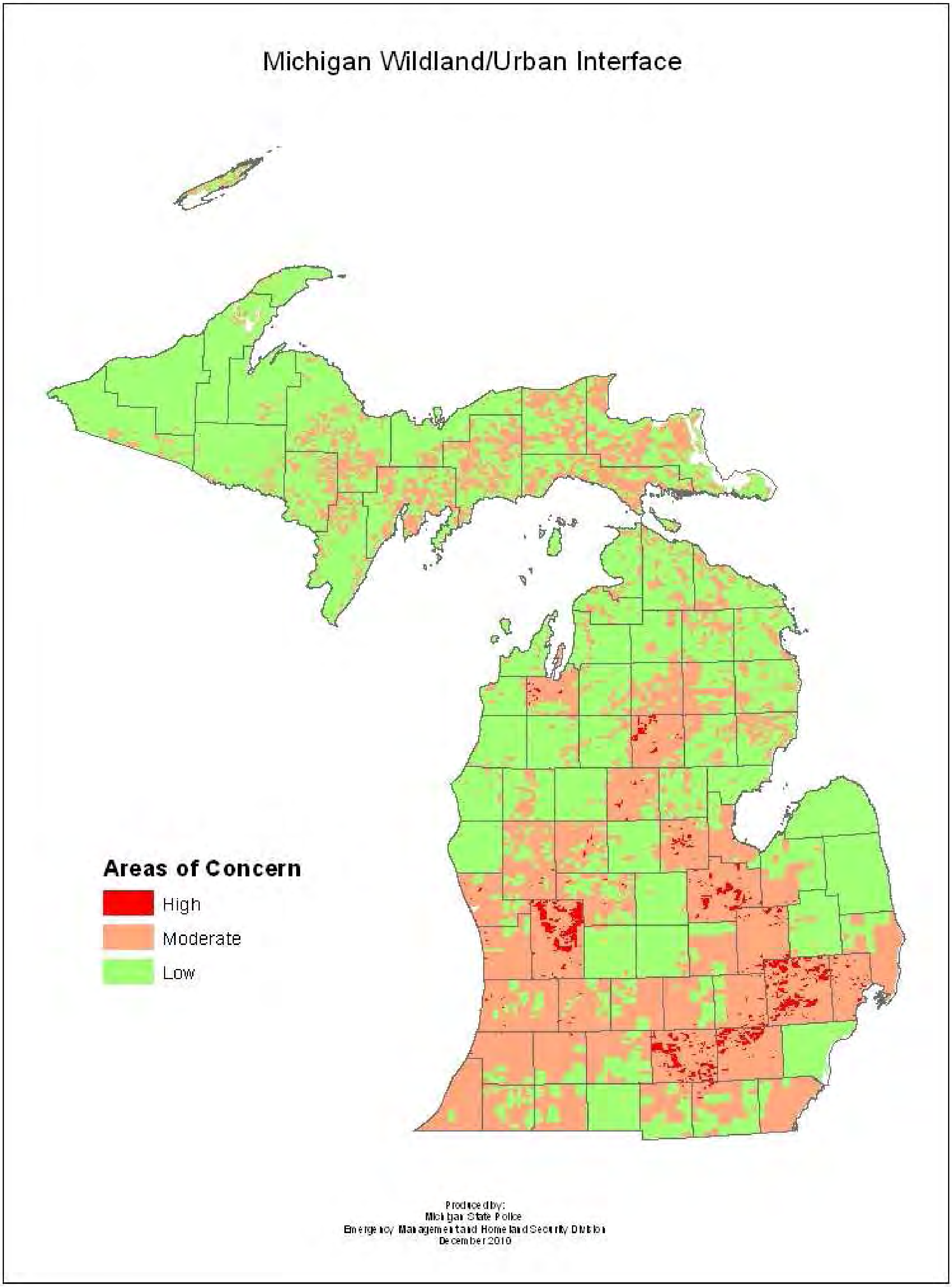
*rounded to nearest whole number

Source: Michigan Department of Natural Resources—Forest Management Division

Michigan Wildland/Urban Interface Map

Source: Michigan Department of Natural Resources, Forest Management Division

NOTE: This map is an example from a previous analysis and is being updated by more valid GIS modeling - not recommended for current use except as a highly generalized indicator



INVASIVE SPECIES

A species that has been introduced by human action to a location where it did not previously occur naturally, becomes capable of establishing a breeding population in the new location without further intervention by humans, and becomes a pest by threatening local biodiversity and causing human health impacts, significant economic costs, and/or harmful ecological effects.

Hazard Description

An invasive species is defined as a species that is (1) non-native (alien) to the ecosystem under consideration and (2) whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary consideration here as a means of invasive species' introduction (thus distinguishing the situation from natural shifts in the distribution of species). Nationally, the current environmental, economic, and health costs of invasive species were estimated as exceeding the costs of all other natural disasters combined.

Invasive species can be transported in many ways, such as on animals, vehicles, ships, commercial goods, produce, and clothing. Although non-native species are the foundation of U.S. agriculture, and also are used to prevent erosion, to provide fishing and hunting opportunities, and as ornamental plants and pets, occasionally a non-native organism flourishes too well and causes unwanted economic, ecological, or human health impacts. The terms "invasive" or "nuisance" are used to describe such species. New environments may affect rates of reproduction, susceptibility to disease, and other features that affect a species' success. Consequently, a plant or animal that causes little damage to agriculture or natural ecosystems in one area may cause significant problems in another. Certain non-native species are very successful in their new habitats because they out-compete native plants or animals and have no natural controls (predators, diseases, etc.) in the new area. At least 200 well-known, high-impact, non-native species presently occur in the United States. They range from the European gypsy moth and emerald ash borer to crabgrass, dandelions, and German cockroaches, annually costing well over a billion dollars to control. Some even pose human health risks. Others, like the zebra mussel, threaten widespread disruption of ecosystems and the displacement or loss of native plants and animals.

Hazard Analysis

Hundreds of new species from other countries are introduced intentionally or accidentally into the United States each year. These invasive species may arrive on our shores in a variety of ways. Transportation efficiencies that make it possible to travel around the globe in hours rather than weeks make it possible for organisms to survive transportation from one continent to another

As more adaptable and generalized species are introduced to environments already impacted adversely by human activities, native species are often at a disadvantage to survive in what was previously a balanced ecosystem. There are many examples of decreased biodiversity in such areas. One of the primary threats to biodiversity is the spread of humanity into what were once isolated areas, with land clearance and habitation putting significant pressure on local species. Agriculture, livestock, and fishing can also introduce changes to local populations of indigenous species and may result in a previously innocuous native species becoming a pest, due to a reduction of natural predators. This threat intensifies the need for scientists, managers, and stakeholders to cooperate to build better systems to prevent invasion, improve early detection of invaders, track established invaders, and to coordinate containment, control, and effective habitat restoration.

Although invasive species, in most cases, primarily cause environmental damage and degradation, there are situations in which serious threats to public health, safety, and well-being can occur due to animal disease or plant/animal infestations. For example, certain diseases could wipe out large segments of an animal population, creating a potentially serious public health emergency and the need to properly (and rapidly) dispose of the dead animal carcasses.

Similarly, a widespread insect infestation, such as that of the Emerald Ash Borer, can create serious public safety threats (especially in densely populated urban areas) due to dead and dying trees being fire prone (because of their dry, brittle nature) or to partial/total collapse due to high winds or ice/snow accumulation. The falling trees or limbs can also bring down power lines, cause damage to public and private structures, and cause injuries or even death.

The invasive species hazard has not yet been identified as one of the most significant hazards in any of Michigan's local hazard mitigation plans.

Impact on the Public

The emerald ash borer has caused extensive damage to trees in Michigan, and those weakened trees have often (1) collapsed and caused property damage, or (2) required removal, at considerable expense. A disaster declaration request was sent to FEMA, but the request was not accepted by that agency, leaving state and local budgets, residents, and insurance companies to try to cover the considerable expenses and efforts involved in dealing with the problem. Similar terrestrial species include the Asian Long-Horned Beetle and the Cedar Long-Horned Beetle, although aquatic species and some microbes are also of concern, since they may disrupt or impede forestry, horticulture, and fishing for Michigan residents, tourists, and industries.

Impact on Public Confidence in State Governance

Terrestrial species are likely to have more general public awareness than aquatic ones, and thus more likely to be a cause for dissatisfaction or loss of public confidence in government. Although there have been well-publicized aquatic species of concern (e.g. zebra mussels, Asian carp), people tend to be more aware of the impacts of terrestrial species, unless their recreational or business activities are more heavily curtailed by aquatic ones. The most recent widespread terrestrial species of concern has been the emerald ash borer insect—trees killed by these insects are prone to collapse, causing property damage, blocked roads, broken utility lines, etc. Citizens and businesses that are more heavily connected with agriculture and tourist industries are more likely to be aware of the impact of invasive species, and thus more likely to express doubts about government policies.

Impact on Responders

The invasive species hazard is a less familiar one for the general public, generally long-term and insidious in its effects, and rooted in an understanding of the biological sciences. Most emergency management training does not focus on the topic. Emergency management consideration of invasive species is recent and therefore needs to be increased. MSP/EMHSD has recently been strengthening coordination with the U.S. Geological Survey, which has specialized offices dealing with this hazard. An Ann Arbor USGS office deals with Great Lakes aquatic species, and a separate USGS office in Fort Collins, Colorado, deals with terrestrial species. Information and resources derived from this coordination will be made available to emergency management partners, and should be promulgated through the next update of the Michigan Hazard Analysis.

Impact on the Environment

Terrestrial and aquatic forms of invasive species both pose problems for the ecosystems in which they are introduced. Whether invasive species are brought to an area on purpose or by accident, these non-native life forms can alter the existing ecosystem and decrease an area's biodiversity. Like many hazards that affect Michigan's environment, invasive species have both direct and indirect impacts. The Zebra Mussel, for example, has been invading Michigan's water bodies since the mid 1980's and is responsible for eating the microscopic food supply that is vital to the existing ecosystem. Further, the Zebra Mussel attaches to water intake pipes and screens used for drinking water and industrial plants. Not only do these pests cause environmental problems, but they cause secondary economic impacts to a community as well. Similarly, the Emerald Ash Borer, a non-native insect, is responsible for killing millions of Ash Trees in Michigan, which changes the biodiversity of the forest and diminishes wildlife habitats. Dead trees pose problems for the human-built environment, as well, pulling down nearby wires and damaging structures.

NOTE: The following lists and descriptions provide examples of invasive species that pose some threat to Michigan, or have already affected Michigan. For each of these categories, at least several other species could have been included. Some of these species, such as the Gypsy Moth, are already well-established throughout the state, but the text provides information about the kinds of impacts that can result from the invasive species hazard.

Much additional information can be found at http://www.invasive.org/ and http://web4.msue.msu.edu/mnfi/.

Examples of Potentially Threatening Invasive Insects
(Note: Not all of these species currently occur in Michigan.)

Balsam Woolly Adelgid (Adelges piceae)
Hosts: All true firs.
Symptoms: Small white masses on tree, stunted shoots, formation of galls, tree crown turns red.
Damage: Feeding on the branches of the crown and main stem, causing mortality in 2-6 years.
Control/Treatment: Spraying of individual trees from the ground with lindane has proved effective for control. The spray, prepared by mixing 2.5 pints of 10% emulsifiable concentrate per 100 gallons of water, is applied as a bark drench with a hydraulic sprayer from May through June and September through October to control crawlers. Treatment will reduce populations to below the tree-killing level, and some treated trees may remain generally free from aphids for at least 2 years. Spraying is warranted only in accessible areas supporting relatively high-value trees.

Hemlock Woolly Adelgid (Adelges tsugae)
Hosts: Eastern Hemlocks.
Symptoms: Small white cottony masses at the base of the needles. Needles turn grayish green and drop off. There is a lack of new buds, and low vigor.
Damage: Feeding on twigs by nymphs cause the trees to die within 1-4 years.
Control/Treatment: Horticulture oils that smother the insects have been the best insecticidal treatment. The oils are non-toxic to the trees, as opposed to soap, which is an otherwise effective treatment. However, the least harmful cure may be the introduction of Japanese ladybugs.

Asian Long-Horned Beetle (Anoplophora glabripennis)
Hosts: Several species of hardwood trees found in Michigan. Its favorite host is the Norway maple, although it has been found in other maple species, horse chestnut, elm, box elder, mulberry and poplar trees.
Symptoms: Dark, wet areas on branches and trunks or white foamy sap are often the first symptoms seen in infested trees. The sap often attracts bees, wasps and hornets.
Damage: Trees infested are first weakened, and then die. Damage from these insects and secondary pests will kill a tree within a few years.
Control/Treatment: The only known way to eradicate the beetle is to cut down and burn infested trees.

Japanese Cedar Long-Horned Beetles (Callidiellum rufipenne)
Hosts: Nest in white cedar, eastern red cedar, and cypress trees.
Symptoms: Oval exit holes on tree bark, or deep irregular galleries in wood.
Damage: Larvae bore into wood and weaken the tree. Heavily infested trees may die.
Control/Treatment: None at this time.

Emerald Ash Borer (EAB) (Agrilus planipennis)
Hosts: White, black, and green ash trees.
Symptoms: Typically the upper third of a tree will die back first, followed by the rest during the next year. This is often followed by a large number of shoots or sprouts arising below the dead portions of the trunk. The adult beetles typically make a D-shaped exit hole when they emerge. Tissue produced by the tree in response to larval feeding may also cause vertical splits to occur in the bark. Distinct S-shaped tunnels may also be apparent under the bark. Adults are dark metallic green in color, 1/2 inch in length and 1/16 to 1/8 of an inch wide and are only present from mid May until late July. Larvae are creamy white in color and are found under the bark.
Damage: The adult beetles feed on ash foliage but cause little damage. The larvae feed on the inner bark of ash trees, disrupting the tree's ability to transport water and nutrients. Many trees appear to lose about 30 to 50 percent of their canopy in one year and the tree is often killed after 2-3 years of infestation. Most of the devastation in Michigan has occurred in the southeastern Lower Peninsula, where about 20 million trees have been killed. Fallen trees have caused extensive property damage. Please refer to the map at the end of this section for information about EAB quarantine areas in Michigan.
Control/Treatment: Treatment options for controlling infected or at risk trees include systemic insecticides applied as soil injections, systemic insecticides applied as trunk injections, noninvasive systemic sprays, and protective cover sprays. If properly applied, these treatment options can prevent EAB larvae from taking over the ash tree about 70% of the time. Treatment also proves to be successful when managing at-risk trees in areas where EAB has been identified. In continuing efforts to halt the expansion of the EAB, the Michigan Department of Agriculture and Rural Development (MDARD) has placed restrictions on the movement of firewood throughout the state and has taken other appropriate response measures. More information on the EAB can be found on the MDARD's website: www.michigan.gov/eab.

Gypsy Moth (Lymantria dispar)
Hosts: Tree foliage.
Symptoms: The egg mass is usually laid within a few feet of the female pupa casing. They are covered by a dense coating of hairs.

Damage: During high population levels, total defoliation can occur. During the months of June and July, defoliating populations cover sidewalks, homes, children's play equipment and other objects, making outdoor activity in residential and recreational areas almost impossible. For Michigan's nursery industry, additional expense and pesticide use are required. For the forest products industry, high gypsy moth populations mean the potential loss of wood fiber from reduced production (due to tree stress or mortality).
Control/Treatment: Counties may get involved in the Michigan Cooperative Suppression Program. The only pesticide used in the Cooperative Suppression Program is Bacillus thuringiensis, most commonly referred to as Bt.

Khapra Beetle (Trogoderma granarium)
Hosts: The beetle prefers hot, dry conditions and can be found in areas where grain and other potential food is stored, such as pantries, malt-houses, grain and fodder processing plants, and stores of used grain sacks or crates.
Symptoms: Destruction of grains and seeds. They can multiple quickly in stored items such as crackers, wheat, flour and baby cereal and rapidly spread to warehouses, storage bins, and mills.
Damage: The beetles can potentially cause severe harm to the agriculture crop industry such as grains and seeds including wheat, soybean, barley, corn and rice.
Control/Treatment: Fumigation with methyl bromide in containers to quarantining shipments until treatment. Powdered neem has been used to control the beetle in wheat stores in India.

Common Pine Shoot Beetle (Tomicus piniperda)
Note: Although previously listed in the Michigan Hazard Analysis, this species is no longer considered as damaging as it originally had been when first discovered in Michigan during the 1980s. The insect is now widespread throughout the Great Lakes and currently causes little economic impact.




Some invasive insects in Michigan, from left to right: Asian long-horned beetle, cedar long-horned beetle, emerald ash borer, gypsy moth

Examples of Potentially Invasive Microbes

(NOTE: Sudden Oak Death was described in previous editions of this plan, but has only occurred in California and Oregon. Examples listed here are not necessarily found in Michigan at the present time.)

At left, Dutch elm disease; at right, the plum pox virus

Dutch Elm Disease
Hosts: Elm trees
Symptoms: Trees infected by elm bark beetles first show wilting, curling, and yellowing of leaves on one or more branches in the upper portion of the tree, as a fungus from the beetles progressively affects the tree's health.
Damage: Large trees may survive and show progressively more symptoms for one or more years. Trees infected through root grafts wilt and die rapidly; this frequently occurs in the spring, soon after the trees have leafed out, and progresses from the base of the tree upward.
Control/Treatment: Dutch elm disease control has involved two different but related programs: (1) community-wide sanitation programs designed to reduce the level of elm bark beetles (principal carriers of the Dutch elm disease fungus); and (2) prevention of the spread of the disease through natural root grafts from infected trees to adjacent healthy trees. There are probably no community-wide programs being used any more, with a shift toward disease management involving the planting of different species of trees. There is no way to eliminate Dutch elm disease once it begins, but different species such as Siberian elms are resistant to the disease.

Plum Pox Virus
Hosts: Peach, plum, nectarine, apricot, almond, cherry.
Symptoms: Discolored viral rings on leaves and fruit.
Damage: Smaller deformed fruit and reduced fruit production.
Control/Treatment: Control and prevention measures include field surveys, use of certified nursery materials, use of virus-resistant plants (when available), control of aphids, and the elimination of infected trees in nurseries and orchards. A team of scientists from the United States and France has genetically engineered a PPV-resistant plum (known as C5), and this resistance can be transferred through hybridization to other plum trees. This provides a source of germplasm for future breeding programs worldwide. Similar success has not yet occurred in attempts to genetically modify other Prunus species.

Thousand Canker Disease of Walnut

Hosts: Black walnut and other walnut species.

Symptoms: Infected trees show wilting, curling, and yellowing of leaves on one or more branches in their upper portions, as a fungus from the walnut twig beetles progressively affects the tree's health.

Damage: Causes thousands of small cankers on and under the bark, disrupting the flow of nutrients to the branches. Tree mortality is directly proportional to the number of feeding sites present on the tree.

Control/Treatment: There is no practical treatment, once infected. Landowners should remove affected trees to prevent spread to nearby trees.

Examples of Invasive Water Species Affecting Michigan

Asian Carp (Ctenopharyngodon idella, hypophthalmichthys nobilis, and hypophthalmichthys molitrix)

Hosts: Asian carp made their way into the Mississippi River from Arkansas fish farms in the 1970s as a result of flooding and have steadily swum upstream for years at a pace of 40 to 50 miles a year. Asian carp are currently in the Illinois River and only miles away from entering the Great Lakes.

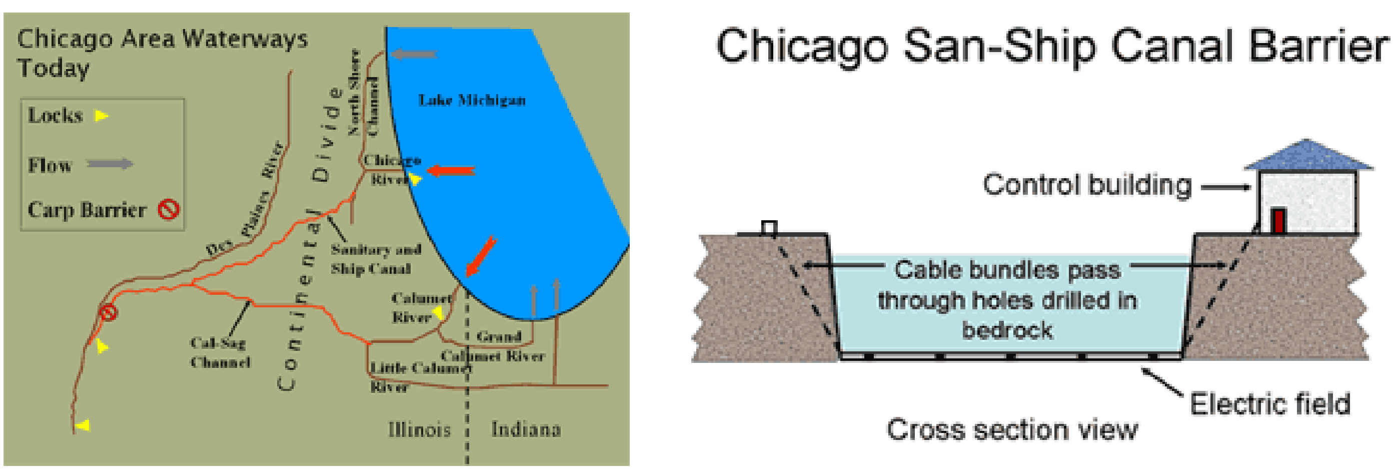
Symptoms: Decline in native fish species**.** There are three different species of Asian carp that have invaded the Mississippi River: grass (ctenopharyngodon idella), bighead (hypophthalmichthys nobilis), and silver (hypophthalmichthys molitrix). All three species of Asian carp pose a problem to the waterways by devastating habitats and destroying water quality. However, the bighead and silver carp are of the greatest concern, due to their size. These fish can each grow to be 50 to 100 pounds. Although great attention has been focused on these fish recently, dreissenid mussels have already invaded the Great Lakes and caused extensive impacts. (A description of mussels also appears in this section.)

Damage: Researchers expect that Asian carp would disrupt the food chain that supports the native fish of the Great Lakes. Due to their large size, ravenous appetites, and rapid rate of reproduction, these fish could pose a significant risk to the Great Lakes Ecosystem. If bighead or silver carp enter the great lakes, the economic impacts on the fishing industry would be devastating, putting the Midwest's multi-billion dollar-a-year fishing industry at risk. Also, silver carp have been known to cause injuries to boaters, as they jump out of the water.

Control/Treatment: To prevent the species from entering the Great Lakes, the U.S. Army Corps of Engineers, U.S. EPA, State of Illinois, International Joint Commission, Great Lakes Fishery Commission, and U.S. Fish and Wildlife Service constructed a temporary electronic dispersal barrier on the Chicago Sanitary and Ship Canal near Romeoville, Illinois, which was activated in April, 2002. In late October 2004, construction began on a second, more permanent barrier. The new barrier, completed in February 2005, stretches two rows of electrodes across the canal approximately 220 feet apart. The electrodes pulse DC current into the water, causing fish to turn back rather than pass through the electric current. The electric current poses no threat to humans. A model of the Chicago Canal Barrier can be seen below.

In November 2009, evidence of the presence of Asian carp was detected beyond the electric barrier, which left only a single lock/dam on the Calumet River between the carp's detected location and Lake Michigan. Due to the major ecological threat to Lake Michigan and to recreational boaters, the U.S. Army Corps of Engineers shut down one of the electric barriers for maintenance in December 2009. The Illinois Department of Natural Resources responded to the situation by dumping 2,200 gallons of the toxin rotenone into the canal. Rotenone is deadly for fish but not harmful to humans, animals, or most other aquatic life. The intentional fish kill cost $3 million and produced about 90 total tons of dead fish, but only one carp was found in the Lockport Lock and Dam area. In June 2010, a 19-pound Asian carp was found near the shore of Lake Michigan, in Lake Calumet, about six miles downstream from Lake Michigan, by a commercial fisherman hired by the state of Illinois to do routine fish sampling in the area. The fish confirmed existing DNA evidence suggesting that the Asian carp had indeed breached the electric barrier on the Chicago Sanitary and Ship Canal, which had been considered the last line of defense for Lake Michigan.

NOTE: New developments occur frequently. This information was considered accurate as of 12-2010.



Chicago Sanitary and Ship Canal Dispersal Barrier System (Source: U.S. Geological Survey)

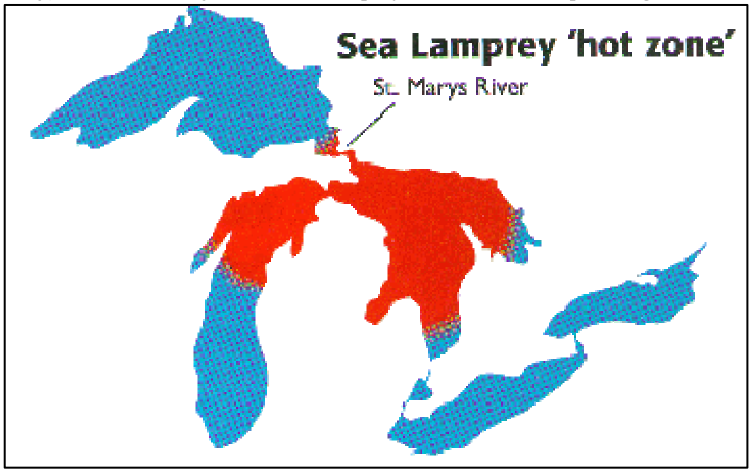
Sea Lamprey (Petromyzon marinus)

Hosts: Found in both fresh water and salt water habitats, they breed in freshwater streams and lakes and were first discovered in the Great Lakes in the 1800s.

Symptoms: Sea lampreys prey on a wide variety of fish. The lamprey uses its suction-cup like mouth to attach itself to the skin of a fish (possibly for days) and rasps away tissue with its sharp probing tongue and many hooked teeth, arranged in numerous rows. Secretions in the lamprey's mouth prevent the victim's blood from clotting, and the lamprey sucks the victim's blood. Victims (usually smaller ones) typically die from excessive blood loss or infection. Mature sea lampreys average 2 to 2½ feet long, up to a maximum of about 3 feet. Sea lampreys are considered a pest in the Great Lakes region and were introduced as an invasive species in the 1800s, originating from the inland Finger Lakes and Lake Champlain in New York and Vermont. Sea lampreys created a problem for key predator fish species including lake trout, lake white fish, and lake herring. The elimination of these key predator fish allowed the alewife, another invasive species, to explode in population, having adverse effects on many native fish species.

Damage: The introduction of the sea lamprey to Lake Superior caused serious declines in fish populations, and an alteration of the ecosystem. The lake trout played a vital role in the Lake Superior ecosystem because it is considered an apex predator, which means that the entire system relies on its presence to be diverse and healthy. As an apex predator was removed from the system, the entire system felt the effects all the way down the food chain. The sea lamprey is an aggressive predator by its nature, which gives it a competitive advantage in a lake system where it has no predators and its prey lack defenses against it. The sea lamprey played a large role in the drastic decline of the Lake Superior lake trout population. One sea lamprey can upset an ecosystem and food chain by eating an estimated 40 pounds of fish or more in its lifetime. This resulted in an unbalanced relationship between predators and prey in the Great Lakes' Ecosystem.

Control/Treatment: Control efforts to mitigate the destructive effects of the sea lamprey have included the use of electric currents, chemicals, and barriers. In 1958, scientists found a chemical (still used today) that selectively killed sea lamprey larvae in their spawning streams, and brought the lamprey under control. In 1986, DNR fish managers, technicians and engineers designed a new lamprey barrier which let fish migrate through to spawn, but captured the lamprey. The new barrier was expected to reduce the number of lamprey beyond it to nearly zero. Lamprey numbers in Lake Michigan are currently only about 10 percent of their peak numbers in the 1950s. Today, biologists and researchers are still looking for new ways to stop the spread of lampreys in lakes, streams, and rivers. It is the hope of the Great Lakes Fishery Commission that at least some of this scientific work on the sea lamprey, including genetic and pheromone studies, will result in a more effective management technique that could one day drastically reduce the need for chemical treatments of spawning grounds. Several million dollars are spent each year on environmentally friendly control methods. Native predatory fish, like the whitefish and lake trout, have been restocked by fisheries professionals to help maintain a healthy level of these species.



__Dreissenid Mussels (including Zebra Mussels and Quagga Mussels)__ **(family Dreissenidae)**

Hosts: Freshwater lakes and streams

Symptoms: By firmly attaching to hard surfaces, dreissenid mussels have clogged water-intake pipes and fouled hard-shelled animals such as clams and snails. In addition, zebra mussels have reduced plankton populations, as colonies of mussels filter large volumes of water for food, potentially depleting food resources of larval and planktivorous fishes such as smelt, chub, and alewife. Transfer of suspended material to the lake bottom in mussel waste products also leads to increased water clarity and increased growth of aquatic plants. Although clear water is often considered aesthetically pleasing, this clarity indicates that drastic changes have occurred at the base of the food web and that energy flows through the ecosystem has been altered. The mass media has given a great deal of attention to the zebra mussel, but quagga mussel infestations are actually far more extensive in the Great Lakes. Both zebra and quagga mussels belong to the same genus, dreissenid mussels, but quagga mussels are more tolerant of colder and deeper waters than zebra mussels are. Quagga mussels were first spotted in the Great Lakes around 1990, and have devoured so much plankton that the food web is being altered.

Damage: Communities along the affected lakes and rivers rely on these waters for drinking, industrial water supplies, transportation, commercial fishing and shelling, and recreation. Rapidly expanding populations of dreissenid mussels could ultimately affect many of these activities, in addition to changing the structure of the ecosystem.

Control/Treatment: Applications of hot water and bleach have been used. A new method involving bacteria is being refined.

A couple of invasive aquatic species: Asian carp and zebra mussel.

Invasive Plant Species in Michigan

Please refer to the information in the MDNR publication "Meeting the Challenge of Invasive Plants: A Framework for Action," which can be found at the following website:

http://www.michigan.gov/documents/dnr/Invasives_strategy_final_289799_7.pdf. Numerous online resources provide more information about plants, such as the NRCS database at http://plants.usda.gov/java/.

Example of a Terrestrial Animal Species that Poses a Threat to Michigan

Boar or Wild Hogs (Sus scrofa)

Feral swine are defined as free-ranging pigs and are considered to be an aggressive public nuisance. They have been known to attack and chase humans. They can become infected with, and may transmit, diseases that affect human health, domestic livestock, and wildlife, such as brucellosis, tuberculosis, bubonic plague, tularemia, anthrax, and trichinosis. In Michigan, pseudorabies-positive feral swine were removed from private land in 2008. Feral swine have the potential to cause great economic harm to the domestic swine industry, if they were to transmit such disease to commercial swine.

The appearance of feral swine may vary greatly, as they can originate from several subspecies, including the Russian Boar, the wild Eurasian boar, escaped domestic swine, and quite often a mix of domestic and wild-type breeds. These animals can weigh up to 400 pounds, may be covered in coarse hair, may have tusks, and are known to travel in groups. Females in warm states produce two large litters of 8 to 10 piglets per year. In Michigan, feral swine are known to survive the harsh winters. Feral swine tend to follow creeks and drains between food sources. They favor agricultural crops, but when the crops are harvested in the fall, they turn to wildlife food plots, acorns, and other mast foods. Feral swine are known to eat ground nesting birds, small mammals, and grubs.

Damage: Feral swine can tear up the landscape, killing wildlife and pets, damaging farm crops and wildlife habitats, and scavenging uncovered garbage. Their devastating effect on crops accounts for up to $1.5 billion in annual damages nationally. Unlike most animals, feral swine don't stop at just eating crops. They also root holes in the ground as deep as a foot, destroying the crops. Wild hogs can damage as much as 10 percent of a farmer's crop.

To date, the Department of Natural Resources has logged 288 unofficial feral swine sightings by residents in almost every county in Michigan. Since 1999, national experts have estimated that, if unchecked, the feral swine population could become established statewide and cause economic hardship for farmers, and for businesses that cater to wildlife enthusiasts.

Control: On May 13, 2010, the Michigan Legislature amended Public Act 328 of 1976 (Domestic Animals Running at Large) by allowing people to pursue and harvest feral swine at any time. The law does the following: (1) declares swine running at large on public or private property to be a public nuisance, (2) permits a local animal control officer or a law enforcement officer to kill swine running at large on public or private property, (3) permits a person with a concealed weapon permit or a valid hunting license to kill swine running at large on public property, and (4) permits a property owner or other authorized person to kill swine running at large on private property. In the last case, the landowner does not need a hunting license.

Michigan residents who see or shoot a feral pig are asked to report it to the Michigan Department of Natural Resources at (517) 336-5030. USDA Wildlife Services (517-336-1928) and the Wildlife Conservancy (517-641-7677) have feral swine traps available for the use of landowners who are experiencing feral swine damage. The animals will be trapped, removed, and tested for disease, then euthanized and disposed of.

In December, 2010, the Michigan Department of Natural Resources classified feral swine as an invasive, exotic or prohibited species under Public Act 451, the state's Natural Resources and Environmental Protection Act of 1994, but the Director's order does not go into effect until April of 2011.

Partners: The Feral Swine Working Group is an interagency team of veterinarians, biologists, and policy personnel within the state and federal governments, Michigan State University, and from numerous stakeholder groups, including the Michigan Animal Control Association, Michigan Farm Bureau, Michigan Pork Producers Association, Michigan United Conservation Clubs, Michigan Corn Growers Association, the Nature Conservancy, United Deer Farmers of Michigan, the Michigan Hunting Dog Federation, and the Michigan Wildlife Conservancy.

Animal Diseases

There are many animal diseases that have the potential to impact Michigan. Diseases from outside Michigan or the United States have the potential to cause widespread mortality in livestock, wildlife, and companion animals. They could result in huge economic losses (primarily through trade restrictions), require significant resources to be allocated for response, and in some cases could also threaten public health. For more information, please refer to the Reportable Animal Diseases documents of the Department of Agriculture and Rural Development. (One introductory link is: http://www.michigan.gov/mda/0,1607,7-125-48096_48097_48155-71720--,00.html.) Foot and Mouth Disease is an example of a foreign animal disease that would require a heightened response from Michigan agencies.

Example of a Livestock Disease That Poses a Threat to Michigan

Foot and Mouth Disease

Hosts: This infectious virus spreads on surfaces and in the air, and impacts cattle, swine, sheep, goats, deer, and other cloven-hoof ruminant animals. It does not currently exist in Michigan or the United States and has not existed in the U.S. since 1929. However, the disease is of great concern because it is highly contagious and would have grave economic consequences for Michigan's livestock industry.

Symptoms: In cattle, blisters inside the mouth that lead to excessive secretion of stringy or foamy saliva and to drooling; and blisters on the feet that may rupture and cause lameness. Adult animals may suffer weight loss from which they do not recover for several months, as well as swelling in the testicles of mature males. In cows, milk production can decline significantly.

Damage: Though most animals eventually recover from FMD, the disease can lead to myocarditis (inflammation of the heart muscle) and death, especially in newborn animals. Some infected animals do not suffer from or show signs of the disease, but they are carriers of FMD and can transmit it to others.

Control/Treatment: The Michigan Department of Agriculture and Rural Development (MDARD) licenses and regulates Michigan's 500 livestock dealers, truckers, livestock sales, and auction markets to help monitor animal health and ensure the safe and humane handling of animals. The MDARD also monitors and controls the interstate and intrastate shipment of animals and animal products, to eradicate and control the spread of disease. If this disease were discovered in the United States, it would trigger national and state response plans and require rapid and coordinated response in order to control the disease and protect the nation's livestock industry.

Wildlife Diseases that Pose a Threat to Michigan

Chronic Wasting Disease (CWD)

This is a prion disease of the brain. The infectious agent contaminates the environment and is transmitted from one animal to another.

Hosts: Deer and elk are affected by this brain disease that is present in several western states and in Minnesota and Wisconsin. It was also detected in one Michigan location in 2008 (at an enclosed deer breeding facility in Kent County). Mule deer, white-tailed deer, and Rocky Mountain Elk are the only three species of the family Cervidae that are known to be naturally susceptible to CWD. However, it is very likely that other subspecies of C. elaphus are susceptible to the disease. Although no other deer in Michigan have tested positive for CWD (outside of the isolated Kent County case), it remains a major concern due to the large wild population of deer in the state.

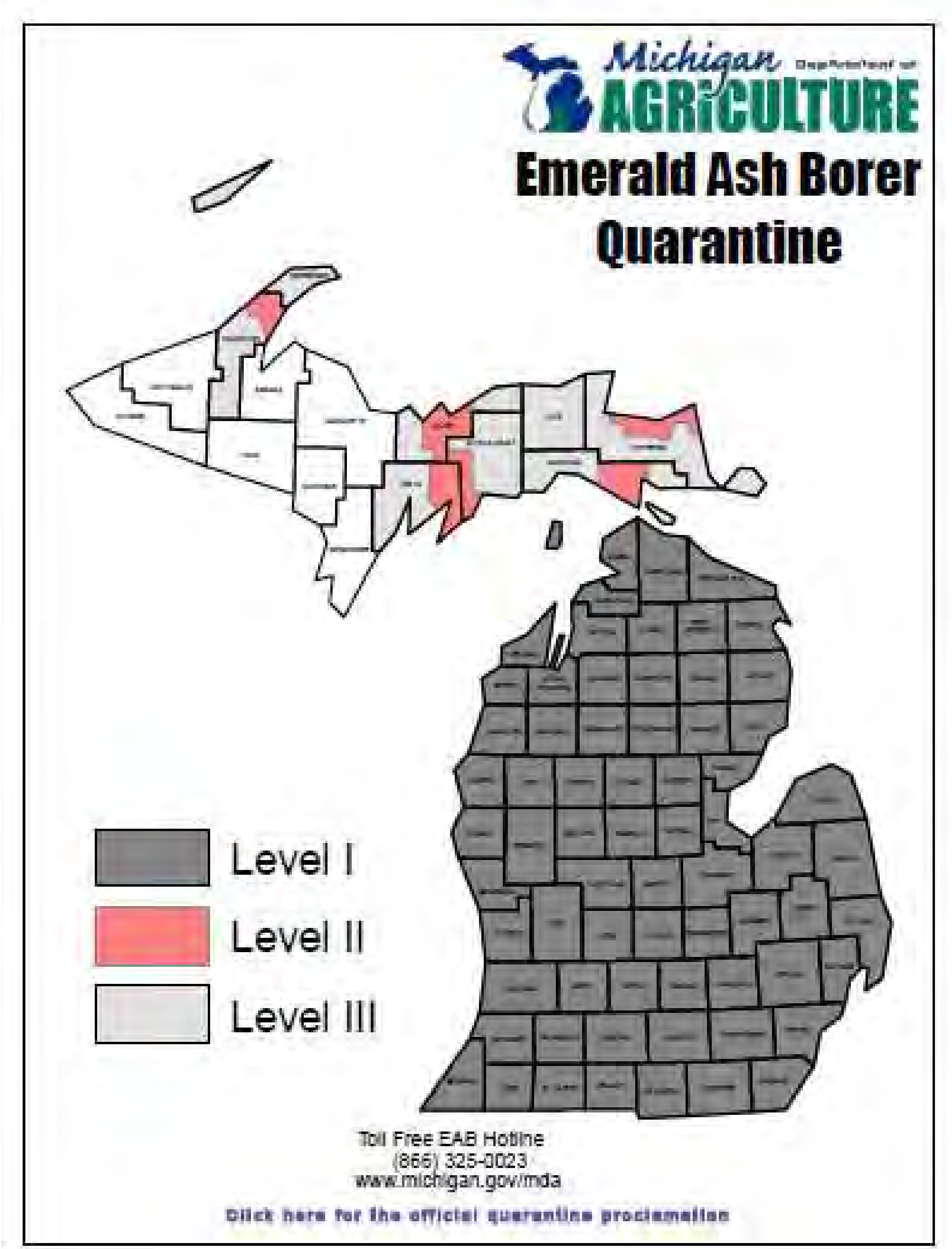
Symptoms: Emaciation, wide stance, lowered head, droopy ears and excessive salivation.

Damage: Animal fatalities

Control/Treatment: Chronic wasting disease is both transmissible and infectious, but most details of its transmission remain to be determined. No treatment is available for animals affected with CWD. Once clinical signs develop, CWD is invariably fatal. Affected animals that develop pneumonia may respond temporarily to treatment with antibiotics, but ultimately the outcome is still fatal. Similarly, no vaccine is available to prevent CWD infection in deer or elk.

Two threatening animal diseases: Chronic wasting disease and foot and mouth disease.

Emerald Ash Borer Quarantine Area Map, as of late 2010



Source: Michigan Department of Agriculture and Rural Development

I. Natural Hazards
D. Geological Hazards

The following outline summarizes the significant geological hazards covered in this section:

1. Ground Movement
    a. Earthquakes
    b. Subsidence
2. Celestial Impacts

Although some states recognize "landslides" as an additional hazard, Michigan's geology and history tends to make it more prone to land subsidence instead. Michigan's two main vulnerabilities to ground movement are therefore identified in the sections on earthquakes and subsidence hazards. Erosion is not in itself typically considered an emergency event, except in cases involving encroachment into shoreline developments near a river or lake, and these have been dealt with in the Hydrological Hazards section of this plan. A new section of this plan, celestial impacts, deals not only with the impact of physical objects on property, but also with the effects of solar storms on our modern infrastructure. It will be seen that the systemic technological impacts of this hazard involve greater expected risks than the more well-known impacts of a meteoritic type. Although meteorite impacts are quite easy to understand and visualize, and do have a small potential to be catastrophic, it is the seemingly abstract and mostly invisible effect of "space weather" that has the greatest probability of causing widespread disruption and harm in the near future.

Overlap Between Geological Hazards and Other Sections of the Hazard Analysis

The most serious Michigan earthquakes would be expected to damage some of the utilities infrastructure in the southern part of the state, and could contribute to the occurrence of an energy emergency. Some flooding could result from broken water mains. There may be some potential for oil and gas pipeline operations to be disrupted, as well. A serious subsidence event may cause a key roadway to collapse and become unusable, and may also cause certain other types of infrastructure to become exposed and vulnerable. Transportation accidents that may result from these hazards could cause the release of dangerous hazardous materials. The real potential for a catastrophic incident exists in the event of a major seismic event involving the New Madrid fault line.

Celestial impacts involving solar flares can cause infrastructure failures and have the potential to cause major transportation accidents involving airplanes and/or seagoing vessels. Other types of celestial impacts, involving the impact of physical bodies upon the Earth and its atmosphere, are usually minor but rarely will have the potential to be catastrophic, capable of causing damage equivalent to a nuclear attack and the associated casualties, mass fires (including wildfires), infrastructure failure, severe winds, and physical damages associated with the nuclear attack hazard (but without as intense of radiological effects).

Earthquakes

A shaking or trembling of the crust of the earth caused by the breaking and shifting of rock beneath the surface.

Hazard Description

Earthquakes range in intensity from slight tremors to great shocks. They may last from a few seconds to several minutes, or come as a series of tremors over a period of several days. The energy of an earthquake is released in seismic waves. Earthquakes usually occur without warning. In some instances, advance warnings of unusual geophysical events may be issued. However, scientists cannot yet predict exactly when or where an earthquake will occur. Earthquakes tend to strike repeatedly along faults, which are formed where tectonic forces in the earth's crust cause the movement of rock bodies against each other. Risk maps have been produced which show areas where an earthquake is more likely to occur. Earthquake monitoring is conducted by the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and universities throughout the country.

The actual movement of the ground in an earthquake is seldom the direct cause of injury or death. Most casualties result from falling objects and debris. Disruption of communications systems, electric power lines, and gas, sewer and water mains can be expected. Water supplies can become contaminated by seepage around water mains. Damage to roadways and other transportation systems may create food and other resource shortages if transportation is interrupted. In addition, earthquakes may trigger other emergency situations such as fires and hazardous material spills, thereby compounding the difficulties of the situation.

A fault line is where a fault meets the ground's surface, but many faults dip at an angle away from their surface location, and therefore earthquakes that occur at some depth will often not line up with the fault at the surface. Faults do not only occur at the boundaries of large geological plates. There are many small plates that exist, as well as faults that are internal to or perpendicular to plate boundaries.

Hazard Analysis

No severely destructive earthquake has ever been documented in Michigan. However, several mildly damaging earthquakes have been felt since the late 1700s. The exact number is difficult to determine, as scientific opinion on the matter varies. With most of these earthquakes, damage (if any) was limited to cracked plaster, broken dishes, damaged chimneys, and broken windows.

In recent years, attention has been focused on the New Madrid Seismic Zone. This zone extends from approximately Cairo, Illinois through New Madrid, Missouri to Marked Tree, Arkansas. During the winter of 1811-1812, a series of earthquakes shook the area. The three worst earthquakes destroyed the town of New Madrid, created a 17,000 acre lake in Northwestern Tennessee, caused ocean-like swells on the Mississippi River (which reportedly ran backwards), and rang church bells as far away as the eastern seaboard. Richter Scale estimates ranged around 8.0. The 1811-1812 earthquakes also included hundreds of aftershocks, some with magnitudes estimated to be between 6.5 and 7.6 on the Richter Scale.

The New Madrid Seismic Zone is significant because scientists predict that a catastrophic earthquake (between 6.0 and 7.6 on the Richter Scale) will occur within the zone sometime during the next few decades. Michigan may be somewhat affected by such an earthquake. A repeat of the 1811-1812 earthquakes is unlikely in the near future. However, should it occur, it could result in damage, disruptions, casualties, and injuries on a scale never experienced from an earthquake in the history of the U.S. The immediate and long-term relief and recovery efforts could place a significant, prolonged burden on the regional and national economies.

Fortunately, Michigan is not located in an area subject to major earthquake activity. Although there are faults in the bedrock of Michigan, they are now considered relatively stable. However, these faults are poorly mapped. According to the U.S. Geological Survey, although Michigan is in an area in which there is a low probability of earthquake occurrences, the area may be affected by distant earthquakes that occur in the New Madrid Seismic Zone and upstate New York. The New Madrid Seismic Zone poses the most significant threat. Based on recent scientific studies, portions of southern Michigan could be expected to receive minor damage were such an earthquake to occur (see the map at the end of this section).

The greatest impact on the state would probably come from damage to natural gas and petroleum pipelines. If the earthquake occurs in the winter, many areas of the state could be severely impacted by fuel shortages. Damage would probably be negligible in well-designed and constructed buildings. However, poorly designed and constructed buildings could suffer considerable damage under the right circumstances.

The following table has a list of earthquakes that have been felt in Michigan. The most severe event centered in Michigan was the 4.7 magnitude event of 1947, which caused some damage to (mainly residential) structures in the southwest region of the Lower Peninsula.

Tectonic Earthquakes Felt or Occurring in Michigan

Date	Origin	Magnitude
4-20-1793*	Porcupine Mt, MI	N/A
12-16-1811 (3 events)	New Madrid, MO	7.9, N/A., N/A
1-22-1812	New Madrid, MO	N/A
1-23-1812	New Madrid, MO	N/A
1-25-1812	New Madrid, MO	7.0
2-3-1812	New Madrid, MO	N/A
2-7-1812	New Madrid, MO	7.5
2-8-1812 (4 events)	New Madrid, MO	N/A
10-20-1870	La Malbaie, QUE	N/A
8-17-1877*	Greenfield, MI	3.2
9-19-1884	Lima, OH	4.8
9-1-1886	Charleston, SC	7.7
10-31-1895	Charleston, MO	6.7
5-26-1909	Aurora, IL	5.1
3-1-1925	La Malbaie, QUE	7.0
8-12-1929	Attica, NY	5.2
11-1-1935	Timiskaming, QUE	6.2
3-2-1937	Anna, OH	5.0
3-9-1937	Anna, OH	5.4
2-12-1938*	Porter, IN	4.0
3-13-1938*	Gibraltar, MI	3.8
3-14-1938*	Gibraltar, MI	N/A
3-9-1943	Lake Erie, OH	4.5
9-5-1944	Massena, NY	5.8
8-10-1947	Coldwater, MI	4.7
11-9-1968	El Dorado, IL	5.5
9-15-1972	Rock Falls, IL	4.5
4-3-1974	Lancaster, IL	4.7
2-2-1976	Pt. Pelee, ON	3.4
7-27-1980	Sharpsburg, KY	5.1
8-20-1980	Harrow, ON	3.2
11-29-1982	Scotts, MI	2.5
10-7-1983	Blue Mtn. Lake, NY	5.1
1-31-1986	Perry, OH	5.0
7-12-1986	St. Mary's, OH	4.6
6-10-1987	Lawrenceville, IL	5.2
11-25-1988	Saguenay, QUE	5.9
9-2-1994	Central Michigan	3.4
9-25-1998	Sharon, PA	5.2
10-23-2001*	Prairie Lake, MI	2.9
4-18-2008 (2 events)	West Salem, IL	5.4, 4.8
2-10-2010	Elgin, IL	3.8
6-23-2010	Val-Des-Bois, QUE	5.0

N/A means that the magnitude information was not available.
* May not have been a natural earthquake. Explosive blasting, mine collapse or other subsidence, and large meteorite impacts can all cause tremors to be felt that may give persons the impression that an earthquake has occurred.
Source: Michigan State University Earthquake Information Center / East Lansing Seismic Station

NOTE: This list has been adapted from the "Earthquakes in Michigan" source list found at https://www.msu.edu/~fujita/earthquake/eqinfo.html. Earthquakes that may not have actually been felt in Michigan were not included in the list.

Historical earthquake occurrences appeared to have an element of a cyclical nature about them, with some decades containing numerous events, surrounded by decades with only a few events, and followed by periods with nearly no occurrences at all. Over time it may be that (probably due to increases in population and development) the number of occurrences gradually increases within this cycle, although this is uncertain. (The pattern is not extremely clear and long, and may just happen to be a statistical artifact.) The potential pattern is illustrated through the listing of natural tectonic earthquake events by decade, with arrows pointing to small peaks of earthquake activity approximately every 50 years. (This is shown on the next page.)

The hypothesis that there may be a kind of cyclic trend is based purely upon the historical data. A recent text, Michigan Geography and Geology (editor in chief, Randall Schaetzl), includes a chapter on earthquakes and states that "about once every 50 years, a magnitude 3-4 event occurs within the state, south of a line between Grand Rapids and Pontiac." Although the event information (listed above) had fit pretty well into this pattern, the most recently updated information from the same source has not quite fit perfectly into the proposed pattern, for instead of the earthquake activity dropping to zero after a clear peak during the 1980s, it has instead fallen into a pattern of about two events per decade, and one of those decades (the 2010s) has only just begun! Thus, there seem to be more earthquakes being felt recently than might have been expected, according to the previous pattern. It is possible that this level of disturbance might be comparable to the periods that would have been marked with zeroes in the past, and that the next occurrence of a peak (in the 2030s?) may therefore involve a record number of events, if there is indeed a gradual trend toward an increased number of disturbances.

1790s:	0	
1800s:	0	
1810s:	12	←These were all New Madrid events and aftershocks, and may not fit into a cyclic trend for Michigan
1820s:	0	
1830s:	0	
1840s:	0	
1850s:	0	
1860s:	0	
1870s:	1	
1880s:	2	←Possible peak in a cyclic trend
1890s:	1	
1900s:	1	
1910s:	0	
1920s:	2	
1930s:	3	←Possible peak in a cyclic trend
1940s:	3	
1950s:	0	
1960s:	1	
1970s:	3	
1980s:	8	←Possible peak in a cyclic trend
1990s:	2	
2000s:	2	
2010s:	2	←Recent trend might not quite match the proposed 50-year cycle

Earthquake Risk Calculation

Although earthquakes are generally not considered a major hazard in Michigan, other states have had so many problems with this hazard that very detailed techniques have been developed to estimate earthquake risks. Each area of the country has been assessed by geologists (according to types of bedrock, fault line proximity, and other factors) and sorted into general zones of earthquake risk. (For a national map showing this, see the web site at http://earthquake.usgs.gov/research/hazmaps/.) These zones are expressed in terms of a probability that significant ground movements will be felt. For example, there may be a 10% chance of an area experiencing significant ground movement within a 50 year period, (which is similar to the "500-year" floodplain, since the annual probability of such an event calculates as roughly .0021). Another component of risk calculation would be to estimate the amount of damage that is likely when such an event occurs. Official measures use the concept of Peak Ground Acceleration (PGA, which is also abbreviated as %g). The key task is to translate the severity of (PGA) ground motion into estimates of structural damages and other economic costs. FEMA has developed a computer application (HAZUS) to give estimates of these earthquake effects.

Michigan has a comparatively low risk of experiencing damaging ground movements. Because of this low risk, however, many designers and developers did not take into consideration the possibility that an earthquake *might* occur. Some of Michigan's communities may actually be quite vulnerable to earthquake effects—especially Michigan's underground utilities—in cases where developed areas were not designed to withstand any ground movements.

Urban areas and active mineland/quarry areas may experience seismic effects as a result of blasting activities, subsidence, structural collapses, vibrations from trains and trucks, or explosions (such as from industrial accidents or terrorist activity). It is therefore worth considering a strengthening of infrastructure as well as interior design enhancements to resist both natural and other types of seismic impacts, vibrations, and stresses.

Impact on the Public

Earthquakes have the potential to cause impacts on an area's infrastructure and energy if a significant event occurs. Impacts could include higher prices for energy and supplies, and the potential for limited supplies of needed goods and resources. A major event, such as a large-scale temblor in the New Madrid Zone, may constitute a National Emergency event (on the scale of Hurricane Katrina), in which there is a need for mutual aid to be provided to states which were strongly affected, and the intake of evacuees from those states. There is a moderate potential for property damage to occur in areas of southern Michigan that are more prone to experiencing seismic activity, and these damages would clearly be inconvenient for homeowners and businesses, at the very least.

Impact on Public Confidence in State Governance

The public may perceive earthquake effects in terms of a governmental failure to plan for and maintain appropriate standards for infrastructure durability and hardening. Some questions may also be raised about whether sufficient geological research had been conducted in the area, and about whether there was a successful means of providing advance warning that the area might experience an earthquake.

Impact on Responders

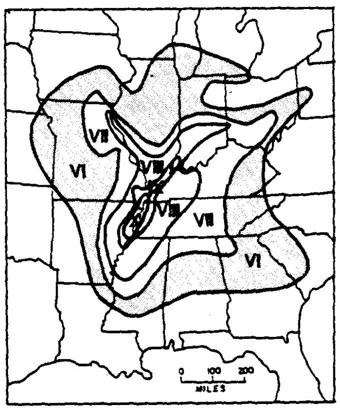
Response operations have the potential to include search and rescue activities, which involve special risks and requirements for training and equipment. Earthquake-related infrastructure failures or road subsidence may inhibit efficient and safe response to the incident, and may interfere with the access and use of resources needed for normal and emergency response activities.

Impact on the Environment

A significant earthquake has the potential to cause problems for the environment, both directly and indirectly. Ground movement may disrupt wildlife habitats and change an area's landscape. Secondary environmental impacts caused by a significant event may involve a hazardous materials release into the ground, air, or water from damaged buildings and infrastructure. Fortunately, it is unlikely that an earthquake, even a significant-magnitude New Madrid event, would cause great environmental impacts in Michigan.

Earthquake Threat in Michigan

Source: U.S. Geological Survey



Regional map of maximum intensities that would result from a magnitude Ms=7.6, maximum intensity earthquake *anywhere* along the New Madrid Seismic Zone.

Subsidence

The lowering or collapse of a land surface, caused by natural or human-induced activities that erode or remove subsurface support.

Hazard Description

Subsidence is the lowering or collapse of a land surface, due to loss of subsurface support. It can be caused by a variety of natural or human-induced activities. Natural subsidence occurs when the ground collapses into underground cavities produced by the solution of limestone or other soluble materials by groundwater. Human-induced subsidence is caused principally by groundwater withdrawal, drainage of organic soils, and underground mining. In the United States, these activities have caused more than 17,000 square miles of surface subsidence, with groundwater withdrawal (10,000 square miles of subsidence) being the primary culprit. In addition, approximately 18% of the United States land surface is underlain by cavernous limestone, gypsum, salt, or marble, making the surface of these areas susceptible to collapse into sinkholes.

Generally, subsidence poses a greater risk to property than to life. Nationally, the average annual damage from all types of subsidence is conservatively estimated to be at least $125 million. The National Research Council estimate of annual damage from various types of subsidence is outlined in the table below:

Land Subsidence: Estimated Annual National Damage

Type of Subsidence	Annual Damage ($)
Drainage of organic soils	40,000,000
Underground fluid withdrawal	35,000,000
Underground mining	30,000,000
Natural compaction	10,000,000
Sinkholes	10,000,000
Hydrocompaction (collapsible soils)	N/A
TOTAL:	**$125,000,000**

Source: National Research Council; Multi-Hazard Identification and Risk Assessment, Federal Emergency Management Agency

Mine Subsidence

In Michigan, the primary cause of subsidence is underground mining. Although mine subsidence is not as significant a hazard in Michigan as in other parts of the country, many areas in Michigan are potentially vulnerable to mine subsidence hazards. Mine subsidence is a geologic hazard that can strike with little or no warning and can result in very costly damage. Mine subsidence occurs when the ground surface collapses into underground mined areas. In addition, the collapse of improperly stabilized mine openings is also a form of subsidence. About the only good thing about mine subsidence is that it generally affects very few people, unlike other natural hazards that may impact a large number of people. Mine subsidence can cause damage to buildings, disrupt underground utilities, and be a potential threat to human life. In extreme cases, mine subsidence can literally swallow whole buildings or sections of ground into sinkholes, endangering anyone that may be present at that site. Mine subsidence may take years to manifest. Examples of collapses occurring decades after mines were abandoned have been documented in several areas of the country.

Michigan's Mining Experience

Michigan's rich mining heritage has played a significant role in the State's development into a world economic power. Due to its diverse geology, Michigan has a wide variety of mineral resources, most notable of which are copper ore, iron ore, coal, sand, gravel, gypsum, salt, oil and gas. It is not surprising then that underground mining has occurred on a significant scale throughout Michigan's history. The principal types of underground mining that occurs, or has occurred in Michigan, include coal mining, metallic mineral mining, salt mining, gypsum mining, and solution mining.

<u>Copper Mining</u>

Copper mining, in particular, put Michigan on the map as a major mining area. Although native copper ore occurs in other parts of the world, at one time the quantity of Michigan's native ore was unsurpassed. From the mid to late 1800s, Michigan's Keweenaw Peninsula mines produced more native copper ore than any other mining area in North America. As those resources became depleted, copper mining began near White Pine in Ontonagon County. The target strata in the White Pine mining operations were on an anticline that was mined both at depths as shallow as 100 feet and as deep as 2900 feet. Over-mining of pillars in shallow parts of the mine caused collapse and subsidence at the surface, on mine property, during the 1980s. The "Copper County" area generally crosses Ontonagon, Houghton, and Keweenaw Counties.

<u>Iron Ore Mining</u>

Michigan's Lake Superior region has been home to significant iron ore mining operations since the mid-1800s. The iron producing areas are referred to as ranges, since the iron deposits generally occur on the slopes or at the base of remnants of ancient mountain ranges. Michigan has three ranges: 1) Gogebic Range, which extends from Gogebic County into Wisconsin; 2) Marquette Range, in Marquette County; and 3) Menominee Range, in Dickinson and Iron Counties. Most near-surface iron deposits in these three ranges have been exhausted, so underground mining has become the primary extraction technique. Nearly two billion tons of iron ore have been extracted from these areas. Unfortunately, economics have forced the closure of many of the underground iron mining operations, although one company still mines in the region. The "Iron Range" area generally includes the five counties of Baraga, Dickinson, Gogebic, Iron, and Marquette.

<u>Salt/Solution Mining</u>

Michigan also has one of the world's largest underground salt accumulations. The thickest salt beds lie under most of the Lower Peninsula. These formations are, in some places, over 3,000 feet thick and composed of layers of salt and other minerals. Michigan ranked first or second in national salt production from 1880 to the late 1920s. The bulk of the salt production was from natural brines pumped from six salt formations. Salt was also produced from artificial brines that were derived by injecting freshwater into salt formations and retrieving the resulting brines (called solution mining). The old Detroit salt mine produced rock salt using the "room and pillar" method until 1983. (The room and pillar method involves creating large underground expanses [rooms] in which to mine, supported by pillars [natural or artificial structural members] that held in place the roofs of these rooms.) The Detroit salt mine was approximately 1,100 feet below ground, and encompassed approximately 1,100 acres of subsurface land. The room and pillar method is being used only in the single salt mine that is still operating in Michigan, by the Detroit Salt Company, which has an excellent safety record. Salt is also being produced from brines extracted at various locations within the state.

<u>Gypsum Mining</u>

Gypsum has been mined in Michigan since 1841. In the Grand Rapids area, gypsum is mined by the "room and pillar" method. Open pit mining is used in the Alabaster region (Iosco County). In both of these areas, gypsum beds directly underlie thin layers of glacial drift. Closed topographic lows observed in both areas are believed to be due to groundwater solution of the gypsum and subsequent collapse of the overlying material.

<u>Coal Mining</u>

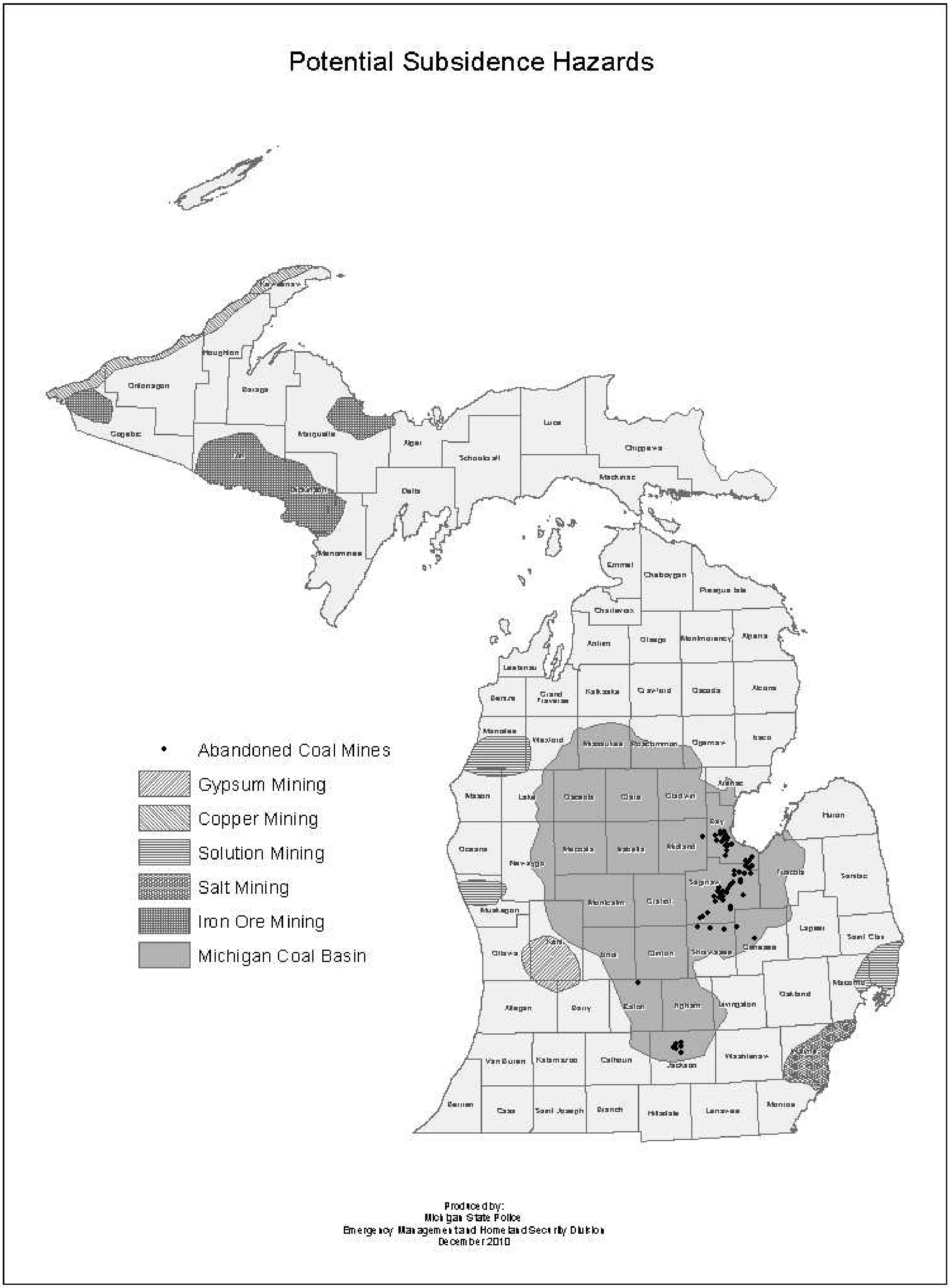
Michigan also once supported a thriving coal mining industry. Records indicate that over 165 different coal mines operated in Michigan's coal-bearing region, which includes 31 counties in the south-central portion of the Lower Peninsula. Over 100 of the 165 known coal mines in the state were located in the Saginaw Bay area. (See the map on the following page for an outline of Michigan's Coal Basin.) Coal was first discovered in Michigan in 1835 in Jackson County. From that discovery, several small underground and surface coal mines were opened in that area of the state. In 1861, coal was discovered near Bay City, and in 1897 commercial coal mining began in Bay County.

That led to the establishment of numerous additional mines in Saginaw, Tuscola and Genesee counties, which tended to be larger, deeper and more extensive mines. That was the start of Michigan's coal mining industry.

The state's underground coal mines were an average of 110 feet deep, and were worked by the "room and pillar" method. Michigan had continuous coal mining from 1897 to 1952, when the last underground coal mine near St. Charles, Saginaw County, closed. From 1860 (the year mine records were first kept) until 1975 (the year the last surface coal mine closed), the 165 commercial coal mines produced a total output of over 46 million tons of coal. The maximum coal output was achieved in 1907, when Michigan's 37 operating coal mines produced two million tons per year - enough to supply 16% of Michigan's then total demand for coal.

Mine-Related Subsidence Threats in Michigan

Source: Michigan Department of Environmental Quality, Office of Geological Survey



Mine Subsidence Problem in Michigan

The legacy of underground mining can be felt in numerous locations across the state. Many of the underground mining areas, whether active or abandoned, are vulnerable to subsidence in some form. The map on the previous page indicates the areas in the state that are potentially vulnerable to mine subsidence. Unfortunately, records of abandoned mines are often sketchy and sometimes non-existent. Therefore, it is often difficult to determine exactly where the mines were located. Many areas of Michigan may have developed over abandoned mines and may not even be aware of it. Oftentimes, the only way a community or home / business owner becomes aware of a potential hazard is when subsidence actually occurs and damage or destruction results.

Water-Related Subsidence

Compaction of soils in some aquifer systems can accompany excessive ground-water pumping and cause subsidence. Excessive pumping of such aquifer systems has resulted in permanent subsidence and related ground failures. In some systems, when large amounts of water are pumped, the subsoil compacts, thus reducing in size and number the open pore spaces in the soil that previously held water. This can result in a permanent reduction in the total storage capacity of the aquifer system. More than 80% of the identified subsidence in the United States is a consequence of human impact on subsurface water. Three distinct processes account for most of the water-related subsidence: compaction of aquifer systems, drainage and subsequent oxidation of organic soils, and dissolution and collapse of susceptible rocks.

Mining Ground Water

Groundwater in the pore spaces of an aquifer supports some of the weight of the overlying materials. When groundwater is depressurized or even removed from aquifers, where the materials are very compressible and pore pressures can be high, compaction may occur. This subsidence may be partially recoverable if pressures rebound, but much of it is not. Thus the aquifer is permanently reduced in capacity, and the surface of the ground may also subside. The picture on the next page shows the unconsolidated aquifer systems in Michigan

Drainage of Organic Soils

Land subsidence may occur when soils rich in organic carbon are drained for agriculture or other purposes. The most important cause of this subsidence is microbial decomposition, which, under drained conditions, readily converts organic carbon to carbon-dioxide gas and water. Compaction, desiccation, erosion by wind and water, and prescribed or accidental burning can also be significant factors. The picture on the next page shows the location of the organic soils in Michigan.

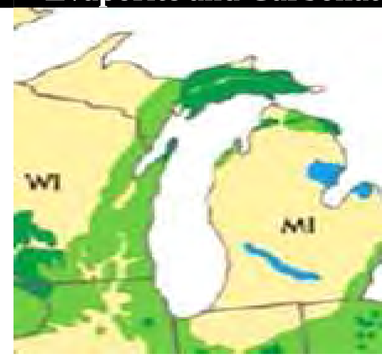
Collapsing Cavities

This type of subsidence is commonly triggered by ground-water-level declines caused by pumping and by enhanced percolation of ground water. Collapse features tend to be associated with specific rock types, such as evaporites (salt, gypsum, and anhydrite) and carbonates (limestone and dolomite). These rocks are susceptible to dissolution in water and the formation of cavities. Salt and gypsum are much more soluble than limestone, the rock type most often associated with catastrophic sinkhole formation. Evaporite rocks underlie about 35 to 40% of the United States, though in many areas they are buried at great depths. Collapse sinkholes may develop over a period of hours and cause extensive damage. The picture on the next page shows the location of the evaporite and carbonate rocks in Michigan.

Water-Related Subsidence Problems in Michigan

In the past there has been pressure for the Great Lakes states to export bulk quantities of water to various locations in the United States. If these plans to withdraw large amounts of water from the Great Lakes ever took place, it may have a major effect on the level of the ground water tables in Michigan, which may possibly make subsidence a more common occurrence. Currently, broken water pipes and the improper discharge of rainwater are the most common causes of water-related subsidence in Michigan. It most commonly occurs on sandy or silty ground when the water from the leak washes out the fine particles beneath the foundation, causing voids that result in collapse or subsidence.

Water-Related Subsidence Threats in Michigan

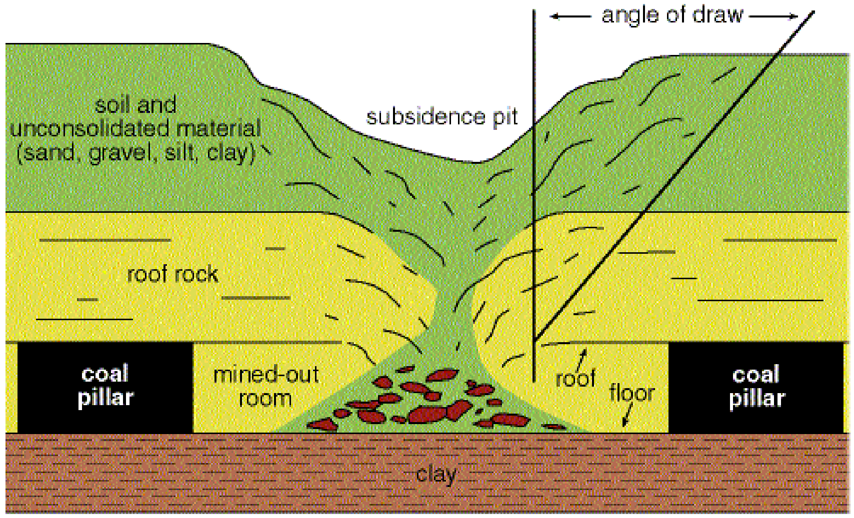
Unconsolidated Aquifer Systems	Organic Soils	Evaporite and Carbonate Rocks
		

Source*:* U.S. Geological Survey*, Ground Water and the Rural Homeowner, Pamphlet, 1982*

Overall, subsidence is not a very well-known hazard in most parts of Michigan, although it occurs with some regularity in parts of the state that have experienced past underground mining activity. The impacts of subsidence in Michigan tend to be limited in scope to individual sites and structures. Unlike some other areas in the country, such as Illinois, Ohio, Kentucky, West Virginia, Florida, Louisiana, and Pennsylvania, where subsidence is a serious concern, Michigan does not devote a great deal of state resources to the problem. Subsidence simply does not have the widespread impact potential of other natural and technological hazards that are prevalent in the state.

Underground mining has, in some respects, proved to be a double-edged sword for Michigan. On the one hand, it has fueled tremendous economic growth in many parts of the state, providing hundreds of thousands of jobs through direct mining or related industrial production activities. Mining helped put Michigan on the map as a world economic power, and even today it continues to be a major economic activity in some areas of the state. On the other hand, underground mining has also left a legacy of subsidence or threat of subsidence in some parts of Michigan. Old abandoned mines eventually begin to collapse under their own weight or human neglect, and oftentimes they swallow up whatever is built upon them. The following pictures show typical mine subsidence cross sections.

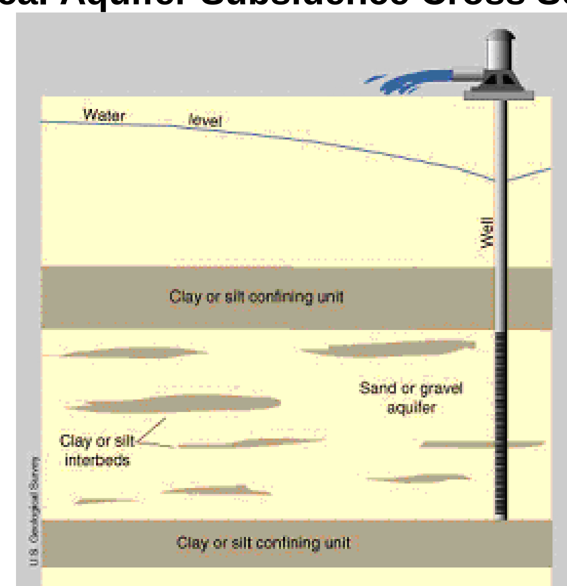
Typical Mine Subsidence Cross Section



Diagrammatic cross section of typical subsidence resulting from mine-roof collapse. No scale implied.

Source: State of Ohio, Department of Natural Resources web page

Typical Aquifer Subsidence Cross Section



Source: U.S. Geological Survey

In some areas where ground-water pumping has caused subsidence, the subsidence has been stopped by switching from ground-water to surface-water supplies. If surface water is not available, then other means must be taken to reduce subsidence. Possible measures include reducing water use and determining locations for pumping and artificial recharge that will minimize subsidence. Optimization models, coupled with ground-water flow models, can be used to develop such strategies. The picture above shows a typical aquifer-related subsidence cross section.

Because subsidence tends to be a more sporadic hazard, and because it poses a greater hazard to property than to life, it does not receive much attention from government agencies or the public. Other natural hazards, such as tornadoes, floods and severe storms receive much more attention because of their more widespread and severe impacts. However, subsidence will continue to be a hazard that a segment of the Michigan population will have to deal with in the future. Major incidents that lead to catastrophic damage are nearly unknown in Michigan, but smaller incidents occur with some regularity in old mining areas. Overall, about four moderate incidents per decade have been noted.

Probably the most effective way to mitigate subsidence hazards is through community education and awareness. Local officials in subsidence-prone areas need to be aware of their community's potential vulnerability to subsidence, and that awareness needs to be communicated to the public. Communities that have experienced mineral and water mining activity in the past, or that have ongoing mining operations, should conduct a thorough investigation of potential subsidence sites as part of their community's hazard analysis process. More often than not, local records of mining activity are the best (and sometimes only) source of information on the nature and potential extent of the problem. Local officials can use that information to make informed community development decisions so as to avoid, to the extent possible, areas potentially vulnerable to subsidence.

Ideally, information about the locations and subsurface conditions of all mines in an area would be found, and testing or inspection could then determine their stability and safety. However, the information that does exist has no guarantee of being comprehensive, and since many mines exist on private property, the owners of that property often have an interest in not allowing any mine details to be publicized (lest the information cause trespassers to be attracted to their property). MSP/EMHSD learned about valuable information that had been collected on this topic through an academic research process, but the information was not available to the general public. The information had been provided to the relevant counties as a part of their local hazard analysis process, and it was reported that the same type of information was also known to local Mine Inspectors. The best resource to consult for each local area is probably the relevant Mine Inspector for that area. Please refer to the list available at
http://www.mg.mtu.edu/mine_inspectors.htm.

Impact on the Public
Although some incidents may cause private property damage and casualties, others may affect roadways or other public infrastructure, and thus cause a more general impact on the population of an area. (Please refer to the infrastructure failures subsection.)

Impact on Public Confidence in State Governance
The public may be prone to overestimate the amount of knowledge possessed by State government regarding areas and specific locations in which historic mines have existed. Subsidence events that involve damage to infrastructure or roadways may be attributed to poor maintenance or funding, rather than to the actual cause of subsidence that was responsible. Uncertainty about the extent of risk from subsidence may cause collective dissatisfaction with the area in which the hazard is present (or perceived to be present), and (at an extreme) may lower property values and cause or exacerbate emigration from the area.

Impact on Responders
Special hazards may be present in old mines or ground subsidence areas, which may present a risk of further collapses during emergency response. Areas that involve deep spaces, into which personnel and equipment may fall, necessarily entail a more complicated and dangerous situation for responders. Old mining tunnels may also contain toxic gases (as referred to in the oil and gas well subsections of this document).

Impact on the Environment
Environmental impacts stemming from subsidence are somewhat similar to those caused by an earthquake. Changes in an area's landscape, wildlife habitat and the natural ecosystem can all result from a sudden depression in the Earth's surface. In a severe event, infrastructure may be damaged and could release toxins into the air, soil, or waterways.

CELESTIAL IMPACT

An impact or threatened impact from a meteorite, asteroid, comet, satellite, space vehicle, space debris, solar storms, or similar phenomena that may cause physical damages or other disruptions.

Hazard Description

The celestial impact hazard primarily concerns the effects of large forces (from objects or energy) upon the Earth or its atmosphere. Most such forces are extraterrestrial in origin—**meteors** (which burn up in the atmosphere) or **meteorites** (which impact physically upon the ground) that were originally **asteroids** or **comets** from elsewhere in the solar system. It must be noted that even in cases where no meteorite actually strikes the ground, the explosive energies from the meteor's impact upon the many layers of atmosphere can create an intense heat and blast area, along with very strong winds, and can release more energy than even the largest nuclear bombs. Massive or fast moving bodies that impact upon either the ground, the oceans, or the atmosphere can cause widespread destruction and disruption of both human and natural systems, including secondary hazards such as earthquakes, volcanoes, tsunamis, and severe winds, although events of that magnitude are extremely rare.

Much more common is the flare-up of energy and charged particles that are emitted and ejected by the Sun and impact upon the Earth's atmosphere. These **solar geomagnetic storms** (also known as **space weather**) can cause widespread failures of important satellite, electronic, communication, navigation, guidance and electric power systems—which have all formed a very important part of our modern technology and lifestyles. Because of the amount and complexity of information concerning the potential impacts from space objects, a great deal of this section has been devoted to an explanation and analysis of that hazard. However, it is important to note at the outset that the solar storm hazard is far more likely in the near term to cause disruptive effects, large economic impacts, and risks to human life. The smaller amount of text dedicated to space weather in this document should not mislead readers into a sense that it is considered less important, or that it is expected to cause less impact in the near future. Rather, the conclusion of the analysis presented here is that the effects of space weather have already had, and are much more likely to have, strong impacts upon Michigan within the normal historical timeframe that is typical for this type of plan. By contrast, the extensive discussion of impacting physical objects is given primarily to be "on the safe side" so that readers and emergency managers can be well-informed in the unlikely event that a very serious incident does occur, or threaten to occur.

Although it has been estimated that a major impact from a physical body upon the Earth occurs approximately once per century, recent discoveries (and the fact that much more of the Earth has been covered by human developments within the recent past) have caused increasing concern over this hazard. Although most meteorites would be expected to strike an ocean rather than a continent, the effects of a large enough ocean strike can still be widely damaging, through resulting tsunami and seismic activities.

An important type of celestial impact involves the interference or disruption of modern electronic and communications systems, including those upon which our modern aviation networks rely. Solar flares and storms (also known as "space weather") are highly relevant for their potential impacts and possible disruption of these complex modern communication systems—satellites, television, radio, GPS, power supply networks, and the extensive human and technological infrastructure that relies upon those communication and utility networks.

Extensive evidence of previous celestial impacts upon Earth has been discovered, including evidence of a historic crater site located in southwest Michigan, but the vast majority of historical Earth impacts have had their evidence erased from normal observation by the ongoing geological processes that take place over time. Even the largest of impact sites would no longer be evident to normal observation after a period of about 200 million years (usually much, much less). Such an amount of time is less than 5% of the Earth's overall age, but it has been found that impacts used to occur much more frequently during the earlier periods in Earth's history (i.e. nearer to the period of planetary formation) than they do in recent geological periods. Clearer evidence of the many historical impacts can be seen on other celestial bodies that are less geologically active, such as Earth's own Moon.

Asteroids

Most asteroids are located in the main asteroid belt and have well-defined orbits there between 200 and 310 million miles from the Sun, but thousands of asteroids also exist in other parts of the solar system. There are groups of "Trojan" asteroids that share an orbit with Jupiter, for example, located 60 degrees both ahead of and behind that planet itself while going around the Sun. Asteroids that have paths which cross over Earth's orbit are classified as Near-Earth Objects (NEOs), and are called Apollo asteroids. Two other types of NEOs are Amor asteroids, which approach the Earth's orbit from positions outside of it, and Aten asteroids, which approach the Earth's orbit from the direction of the Sun. As of January 2009, there were 6,021 NEOs identified, of which 1,026 were classified as posing the possibility of threat (having the potential to come within 466,000 miles of the Earth's orbit). The typical asteroid would impact upon the Earth at an angle of 45 degrees and a speed of 10 miles per second.

Comets

More than 99% of all meteorites come from asteroids, but some comet impacts have also been confirmed (9 are known, constituting less than 0.03% of all meteorites). The main difference between comets and asteroids is that comets tend to have elliptical orbits that carry them out beyond the "nebular frost line" (located in the main asteroid belt, about 250 million miles from the Sun) and thus their composition includes a substantial amount of icy and frozen matter. Comets usually lose about 0.1% of this matter each time they pass by the sun, due to the effects of warming and the pressure of solar radiation, and this matter trails behind them in their long "tails," which include charged particles (with associated magnetic fields) and can stretch across many tens of millions of miles of space. Where such tails cross the Earth's orbit, this matter (typically small and harmless to us) generates sometimes spectacular "meteor showers" as it periodically burns up in the Earth's atmosphere at regular times during the year. After a certain number of orbits, however, the comet simply breaks apart. Even if less dense than the average asteroid, a comet's heavy nucleus can be sizeable (from several hundred meters to over 40km in diameter), and a comet impact upon the Earth would typically occur at a speed of 31 miles per second—about three times as fast as the average asteroid, with a proportionally larger momentum of destructive energy if the amount of mass is the same. (It is worth noting here that the maximum impact upon the Earth for any object orbiting the Sun would be no more than 44.5 miles per second—160,000 miles per hour.)

Comets are classifiable by their orbital period, with long period comets taking more than 200 years to travel around the Sun, and short period comets taking less than that. The short period comets are further subdivided into Halley-type comets with orbital periods between 30 and 200 years, and Jupiter-type comets with orbital periods of less than 30 years. Long period comets originate in the farthest reaches of the Solar System (the Oort Cloud) and approach the Sun and Earth from every direction, while short period comets originate from the "Kuiper Belt" that exists beyond Neptune and is approximately in the same plane as all of the major planets. Short period comets thus would approach us from more predictable, shallow angles. The comet only begins to glow, though, when it approaches to within 3 and 5 Earth-distances from the Sun (3 to 5 astronomical units). Since short-period comets tend to last for only a matter of hundreds or perhaps thousands of orbits, their number seems to be replenished by a reservoir in our solar system (whose orbits eventually become shifted by gravitational perturbations). The Oort Cloud probably contains about a trillion comets, but most of these remain so far away that we remain unaware of them. The Kuiper Belt contains billions of comets, and the average diameter of one that comes near to the Sun is about 10 km.

If advance notice of an approaching meteor, asteroid, or comet is available, then widespread alerts might be prompted by this information, much as the explosive breakup of the Space Shuttle Columbia in 2003 had required warnings and alerts across multiple southwestern states, due to the possibility of persons and property being affected by falling debris. (See the event descriptions that appear later in this chapter.) In the case of the Cosmos 954 and Space Shuttle incidents, such debris needed special handling, both for purposes of investigation and out of concern for personal safety, since some of it could have contained hazardous substances. The threat of a celestial impact could be much more dangerous and far-reaching. One clear example of the potential damage was seen in the impact of the comet Shoemaker-Levy 9 on the planet Jupiter, in 1994, which resulted in blasts that were estimated as the equivalent of ten million megatons of explosives. In comparison, the 1979 Mount St. Helens eruption was roughly 5 megatons, and the 1885 Krakatoa eruption in Indonesia was about 100 megatons. Following the Shoemaker-Levy comet impact, Congress authorized new research to analyze this type of celestial impact hazard.

Space Weather

The Sun does not "burn" in the sense that we usually experience that common heat-generating process on Earth, but rather emits huge amounts of energy from the continuous processes of nuclear fusion that take place in the Sun's core. The gravitational pressures of the Sun's enormous mass, pulling toward itself, are thus generally offset by outward pressures from the fusion processes that take place at its core. Enormous amounts of energy are radiated from the Sun, including the spectrum of electromagnetic waves up through gamma wave frequencies. These include infrared (heat) radiation, ultraviolet, all colors of visible light, x-rays, microwaves, and radio waves. The intensity of these forms of radiation varies, and gamma waves are normally only emitted during solar flare events (to be explained shortly). It should also be understood that in the midst of all these solar interactions of matter and energy are powerful magnetic forces, which also affect the distribution of heat energy in and around the Sun and sometimes cause cooler areas, called **sunspots**, to form for a while, readily visible even with crude forms of observational equipment. (Although an observer should never look directly at the Sun, a pinprick of solar light projected onto a surface provides one basic means of seeing a Solar image). The relatively low temperatures of sunspot areas, however, are coupled with a rise in energy above the Sun's surface. **Solar prominences** are arches of plasma that soar above the Sun's surface, in a pattern that is itself shaped by the powerful magnetic fields present. In some cases, these magnetic fields have become too twisted to maintain such forces within these ordinary patterns, and a **solar flare** is generated, which releases a huge amount of energy from the Sun. Normally, a **solar wind** exists in the form of milder pressures exerted by emitted photons, ions, and other particles that flow outward from the Sun until they are eventually halted (beyond the orbit of Neptune, at an area called the heliopause) by the pressure of interstellar gases. Within the realm of the Sun's planets, however, the solar wind is an ongoing feature of the space environment, constantly sending energy and charged particles outward.

Space weather is a term that denotes the impacts of the Sun's activity upon the bodies within this sphere inside the heliopause, including our own Earth. As with the weather on Earth, there are some clear patterns that are exhibited by space weather. More turbulent space weather is produced during times when more sunspots are present (called a solar maximum), and space weather is calm during times when sunspots are rare and small (or not even seen to be present at all, called a solar minimum). A **sunspot cycle** exists, in which sunspot activity regularly shifts between a minimum and maximum level. As with our Earthly seasons, however, it cannot be known in advance exactly how turbulent or calm things will be at a given moment during the sunspot cycle—only that calmer periods regularly give way to more turbulent periods. As to the regularity of the sunspot cycle itself, although it has been found that the average amount of time between a solar minimum and a solar maximum is about 11 years, the actual length varies quite a bit within each cycle. The interval is sometimes as long as 15 years and sometimes as short as 7 years. In addition, it has been observed that long periods can occur with little or no sunspot activity. The "Maunder minimum," which occurred between the years 1645 and 1715, is the primary example of such long-term variation from the normal cycle, but it is not yet known what caused it, or when it might recur. The Earth's atmosphere serves as a shield for us against many types of particles and radiation zipping across space, and Earth also has a **magnetosphere** that similarly provides protection against most of the charged particles traveling through space. There are some weak spots in the Earth's magnetic field, however, that exist near its two magnetic poles and allow many ions to penetrate, where they collide with atoms in the Earth's upper atmosphere and glow to produce the beautiful auroras in the skies of the arctic regions of the north and south. In addition, the Earth is surrounded by "belts" of charged particles (called Van Allen belts) which are hazardous to spacecraft and astronauts. These are known and predictable conditions of calm space weather, however, and the actual hazard is the turbulence that is generated by large solar flares, causing problems with radio communications, damage to satellites, and even disruptions in power delivery networks on the Earth. Currently, as of early 2012, sunspot cycle number 24 is proceeding, from a solar minimum that was reached in December 2008 and is projected to transition to a solar maximum by early 2013 (a relatively short cycle).

Another type of solar disturbance is a **coronal mass ejection** (CME), in which built-up pressures cause a sudden burst in gases and magnetic fields at tremendous speeds, with impacts that reach far across interplanetary space. Like solar flares, CME events are a cause of geomagnetic storm events on Earth (usually 1 to 4 days after the solar event), and they occur more frequently during periods with more sunspots. One of the additional effects of space weather involves increased exposure to ionizing radiation (e.g. x-rays), especially among those in aircraft at high altitudes and along polar flight paths. Extra costs, in fuel and delays, are imposed upon airlines during periods of harmful space weather.

Hazard Analysis

A couple of scales have been developed to numerically summarize the extent of risk associated with extraterrestrial celestial bodies, such as comets, asteroids, and meteoroids. One scale is called the Palermo scale, but since that is tricky to interpret, the Torino Scale has instead been featured in media reports since its initial presentation at a United Nations conference in 1995, and it was adopted by the International Astronomical Union in 1999. Both scales take into consideration the amount of destructive energy that an impact could cause, and the probability of such an impact occurring. It is common for newly discovered objects to have their initial classifications on these scales subsequently downgraded, as additional information is collected that more precisely defines the exact path of the object. In other words, an object that is initially classified as having the potential for impact, and thus being worthy of closer study, is often later reclassified as additional information reveals that little or no significant impact potential exists. The lower numbers on the scale should not be interpreted as indicating any particular concern, and in the previous 15 years, only one object (99942 Apophis) had temporarily been classified as high as a 4 on the Torino scale. Being an asteroid large enough to cause regional devastation if it struck, Apophis had initially been estimated to have a 1 in 45,000 chance of striking the Earth on April 13, 2036, but as more information was obtained about its trajectory, that estimate was downgraded to only a 4 in 1 million probability. Although the asteroid's approach will be spectacular to observe, it is predicted to come as close as 18,300 miles away from the Earth's surface as it passes. (In Celestial terms, this is a very near miss, because that distance is smaller than the circumference of the Earth.)

The official explanation of Torino Scale ratings are provided below. In addition to numerical categories from 0 to 10, the scale is also color-coded in five categories, from white to red.

THE TORINO IMPACT HAZARD SCALE:

No Hazard (White Zone)

0: The likelihood of a collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bodies that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.

Normal (Green Zone)

1: A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.

Meriting Attention by Astronomers (Yellow Zone)

2: A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.

3: A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.

4: A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.

Threatening (Orange Zone)

5: A close encounter posing a serious but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.

6: A close encounter by a large object posing a serious but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.

7: A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.

Certain Collisions (Red Zone)

8: A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.

9: A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.

10: A collision is certain, capable of causing global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Note: This is the Torino Scale as revised in 2005. A graphic of the Torino Scale is also available at http://neo.jpl.nasa.gov/images/torino_scale.jpg .

The Palermo Technical Impact Hazard Scale is a bit different, with values less than -2 reflecting events for which no consequences are likely, values between -2 and 0 indicating situations that merit careful monitoring, and values above zero indicating situations that merit some level of concern. This document presents only the Torino scale in its entirety, since that scale was developed for general public informational uses.

About 40,000 to 60,000 tons of extraterrestrial material falls onto the Earth each year, but most of it is mere dust. Larger materials fall during regular cycles called meteor showers, but again most of it is small enough to harmlessly burn up (through ablation) as it hits the Earth's atmosphere at high speeds (typically about 67,000 mph). During meteor showers, the material is typically leftover debris from comets that had crossed the Earth's orbit, and most such material is very small and harmless to us. Material that does survive ablation to strike the Earth's surface lands in random locations, and since 70% of the Earth's surface is water, these meteorites mostly go unnoticed by ordinary people. The risk to Michigan is calculable in general terms, by considering the proportion of the Earth's total surface area that is occupied by Michigan's land area. This is approximately 2.9×10^{-4}, or 0.00029. The frequency of global impact events can then be multiplied by this factor to estimate the frequency of impact events directly upon Michigan's land area. This results in the following estimates, on average, for different sizes of impacts upon Michigan's land itself:

- About 1 to 5 impacts per year that are larger than 100g (golf-ball size) – This may kill an individual that is struck, but since most space is not occupied by a person at any particular moment, such a thing is exceptionally rare, and there have only been a couple of confirmed meteorite injuries worldwide. Instead, such incidents are more likely to simply cause limited property damage to a car or home, although their appearance in the sky can appear impressive and be accompanied by a sonic boom. (Example: the Washtenaw County strike of 1997.)
- About one impact per century involving an object of more than 100kg (220 pounds), and about one impact every 1700 years involving an object of more than 1000kg (about 2200 pounds) – These types of events would result in loud sounds and bright flare-ups in the sky, leaving a field of fragments strewn across an area that is miles across, but actual damages are likely to be only moderate unless a dense urban area or critical facility happens to be struck. (Example: the Park Forest, IL event of 2003.)
- About one impact every 350,000 years involving an object of more than 100,000kg (about 220,000 pounds) – This is the type of impact that resembles an atomic blast, exploding brightly in the sky and producing a very strong blast wave and severe winds that would cause extensive building damages and collapse at ground level, would flatten forest lands, and could start a large wildfire. (Example: the Tunguska, USSR event of 1908.)

Although that last type of event is so rare that it need not be of general concern for Michigan, the probability of such an event affecting some part of the U.S. and potentially causing a national emergency is a bit larger, but still remote. It is most probable that the next such event will occur elsewhere in the world (on the order of about 1 event per century) and, although potentially devastating to that area, Michigan's role would probably only involve the voluntary donation of humanitarian aid to the disaster area. One foreseeable scenario could involve an asteroid impact in the ocean, which causes tsunami impacts upon the associated coastline of the U.S.—waves could be more than 100 feet high from the impact of an asteroid with a diameter of 1300 feet, although that scale of event would only be expected about once in 80,000 years. These type of large events, of the type that would actually form sizeable craters and cause catastrophic national or global impacts (including major seismic and volcanic effects and global cooling from gaseous effects and dust, smoke, and particulates deposited into the atmosphere), are rare enough that no extensive description will be provided here—past events of that type are well-established in a geological timeframe but not in a human historical timeframe. (Reference will be made to such events primarily in the description of mitigation strategies.)

Since meteors flare up brightly in the sky, some persons have speculated about whether meteorites could then cause wildfires to start up. As it turns out, this is generally not the case. The flaring fireballs are caused by ablation, as the very fast meteors encounter the atmosphere and friction generates heat, but a great amount of material typically burns away in this process, followed by miles of additional falling before ground impact, during which time the contact with blowing air exerts a cooling effect. The vast majority of meteorites are actually cool when they strike the ground. It would take a very large impact to bring a degree of heat that is capable of igniting a forest fire, and impacts of that size are very rare. That type of rare, large impact would also tend to flatten forest lands at the same time, with blast pressure and wind effects that could offset much of the fire risk. A large (Tunguska-sized) event would cause forest fires, along with huge amounts of other damage, and it is conceivable that a smaller-sized (but still very rare) impact might cause wildfire ignition if there are already drought conditions present that have increased the natural wildfire risk. In general, wildfires will not be caused by meteorites, and there is no good evidence that any of Michigan's historic wildfires were of meteoritic origin.

Space weather can be very expensive for those who use or rely upon satellites. During a solar maximum, the Earth's upper atmosphere expands and increases the drag upon satellites within low orbits, which will then require boosting in order to remain aloft. Electronic circuits can malfunction and cause interruptions or complete losses in operational capacity. Space missions may also need to be delayed, in order to ensure their safety and success. Special design features may require additional expenses, to mitigate the effects of space weather. Communication disruptions can inhibit navigation and hinder the safe management of air and sea traffic. Electric currents are induced by the relative motion of magnetized material, and these can affect power supply and pipeline infrastructure, potentially causing weakening and damage in these systems as well as electronic malfunctions. Three space weather scales are in use by NOAA/NWS to summarize the intensity and potential impact of three different types of space weather effects. Each uses a 5-category classification scheme, and the three scales denote (1) geomagnetic storm intensity, on a G-scale, (2) solar radiation storms, on an S-scale, and (3) radio blackouts, on an R-scale. Weaker events are given a number of 1 on the scale, and extreme events are rated as a 5. In this document, selected material is summarized below. For more detailed information, please refer to the NOAA web site at http://www.swpc.noaa.gov/NOAAscales/.

NOAA Space Weather Scales

NOTE: Each type of space weather may occur separately. Descriptions of all three types of space weather warnings are here combined into one table merely to conserve space.

HF means high frequency (radio waves), but other radio frequencies may also be affected by these events. LF means low frequency (radio waves). F: refers to event frequency.

Category Labels	Geomagnetic Storms (effect & frequency)	Solar Radiation Storms (effect & frequency)	Radio Blackouts (effect & frequency)
Minor G1 S1 R1	G1 events can cause weak power grid fluctuations, minor impacts on satellite operations, effects on migratory animals, and widely visible auroras seen in Northern Michigan. F: about 900 days per solar cycle.	S1 events result in minor impacts on HF radio in polar regions. F: about 50 such events per solar cycle, each of which can last more than 1 day.	R1 events cause weak or minor degradation of HF radio communication on the sunlit side of Earth, and occasional loss of radio contact. LF navigation signals used by maritime and general aviation systems may be degraded for brief intervals. F: about 950 days per solar cycle.
Moderate G2 S2 R2	G2 events can cause high-latitude power systems to experience voltage alarms. Long-duration storms may cause transformer damage. Corrections to satellite orientation and orbital drag prediction may be required. HF radio propagation can fade at higher latitudes. Auroras may be visible throughout Michigan. F: about 360 days per solar cycle.	S2 events may expose persons in high-flying aircraft to an elevated radiation risk* in areas of high latitude. Infrequent single-event upsets of satellite operations are possible. Possible effects on HF propagation and navigation through polar regions. F: about 25 events per solar cycle, each of which can last more than 1 day.	R2 events cause a limited blackout of HF radio communications on the sunlit side of Earth, and loss of radio contact for tens of minutes. LF navigation signals may also be degraded for tens of minutes. F: about 300 days per solar cycle.
Strong G3 S3 R3	G3 events may require voltage corrections at power systems and may trigger false alarms on their protection devices. Satellite orientation problems may need correction. Increased atmospheric drag and component surface charging may occur. Intermittent LF radio navigation problems may occur. F: 130 days per solar cycle.	S3 events can expose persons in high-flying aircraft to a radiation risk* in areas of high latitude. Satellite operations may experience single-event upsets, imaging system noise, and slight solar panel inefficiencies. Degraded HF radio propagation in polar regions. Navigation position errors are likely. F: about 10 events per cycle (each can exceed 1 day).	R3 events cause a wide area blackout of HF radio communication and loss of radio contact for about an hour on the sunlit side of Earth. LF navigation signals may be degraded for about an hour. F: about 140 days per solar cycle.
Severe G4 S4 R4	G4 events may cause widespread voltage control problems for power systems, and mistaken exclusion of key assets from a power grid by some protective systems. Satellites may experience surface charging, tracking and orientation problems that may need correction. Pipelines may experience induced currents. HF radio propagation sporadic. LF radio disrupted. Satellite-based navigation may be degraded for hours. F: about 60 days per solar cycle.	S4 events can expose persons in high-flying aircraft to a radiation risk* in areas of high latitude. Satellites may experience memory device problems, imaging systems noise, orientation problems, and degraded solar panel efficiency. A blackout of HF radio communications is likely through the polar regions. Increased navigation errors over several days are likely. F: about 3 events per solar cycle (each can exceed 1 day).	R4 events cause an HF radio communication blackout on most of the sunlit side of Earth for 1 to 2 hours, with HF radio contact lost during this time. LF navigation signals cause increased errors in positioning for 1 to 2 hours. Minor disruptions of satellite navigation are possible on the sunlit side of Earth. F: about 8 days per solar cycle.
Extreme G5 S5 R5	G5 events may cause widespread voltage control and protective system problems in power systems, with some grid systems completely blacking out or collapsing, and possible damage to transformers. Satellites may experience extensive surface charging, orientation, tracking, and linkage problems. Pipelines may receive induced currents reaching hundreds of amps. HF radio may be out for 1 to 2 days in many areas. LF may be out for hours. Satellite-based navigation may be degraded for days. Bright auroral lights visible at night. F: about 4 days per solar cycle.	S5 events can expose persons in high-flying aircraft to a radiation risk* in areas of high latitude. Satellites may be rendered useless, may receive permanent solar panel damage, or may experience memory problems, loss of control, serious imaging data noise, and navigation problems. Complete HF radio communications blackouts are possible throughout the polar regions. Navigation operations will be extremely difficult and error-laden. F: less than 1 event per solar cycle should occur, although an event may exceed 1 day in duration.	R5 events cause a complete HF radio blackout on the entire sunlit side of Earth for a number of hours. No HF radio contact with mariners and aviators in this sector. LF navigation signals experience outages for many hours on the sunlit side of Earth, causing loss in positioning. Satellite navigation errors in positioning increase for several hours on the sunlit side and may spread into the night side of the Earth. F: fewer than 1 event per cycle.

*** Pregnant women are particularly susceptible to radiation risk.**

Meteors are commonly observed, illuminating briefly in the sky as the force of friction with the Earth's atmosphere burns away the solid matter they contain. Some meteors partially survive this process and thus become meteorites by striking the Earth's surface and potentially causing great amounts of damage. However, there are cases in which huge fiery blasts occurred in the sky (bolides) without any meteorite remnants being found. Enormous damage can still occur at ground level from the effects of the heat, blast force, and strong winds that result from the atmospheric impact (see the description provided for the 1908 event at Tunguska, Russia, later in this section).

Part of the usefulness of this analysis is meant to involve the presentation of information that might alleviate confusion throughout Michigan's communities and residents, in case some event actually does occur, or should some warning of an impending impact eventually be given out. In the former case, those who already have some information about meteors, and the potentially spectacular appearance of either sky or ground impacts, would have a means to make sense of an unusual bolide or impact event and would be less likely to mistake the event for a nuclear explosion. A greater general awareness of the variety and nature of Michigan's hazards should eventually translate into a lessened demand for emergency services and information. For example, it might take only 30 seconds to explain to a knowledgeable citizen that a meteor impact caused a huge explosion in the sky (and an impact on the ground), whereas a less-knowledgeable citizen might seek 20 minutes of reassurance that the explosion was not nuclear, that the incident was not connected with a crashing airplane or a confidential military experiment, and so on. The provision of advance information that realistically describes and assesses the nature of unusually severe events can help to provide a framework in which the correct interpretation and response actions can be undertaken more quickly and efficiently.

In the latter case, involving an alert about an impending impact or potential impact, many persons would need information that allows them to understand the nature of the threat, and the techniques that may be used to prevent or mitigate its impacts. For example, there is an enormous difference between an alert that provides only a few weeks of notification, and one that has identified a need for action over the course of several decades.

It should be realized that although the atmosphere and air around us seems to be "light" and only a small obstacle to movement (mostly at high speeds or during strong wind gusts), the air nevertheless has enough substance to sustain heavy aircraft in flight, to hold aloft huge thunderstorm clouds full of rain, and so on. A meteor crashing into the atmosphere thus releases tremendous amounts of energy, as the result of friction from plunging through large quantities of air at enormous speeds. This energy can result in large (and loud) blast waves, even if the meteor's trajectory is oblique enough to cause it to "bounce off" the atmosphere, rather than plunging through it and hitting the ground. For example, if a towel is wrapped around a bowling ball, a baseball can easily be bounced off the top of the bowling ball without leaving a dent or scratch in the bowling ball's surface, but it would still make a clearly audible noise and could crush any small insect that happened to be crawling underneath the towel. The towel can be seen as an analogy for our ecosphere on the surface of the planet, and the visible results of such an atmospheric impact could include great bursts of flame, damaging shock waves, severe winds, deafening noise, and disrupted weather patterns.

While this section does is not intended to focus upon planetary life-ending scenarios (which are remotely possible but extremely unlikely to occur within our lifetimes), it does consider the possibility of a major (averaging once per century) impact that may cause either an area of widespread destruction within the United States, or an impact somewhere else in the world that may cause unusual effects to be felt in distant locations. If a Tunguska sized event (see the 1908 entry in the list of Significant Events later in this section) were to affect a densely populated area, the results could be extreme enough to constitute a National Emergency. (Please refer to the new section describing "Catastrophic Incident," for more discussion about this, as well as the Nuclear Attack section, for more information about problems such as mass fires, which may arise from large blasts.)

This section also considers more common events that have fairly limited effects and damages, but may be associated with a significant degree of uncertainty about the area and population that could be struck by such impacts. Even though the number of celestial impact events has probably not increased in recent times, certain types of vulnerability have increased (see for example the description of the 1859 Carrington Solar Flare event, in the section describing Significant Events). Our public awareness of these possibilities has also increased, resulting in a need for additional information to inform citizens about the actual risks, effects that different types of celestial impact may have, and present-day means to prevent or mitigate some of the worst possible impact scenarios. Most significantly, the size of the human population, and the amount of land area it occupies, has changed greatly during the past century. The global population is nearly four times what it was a century ago, and (especially in the richer nations) this population growth has been accompanied by a much larger portion of the land area that has been built-up for urban uses. Just since World War II, the population of the United States has more than doubled, and even in areas with a relatively stable population, residential neighborhoods take up a lot more space today than they previously had in the period of time before the suburban "explosion." A random impact point today is more likely to affect lands that are developed to at least a moderate residential capacity, which could result in thousands of casualties.

Although most comets and asteroids have very consistent trajectories that change only very slowly, in terms of human history, Earth-threatening space bodies may still remain undiscovered by humans. There is also the possibility that their traditional orbits may be unexpectedly disrupted by collisions with other bodies, or by gravitational effects such as that exerted by Jupiter on Comet Shoemaker-Levy 9, which caused that comet's eventual impact into the planet. "Jupiter-family comets" are those in which a normal (safe) orbit of a comet or asteroid may be "suddenly" altered in a manner that causes it to become a threat to Earth. In either case (a newly discovered object or one whose course is changed), the possibility exists that a serious impact threat may suddenly be discovered. However, extensive observations and calculations have been taking place to identify and track all potential threats of this kind.

It is likely that the next major celestial impact will occur somewhere in the world other than Michigan, and that Michigan's role as part of the United States would at most involve the provision of support to the impacted area and its surroundings. If a major impact happens to occur in North America, then state-level mutual aid may result, and possibly even the intake of evacuees, as had taken place during the Katrina and Rita hurricane disasters of 2005. Several recent bolide events have been documented in the Great Lakes area, but have caused no known damage to the state's area during its European historical era over the past four centuries. It is possible that certain unexplained seismic events reported in the Upper Peninsula more than two centuries ago may have been caused by celestial impacts. For the most part, however, the meteorite hazard is important to know about mainly for preparedness and informational usefulness, rather than due to an actual pattern of damaging effects upon Michigan.

The space weather hazard, by contrast, is likely to cause one or more serious infrastructure failures in the near future, due to the extent of our reliance on complicated electronic and satellite systems that are vulnerable to disruption. In addition to power failures and phone communication breakdowns, it is also quite possible for the disruption of radio and navigational systems to cause risks for air and marine traffic. Even if cautious transportation providers are diligent about maintaining safety during such events, considerable economic impacts and delays can result from the electronic breakdowns caused by solar geomagnetic storm events.

Impact on the Public

A celestial impact from an object that is either sufficiently massive or fast-moving can have an effect that is comparable to nuclear blasts, in terms of the amount of energy released in the form of pressure (shock) waves and thermal effects (heat/fire). Additionally, major earthquake activity would be felt in areas that normally wouldn't have had to worry about such effects. An impact into major water bodies can cause intense tsunamis to occur, and severe winds could also result in extensive physical damages many miles (or hundreds of miles) away from the main impact site. Depending upon the mass and velocity of the meteorite, the impact on the public may range from the barely noticeable to the complete destruction of the entire area, with the most powerful impacts having effects similar to those described for nuclear attack (minus the radioactive fallout and electromagnetic pulse), earthquake, severe winds, wildfires, and storm seiches (shoreline flooding), all described in their own sections in this document. Space weather impacts will result in transportation delays and communication interference, and some cases may result in fatal transportation accidents, large economic losses, and widespread power supply interruptions.

Impact on Public Confidence in State Governance

If a major impact occurs in Michigan or the Great Lakes, many persons may feel disgruntled if no advance warning was able to be provided. There is probably not a widespread familiarity with this type of hazard, and popular conceptions may be rooted in televised or cinematic portrayals in which it was considered that part of the government perhaps "should have known" about a potential impact and been able to prevent it. One of the reasons that this hazard is now being included in state plans is to help provide information that will improve people's understanding of it. Moreover, since a significant celestial impact event could easily be mistaken for a nuclear blast by many persons, an educational process could be useful in overcoming the possible harm caused by such assumptions. For example, if a large bolide is seen, or actually damages an area, it will be helpful for people to have been familiar with what the event actually might be, rather than assuming that it was a deliberate hostile action that may involve secondary radiation and security impacts, or assuming that a mass evacuation or escalated level of security alert may be needed. Rather, if it is understood that there is a natural phenomenon that in some cases may resemble that of an atomic blast or explosive attack, then people's behavior and attention can be more properly guided toward activities and attitudes that are appropriate for a natural disaster rather than those for a homeland security alert. The potential impacts of space weather will require greater public awareness in order to build an understanding about existing weaknesses and the expense involved in correcting those weaknesses, where possible.

Impact on Responders

A small impact incident would not be likely to cause much risk for responders, unless the impact was upon a structure that became weakened to the point of potential further collapse. Larger impact incidents would be extremely unusual, but may be expected to require extensive search and rescue operations, as well as various firefighting operations and probable infrastructure failure impacts to be dealt with simultaneously. The presence of hazardous materials could also be expected at an impact site that had been urban in nature, or had involved key agricultural or infrastructure facilities. A catastrophic impact event could require extensive use of mutual aid and state/federal disaster and emergency assistance, with the possibility that all normal response resources would be disabled within the area of impact, and would need to be replaced by resources from adjacent local areas, or even from beyond the state. Underground sheltering would be a useful way to increase the odds of survival from the wind/shock/frame effects of a huge bolide event, which would likely pass quickly and then enable responders to deal with rescue operations, fires, infrastructure failures, and the organization of mutual aid. The impacts of space weather include interruptions in the function of radios, satellites, electronics, and even power supply systems that may be needed for emergency response. Response activities that involve electronic navigation technologies and Global Positioning Systems may need to fall back upon the use of less technologically advanced means to accomplish their mission.

Impact on the Environment

An extremely large impact, even if not in Michigan, could cause a National Emergency situation to arise, which Michigan may have to help to respond to and recover from (please refer to the chapter on catastrophic incidents). A direct meteorite impact on land could destroy an entire area, and cause fires, earthquakes, and other hazards for a large area around the impact. The same types of effects can also result from the atmospheric blast and heat impacts of a large bolide event, even if the celestial body itself does not strike the ground. A large impact in one of the Great Lakes could cause substantial flooding, seiche, and erosion impacts along areas at or near the lake's coasts. It has been speculated that space weather may be connected with global climate, but this is primarily due to the possibly coincidental occurrence of a "Little Ice Age" (lower average temperatures in America and Europe) during the same time that the Maunder minimum in solar activity was observed. The specific mechanisms that would underlie such a connection have not yet been figured out and therefore such a link should probably still be considered to be purely speculative. On the favorable side, solar activity helps to shield us from some of the cosmic rays that come from throughout the universe.

II. Technological Hazards
A. Industrial Hazards

The following outline summarizes the significant industrial hazards covered in this section:

1. Fires
    a. Structural Fires
    b. Scrap Tire Fires
2. Hazardous Material Incidents
    a. Hazardous Material Incidents – Fixed Site (including industrial accidents)
    b. Nuclear Power Plant Emergencies
    c. Hazardous Material Incidents – Transportation
    d. Petroleum and Natural Gas Pipeline Accidents
    e. Oil and Natural Gas Well Accidents

This section covers many related types of events that stem from breakdowns or weaknesses in industry and the built environment. The starting section, structural fires, considers various types of large fires that occur in the midst of important buildings or structures. Since a frequent cause of structural fires involves natural gas explosions, the chapters involving natural gas (pipelines and wells) appear nearby, to make easier a more thorough reading about this shared source of risk. Although small residential fires are common, and can be the cause of larger urban conflagrations, this hazard analysis focuses in particular on those larger-scale fires that have greater potential to affect an entire community—either through a fire's sheer magnitude or through the vital nature of the facilities or resources it affects. For this 2012 edition of the Michigan Hazard Analysis, new consideration and detail is provided for "urban conflagrations" in which dense urban development may allow fires to spread over many blocks, or even the entire core of the built-up area.

Scrap tire fires are a special case of industrial hazard, for although they do not typically affect a specific structure, these types of fires do involve toxic smoke and chemical residues that have more in common with hazardous material incidents than with ordinary residential and wildfire events. The following chapters, specifically dealing with hazardous material incidents, cover a wide array of extremely hazardous substances across diverse situations that typically involve industrial or warehousing operations. The section on fixed site incidents includes a consideration of fire-related industrial accidents and explosions, even if these did not involve extremely hazardous substances. Again, the emphasis is on events of a relatively large magnitude—those that resulted in community states of emergency, evacuations, impairment or loss of economically significant or critical facilities, or multiple casualties. A separate chapter deals with nuclear power plant emergencies, and then consideration is given to various forms of transportation incidents that may involve hazardous materials, including separate chapters about pipeline infrastructure and wells that have been dug for production purposes.

Overlap Between Industrial Hazards and Other Sections of the Hazard Analysis

Various types of structural, scrap tire, and industrial fires and incidents may stem from deliberate actions, rather than accidental causes. In such cases, the incidents tie in with the terrorism and civil disturbance chapters, in the Human-Related hazards section of the hazard analysis. Large scale disaster events may also cause these types of fires to occur—lightning strikes have actually caused the direct ignition of structural fires, and the destruction caused by tornados can lead to fires as well. Wildfires have a clear potential to ignite structures, and may also come to involve scrap tire storage areas. Although the chances are slim, earthquakes and celestial impact events might also result in the occurrence of structural or industrial fires. There might be certain conditions under which infrastructure failures are connected with fires. An indirect link also exists between extreme temperatures and winter weather, as various means of heating indoor areas have been known to increase fire risks. A major transportation incident has the potential to start a fire, and certain kinds of catastrophic incidents (such as nuclear attack) would certainly create fires.

A structural fire involving one or more critical facilities has the potential to cause infrastructure failures, energy emergencies, flooding, wildfires, dam failures, transportation accidents, and nuclear power plant emergencies. Hazardous materials incidents of any type (including scrap tire fires) may lead to public health emergencies if they are large enough, or if the involved substances are hazardous enough. If a fire or hazardous materials incident stems from some sort of systematic official negligence then there may be a potential for civil disturbance or sabotage/terrorism to take place.

STRUCTURAL FIRES

A fire, of any origin, that ignites one or more structures, causing loss of life and/or property.

Hazard Description

In terms of average annual loss of life and property, structural fires—often referred to as the "universal hazard" because they occur in virtually every community—are by far the most common hazard facing most communities in Michigan and across the country. Each year in the United States, fires result in approximately 5,000 deaths and 25,000 injuries requiring medical treatment. According to some sources, structural fires cause more property damage and loss of life than all types of natural disasters combined. Direct property losses due to fire exceed $9 billion per year, and much of that figure is the result of structural fires.

In 2008 alone, there were 3,320 civilian deaths and 16,705 civilian injuries as a result of fire in the United States, along with 118 firefighters killed while on duty. There were an estimated 1.5 million fires in 2008, and direct property loss due to fires was estimated at $15.5 billion. This figure includes the 2008 California wildfires, with estimated losses of $1.4 billion. There were 515,000 structure fires in the United States in 2008 that resulted in 2,900 civilian deaths, 14,960 civilian injuries, and $12.4 billion in property damage. Every 22 seconds, a fire department responds to a fire somewhere in the nation. A fire occurs in a structure at the rate of one every 61 seconds, and in particular a residential fire occurs every 78 seconds. Nationwide, there is a civilian fire injury every 31 minutes. In 2008, structure fires represented 34% of the total fires across the United States.

Unfortunately, although the United States has made great strides in lessening deaths and injuries caused by other types of disasters, structural fires are worse problems in this country than in many other industrialized countries (even those with a more densely-developed population pattern). The United States Centers for Disease Control (CDC) figures indicate that fire-associated mortality rates in the United States are approximately 2-3 times greater than those in many other developed countries. According to the Federal Emergency Management Agency's National Fire Data Center, residential fires represent 78% of all structural fires and cause 80% of all fire fatalities. Approximately 83% of those fatalities occur in single-family homes and duplexes. Perhaps the most tragic statistic of all is that over 40% of residential fires and 60% of residential fatalities occur in homes with no smoke alarms. (Studies have repeatedly shown that a working smoke alarm dramatically increases a person's chance of surviving a fire.)

Michigan's fire experience generally mirrors the national fire situation. According to statistics compiled by the Fire Marshal Division of the Michigan Department of Licensing and Regulatory Affairs for 2003, nearly 19,000 structural fires occurred in Michigan, resulting in 161 deaths and 624 injuries. The dollar loss for all fires was estimated at over $230 million. The Fire Marshal Division estimated that a structural fire occurred in Michigan about every 28 minutes in 2003. Michigan's fire death rate of 15.4 persons per million puts it toward the middle of all states in the nation in 2006. As the following table indicates, Michigan is ranked 19th in terms of fire deaths per million population. Michigan's fire death rate is ranked third in the Midwest, behind Missouri and Indiana as of 2007.

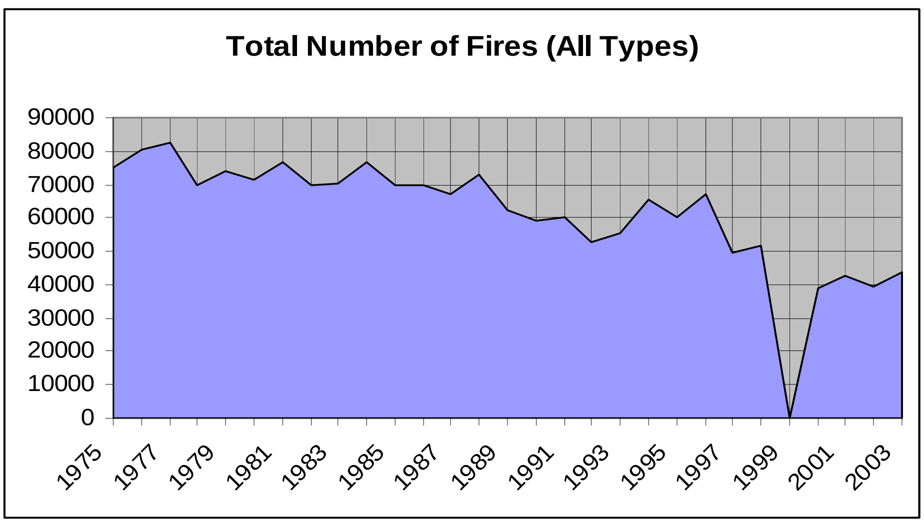
During the period from 1975-2009, the number of reported fires in Michigan (both structural and nonstructural) has trended downwards from a high of just over 80,000 to the current low of around 40,000, with yearly numbers fluctuating within this range. The number of structural fires represents approximately 35-40% of those yearly totals. Although fire risks are clearly a major concern, most of the incidents are of a limited scale and do not threaten or harm an entire community. This analysis will focus on major fires that do cause a severe impact to local communities—as disaster events.

Fire Death Rate per Million Population: 2007

State	Fire Rate	State	Fire Rate	State	Fire Rate
District of Columbia	39.2	Indiana	15.6	Wyoming	9.6
Mississippi	28.4	**Michigan**	**15.4**	Montana	9.4
Arkansas	26.0	Vermont	14.5	Connecticut	9.2
Alaska	25.1	Nevada	14.4	Washington	8.8
Oklahoma	24.9	Illinois	14.2	Iowa	8.7
West Virginia	24.8	Delaware	13.9	Idaho	8.7
Louisiana	23.8	Virginia	13.3	Minnesota	8.7
Alabama	22.6	Wisconsin	12.7	Colorado	8.3
Tennessee	22.5	Ohio	12.5	California	8.2
Missouri	20.1	Nebraska	12.4	Arizona	7.9
North Carolina	19.5	Utah	11.6	New Jersey	7.5
Pennsylvania	19.2	South Dakota	11.3	Massachusetts	6.9
Georgia	18.8	Texas	11.2	Maine	6.8
Kentucky	18.6	New Mexico	11.2	New Hampshire	6.8
South Carolina	17.4	New York	10.7	North Dakota	6.3
Kansas	17.3	Florida	9.8	Rhode Island	5.7
Maryland	16.2	Oregon	9.6	Hawaii	3.9

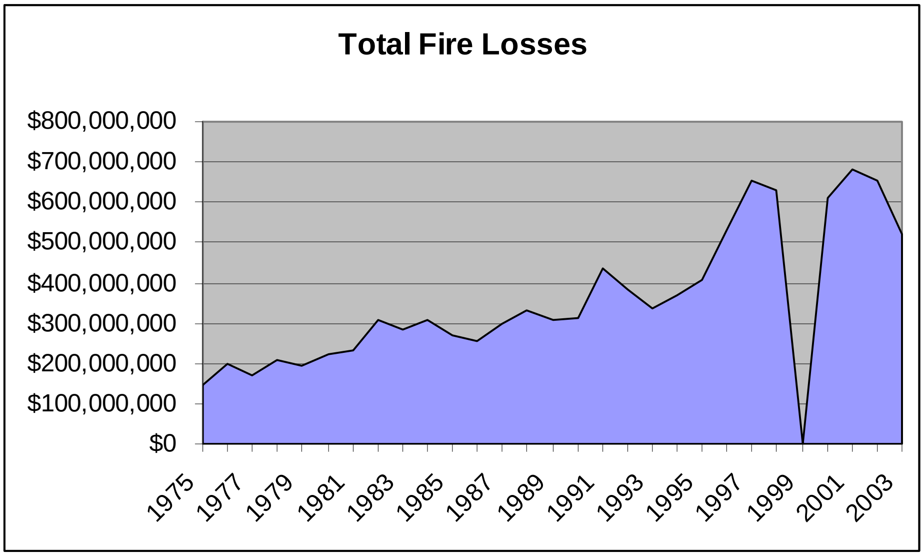
Source: U.S. Fire Administration web page, Federal Emergency Management Agency (National Fire Data Center)

Total Number of Fires (all types) in Michigan: 1975-2003



Note: There was no annual report of Fires in 1999 due to the transfer to NFIRS
Source: Michigan Department of Licensing and Regulatory Affairs (LARA), Fire Marshal Division / MFIRS
(Note: Approximately 35-40% of the total number of fires are structural fires.)

Total Fire Losses in Michigan: 1975-2003



Note: There was no annual report of fires in 1999 due to the transfer to NFIRS
Source: Michigan Department of Licensing and Regulatory Affairs (LARA), Fire Marshal Division / MFIRS
(Note: Approximately 75% of the total losses are structural fire-related.)

The State Fire Marshal, Department of Licensing and Regulatory Affairs / Bureau of Construction Codes and Fire Safety, and local fire departments are proactive in attempting to reduce the number, scope, magnitude, and impacts of structural fires in Michigan. State and local fire service efforts in the areas of training, public education, incident tracking, construction plan review, site inspection and fire analysis are all oriented toward, and contribute to, structural fire mitigation and prevention. However, like most programs, the amount of work that can be done is directly related to funding and programmatic priorities.

Nature/Composition of Michigan Fire Service

The primary challenge facing the State Fire Marshal, in particular, and the State of Michigan, in general, is the nature and composition of the Michigan fire service. The high proportion of fire fighters that are either volunteer or paid part-time (roughly 3/4 of the fire service) presents significant challenges for sustaining adequate code enforcement and inspection efforts. In addition, the relatively high level of turnover within this group places additional demands on state and local training resources. Also, with the effects of recession, especially in the State of Michigan, many fire fighters have been laid off or had their positions cut due to a lack of funding. For example, in March 2010, the city of Flint laid off 23 firefighters and 46 police officers, and closed two fire stations due to budget deficits.

The lack of full-time professional fire fighters in many areas of the state means that less time is available to conduct fire inspections and take other preventive measures necessary to lessen the structural fire threat. In many small towns and rural communities, local efforts in fire prevention are almost non-existent, due to lack of personnel and time to devote to such activities. Out of necessity, efforts in these communities are directed primarily at fire suppression. Clearly, the lack of full-time paid fire professionals in many areas across the state poses great challenges for maintaining a sustainable fire prevention and inspection program.

Lack of State Fire Safety Code

The other major challenge facing the Michigan fire service is the lack of a state-mandated fire safety code and code enforcement program for all occupancy types. Although the State enforces fire safety codes in schools, dormitories, health care facilities, and correctional facilities, plus some businesses, the remainder of the job is left to local officials. Because there is not a uniform, mandated fire safety code for everyone to adhere to, a plethora of local ordinances have emerged. In some communities, fire safety codes do not exist at all. This contributes to Michigan's structural fire problem by allowing serious fire safety violations to go unchecked, often for years at a time. This problem manifests itself more seriously in rural areas and small towns, which typically have few, if any, paid full-time fire fighters. In Michigan's larger cities, full-time fire departments with qualified inspectors are the rule rather than the exception. As a result, fire safety inspections are performed on a more regular basis, but not necessarily as often as they should be.

Even if a mandated fire safety code were instituted statewide, it wouldn't totally solve the problem of structural fire prevention because the costs of compliance in existing buildings would often be prohibitive for business owners. Such a measure would, however, help to ensure that new construction doesn't compound the problem.

Impact on the Public

Structural fires can cause displacement and homelessness, in addition to serious injuries, death, and economic losses. Beyond the small-scale structural fires that only affect a single home or two at a time, emergency management authorities are primarily focused on disaster-level events involving multiple or major structures such as hotels, college residence halls, and major employers and community facilities (such as schools and hospitals). The impacts upon local services and economies can be severe in such cases, due to the number of residents served and the diversity of needs being met by these facilities. Structural fires occur more frequently than other Michigan hazards, and also cause more deaths, injuries, and property damage.

Impact on Public Confidence in State Governance

Structural fires may raise questions about code enforcement and other regulations that may be connected with state government. Some fires may originate from utility malfunctions (e.g. natural gas explosions) or wildfire events, and thus call into question the capacity of the state to foresee, regulate, or manage such situations. Emergency management personnel are particularly interested in structural fires that can produce disaster-level events involving major or multiple structures, major employers, or community facilities. Examples include hotels, college residence halls, schools, hospitals, factories, and "main street" commercial areas. If severe economic or service disruptions result from such fires, the viability and reliability of government operations, design standards, and procedures may be called into question. The fact that regulatory controls may be created and implemented at the local level does not necessarily absolve State government from responsibility, since municipalities are legally considered to be "creatures of the state" and could potentially have their safety policies formulated by state legislation, and implemented by state agents.

Impact on Responders

The structural fire hazard, from the perspective of emergency management, does not generally involve common residential fires that primarily affect a single home, but instead deals with large-scale events that involve critical, large, or multiple structures, utilities infrastructure, industrial facilities, nursing homes, dormitories, hospitals, hotels, and other locations that involve greater risk and complexity due to the potential numbers of vulnerable people involved, the vital nature of the site for the community, or the potential for exposure to hazardous materials. Extensive search and rescue operations may be warranted under major structural fire conditions. Special training, staffing, and equipment is often useful or necessary to effectively deal with such events.

Impact on the Environment

Air pollution issues are inherent to structural fire events, including vast amounts of carbon released from the flames, various chemicals burning within the building's materials, other forms of air pollution, and ash spread widely around the area. Large, dark, and thick smoke plumes from large burning structures can alter atmospheric conditions and lead to shifting wind patterns that affect other areas. Fires may spread to other structures and to natural vegetation, negatively affecting the environment. The burning of nearby native forests, trees, and grasslands can be some environmental consequences of structural fires. Chemicals from combustion may contaminate nearby water in lakes, reservoirs, rivers, and swamps. Agricultural structural fires can also affect farm animals and ruin agricultural products. The waters used to quell fires can spread the combustion products (chemicals, soot, ash) into nearby areas, and into municipal sewer systems where they may affect the environment at system outlet locations.

SCRAP TIRE FIRES

A large fire that burns scrap tires being stored for recycling or re-use.

Hazard Description

With the disposal of an estimated 290 million vehicle tires annually in the United States, management of scrap tires has become a major economic and environmental issue. Michigan generates approximately 10 million scrap tires each year. Although responsible means of storage and disposal have become more common, tire dumps of the last forty years still present environmental and safety hazards. In November 2009, the State of Michigan has identified a total of more than 990,400 tires (those that pose the greatest fire danger) in outdoor stockpiles scattered around the state. Since the MDEQ Michigan Scrap Tire Program began in 1991, the total amount of Michigan's scrap tire stockpile has gone from 31 million to about 3,400,000. The department estimates that most of the remaining tires could be disposed of before the program's ending date in December 2012.

Scrap Tire Disposal Sites in Michigan: November 2009

County	Sites	Tires	County	Sites	Tires
Alpena	2	100,250	Livingston	1	1,000
Arenac	1	37,341	Marquette	1	3,000
Bay	1	700	Mecosta	1	8,000
Benzie	1	10,000	Menominee	1	2,000
Calhoun	2	5,700	Midland	2	121,100
Cass	1	37,000	Monroe	2	7,500
Chippewa	1	500	Montcalm	1	2,000
Clare	1	700	Newaygo	2	27,000
Crawford	1	10,000	Oakland	2	20,633
Dickinson	1	499	Oceana	1	11,000
Eaton	1	300	Osceola	2	2,385,000
Genesee	2	152,000	Ottawa	1	100,000
Grand Traverse	1	1,499	St. Clair	3	9,400
Gratiot	1	2,500	St. Joseph	2	48,000
Hillsdale	1	1,300	Sanilac	2	11,000
Houghton	2	117,500	Shiawassee	1	1,000
Ingham	1	500	Tuscola	2	12,700
Iosco	1	4,800	Wayne	22	168,977
Ionia	1	3,000	Van Buren	2	3,000
Jackson	2	6,600	**Total**	76	3,435,499

Source: Department of Environmental Quality, Waste and Hazardous Materials Division.

NOTE: Inventory totals compiled for tire quantities are approximated and will vary from year to year, as new tires are brought in and others are recycled or otherwise disposed of.

Issues pertaining to the management of scrap tire disposal sites are difficult and diverse. Whole tires are difficult to landfill because they tend to float to the surface. Whole tires are banned from disposal in Michigan landfills due to their associated problems. Scrap tires are breeding grounds for mosquitoes, which can reproduce at thousands of times their natural rate in a scrap tire disposal site, and these mosquitoes can carry and transmit life-threatening diseases. Stockpiles also are home to snakes and small mammals such as rats, opossums, skunks, and raccoons. Stockpiled tires are often soiled with mud, dirt, or other foreign materials that limit potential markets and increase processing costs. From an emergency management perspective, the most serious problem that scrap tire disposal sites pose is that they can be a tremendous fire hazard if not properly designed and managed.

Tire disposal sites can be serious fire hazards due to the sheer number of tires typically present at a site. This large quantity of "fuel," coupled with the fact that the shape of a tire allows air to flow into the interior of a large tire pile, renders standard fire fighting practices nearly useless. Flowing burning oil released by the tires spreads the fire to adjacent areas. Some scrap tire fires have burned for months, creating acrid smoke and an oily residue that can leach into the soil, creating long-term environmental problems.

Deep stockpiles of compacted tire shreds can undergo a progressive series of exothermic reactions that increase pile temperatures and generate combustible gases. Surface symptoms of this phenomenon can be subtle, such as a slight sulfur odor, vapor steaming from isolated sections of the pile surface, or a slight oil sheen on adjacent standing water after rainfall. Due to the potential for auto-ignition, surface fires can ignite on a shredded tire stockpile, especially as shreds are removed from the area near the hot zone. Gases and shreds are then exposed to air and may ignite.

Scrap tire fires differ from conventional fires in several respects: 1) even relatively small scrap tire fires can require significant resources to control and extinguish; 2) the costs of fire management are often far beyond that which local government can absorb; 3) the environmental consequences of a major tire fire are significant; and 4) as alluded to earlier, the extreme heat converts a standard passenger vehicle tire into about two gallons of oily residue, which can leach into the soil or drain into streams.

Current technologies are sufficient to address the reuse of newly generated scrap tires, but some waste tires still migrate to the least expensive disposal method, which usually means they end up in a scrap tire disposal site (sometimes illegally). Lightning strikes, equipment overheating or sparks, unattended burning of debris/refuse, and arson are the leading causes of tire fires. Fires are also sometimes started by site operators or local residents in the wake of publicity over clean-up activities. This publicity can include enforcement proceedings or initial abatement activities, suggesting that a landowner may be acting out of frustration or attempting to avoid costs associated with tire abatement.

Much work still needs to be done to mitigate the impacts of scrap tire fires. Incident management planning, recognition of the hazardous material potential of fires at scrap tire sites, and improving and enhancing disposal site selection and design processes are all critical pre-incident preparedness factors that must be addressed by government and the private sector. In light of the potential consequences of scrap tire fires, prevention must become a primary goal in the treatment of scrap tire disposal sites. The Rubber Manufacturers Association has put together a document on the Prevention and Management of Scrap Tire Fires that can be printed and used by local fire officials. This document can be found at:
http://www.rma.org/scrap_tires /scrap_tires_ and_the_ environment/fireprevention.cfm .

Impact on the Public
Scrap tire fires often involve extensive smoke and pollution that may prompt evacuations from, and lingering odors in, nearby residences. In addition to the disruption and inconvenience of even a temporary displacement (especially on the elderly, disabled, and very young), negative health effects may result from smoke exposure, and considerable time and expense may be involved in the process of cleaning and deodorizing homes afterward. Nearby local roads, businesses, and facilities may be closed during a fire event. Scrap tire piles also tend to serve as breeding grounds for mosquitoes, which cause additional health and nuisance problems for area residents.

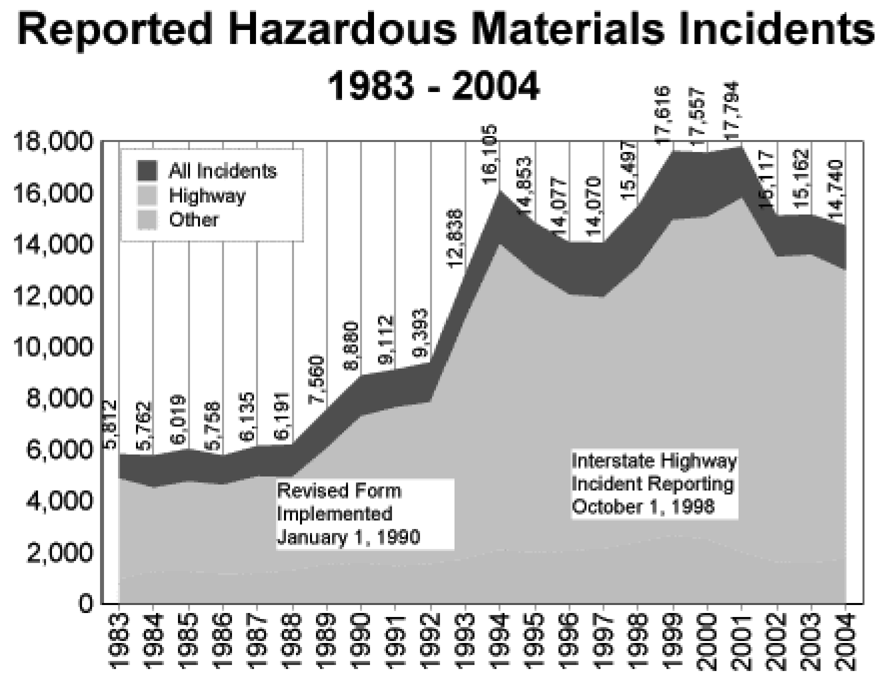
Impact on Public Confidence in State Governance
Some of the public may have an idea that governmental regulations and environmental policy/enforcement should be able to entirely prevent scrap tire piles and fires from presenting a significant hazard. Scrap tire storage/disposal sites, plus any associated fires, can affect an area’s property values, reputation, and environment. Local impacts from scrap tire sites should be viewed in terms of the larger-scale, specialized economic functions being served by these sites and their associated businesses. Abstractions such as economic need/demand are not easy for all residents of an area to immediately understand and accept. The “not in my backyard” (NIMBY) problem is involved in this issue, for although tire disposal must occur (i.e. it is a necessary function) many residents see it as undesirable in their vicinity and would prefer that the service take place at a different location.

Impact on Responders
Scrap tire fires can involve excessive response costs and time/resource commitments that may strain local budgets and staff workloads. Responding personnel are exposed to unusually thick and toxic smoke from these events. Potential problems may also arise involving access to crowded or poorly-organized sites (tire sites with storage arrangements that didn't sufficiently conform to established regulations and restrictions).

Impact on the Environment
Stockpiles of tires may catch fire and the environmental consequences of a major tire fire include air, surface water, soil, groundwater, and residual contamination that have negative impacts on humans, wildlife, and natural vegetation. Scrap tire fires generate dense, black smoke containing partially combusted hydrocarbons. The smoke plume can negatively impact residences and businesses in its path as well as the air quality in a broad area for a significant time period. In addition to smoke, some tire fires produce large quantities of oils that contain hazardous compounds. Under certain conditions, these oils can penetrate porous soils to contaminate groundwater that is a source of the area's drinking water. The oils can also reach surface waters and cause substantial fish kills, due to the oils' depletion of dissolved oxygen levels. Finally, the residuals (ash, wire, and unburned rubber) from a tire fire often require special handling and disposal. Processing equipment can be damaged by handling heavily contaminated or partially burned tires, slowing the abatement process.

HAZARDOUS MATERIAL INCIDENTS

A hazardous material is any solid, liquid, or gas that can cause harm to humans and other living organisms due to its being radioactive, flammable, explosive, toxic, corrosive, a biohazard, an oxidizer, an asphyxiant, or capable of causing severe allergic reactions. Mitigating the risks associated with hazardous materials often requires extensive safety precautions during their transport, use, disposal and storage. Hazardous materials are transported by highway, rail, pipeline, air, and water. Below is a chart showing the number of hazardous material transportation incidents in the United States reported to the federal Pipeline and Hazardous Materials Safety Administration. (Note: the chart only lists transportation incidents, not fixed site incidents.)



Source: Pipeline and Hazardous Materials Safety Administration

Impact on the Public

Both fixed site and transport-related hazardous material incidents involve the potential for evacuation (or sheltering in place), with significant problems possible for special populations in hospitals, schools, nursing homes, and other critical facilities. Certain types of extremely hazardous substances may result in a public health emergency, and a resulting need for triage, mass treatment, and congregate care. In addition to the direct impacts of the hazardous material event itself, transportation incidents may directly affect the transportation infrastructure in the area and cause extensive delays in travel and the conduct of business. This hazard is ranked as the second most frequent in occurrence (behind structural fires).

Impact on Public Confidence in State Governance

Discontent may arise from the NIMBY problem (as referred to in the Scrap Tire Fires section) or from difficulties in planning to avoid conflicting land uses. Mixed attitudes toward useful and needed employers/businesses may be fairly common, recognizing the economic benefits of companies that use hazardous materials, but unsettled by the perceived risks in the location of some of them (or their number, since there were 2,991 SARA Title III sites in Michigan in late 2009). Such perceptions of risk may be over-generalized toward other, undeserving businesses (e.g. those that pose minimal risks). Part of the public may not understand the balance between regulation and business needs concerning the use and handling of hazardous materials. Transportation delays due to transportation-related incidents may cause dissatisfaction with roadway provision, capacity, and maintenance.

Impact on Responders

Special procedures and additional information tend to be needed for incidents involving hazardous materials. Additional risks to responders may be present from exposure to extremely hazardous substances at or near these incident locations. Exposure can involve direct contact, the presence of toxic fumes, or the risk of fires and explosions from chemical reactions. Additional complexity therefore tends to be present in any response involving hazardous materials. A schedule of exercise activities needs to be maintained for staff preparedness, and larger budgets are needed to accommodate the staffing, training, exercising, and equipment needed. In addition to preparing for and handling this type of response, the creation, support, and participation in a Local Emergency Planning Committee is needed, along with work related to Section 302 site planning and mutual aid arrangements with nearby communities and relevant agencies. Extra work is also involved in creating and maintaining special contact lists for railroads, the MDEQ, drain and road commissions, airports, health departments, and private companies who may also be involved in incident response, as well as the State Emergency Operations Center (SEOC) and its notification/coordination procedures and protocols. Special expertise in substance types and risks, as well as software for plume modeling, may also be needed for effective response, and such expertise has an expense associated with its development and maintenance.

Impact on the Environment

An incident involving hazardous material, whether at a fixed site or during transportation, may cause harm to the environment, as various types and quantities of chemicals are released. A hazardous spill involving an industrial or chemical plant can affect air quality, soil surrounding the area of the release, and an area's drinking water. A hazardous spill caused by a transportation accident can similarly impact the air, soil, and nearby lakes and rivers. A toxic release can also destroy the wildlife habitat in or around the areas where the release occurs.

HAZARDOUS MATERIAL INCIDENTS: FIXED SITE
(INCLUDING INDUSTRIAL ACCIDENTS)

Hazardous Material Incident – Fixed Site: An uncontrolled release of hazardous materials from a fixed site capable of posing a risk to life, health, safety, property or the environment.

Industrial Accident: A fire, explosion, or other severe accident (especially if it involves hazardous materials) at an industrial facility that results in serious property damage, injury, or loss of life.

Hazard Description

Hazardous Material Incidents

Over the past few decades, new technologies have developed at a stunning pace. As a result, hazardous materials are present in quantities of concern in business and industry, agriculture, universities, hospitals, utilities, and other facilities in our communities. Hazardous materials are materials or substances which, because of their chemical, physical, or biological nature, pose a potential risk to life, health, property, or the environment if they are released. Examples of hazardous materials include corrosives, explosives, flammable materials, radioactive materials, poisons, oxidizers, and dangerous gases.

Hazardous materials are highly regulated by federal and state agencies to reduce risk to the general public and the environment. Despite precautions taken to ensure careful handling during the manufacture, transport, storage, use, and disposal of these materials, accidental releases do occur. These releases can cause severe harm to people or the environment, and response actions often need to be immediately performed. Most releases are the result of human error. Occasionally, releases can be attributed to natural causes, such as a flood that washes away barrels of chemicals stored at a site. However, those situations are the exception rather than the rule.

Industrial Accidents

Industrial accidents differ from hazardous material incidents in the scope and magnitude of offsite impacts. Whereas hazardous material incidents typically involve an uncontrolled release of material into the surrounding community and environment that may require evacuations or in-place sheltering of the affected population, the impacts from industrial accidents are often confined to the site or facility itself, with minimal physical outside impacts. Nonetheless, industrial accidents, such as fires, explosions, and excessive exposure to hazardous materials, may cause injury or loss of life to workers at the facility, and significant property damage. In addition, industrial accidents can cause severe economic disruption to the facility and surrounding community, as well as significant long-term impacts on the families of the workers injured or killed.

Hazard Analysis

Hazardous Material Incidents

The map at the end of this section illustrates where the identified SARA Title III facilities are located in Michigan. An examination of the map indicates that the greatest concentration of facilities is located in southeastern Michigan and other urbanized areas. Fortunately, these are generally the areas with more resources to prepare for and respond to a hazardous material incident. However, the greater population concentrations also make these areas more vulnerable to a serious hazardous material incident.

Like all heavily industrialized states, Michigan will always be concerned with the risk of accidental hazardous material releases. However, the threat of accidental hazardous material releases that can affect life, health, property or the environment can be greatly reduced by: 1) developing and maintaining adequate community hazardous material response plans and procedures; 2) adequately training hazardous material workers and off-site emergency responders; 3) educating the public about hazardous materials safety; 4) enforcing basic hazardous material safety regulations; and 5) mitigating, wherever possible, the threat of accidental hazardous material releases. Fortunately, many Michigan communities are making great strides in these important areas.

NOTE: Nuclear research facilities can produce / use radioactive materials, as well as other hazardous substances, and therefore need to be dealt with by specially trained personnel. Caution should be exercised at these facilities, and proper radiological survey equipment should be used during a response.

Industrial Accidents

As a major manufacturing and industrial center, Michigan has had its share of industrial explosions and/or fires that resulted in deaths or injuries. Fortunately, industrial and fire safety regulations enacted over the years have kept these types of accidents to a minimum. Although industrial accidents occur with regularity in Michigan, major incidents with mass casualties, such as the four deadly explosions that occurred in 1998 and 1999, are relatively rare.

SARA Title III Sites in Michigan

Source: Michigan Department of Environmental Quality

NUCLEAR POWER PLANT EMERGENCIES

An actual or potential release of radioactive material at a commercial nuclear power plant, in sufficient quantity to constitute a threat to the health and safety of the off-site population.

Hazard Description

Though the construction and operation of nuclear power plants is closely monitored and regulated by the Nuclear Regulatory Commission (NRC), accidents at these plants are considered a possibility, and appropriate on-site and off-site emergency planning is conducted. An accident could result in the release of potentially dangerous levels of radioactive materials into the environment and could affect the health and safety of the public living near the nuclear power plant. A nuclear power plant accident might involve both a release of airborne radioactive materials and radioactive contamination of the environment around the plant. The degree and area of environmental contamination could vary greatly, depending on the type and amount of release, and the weather conditions that are present. Response to a nuclear power plant accident requires specialized personnel who have been trained to handle radioactive materials safely, who have specialized equipment to detect and monitor radiation, and who are trained in personal radiation exposure control.

After a period of decline following the 1979 Three Mile Island accident and the 1986 incident at Chernobyl, there is a recent renewed interest in nuclear energy because it could partially address problems of dwindling oil reserves and global warming, with far fewer emissions of greenhouse gases than the use of fossil fuels. However, the use of nuclear power is controversial because of the problems of storing radioactive waste for indefinite periods, the potential for radioactive contamination by accident or sabotage, and the possibility that its use could in some countries lead to the proliferation of nuclear weapons. As the chart below shows, the United States produces the most nuclear energy of any country in the world, but many other countries actually use nuclear energy as a larger percentage of their overall energy production.

Nuclear Electricity Generation by Country: 2008

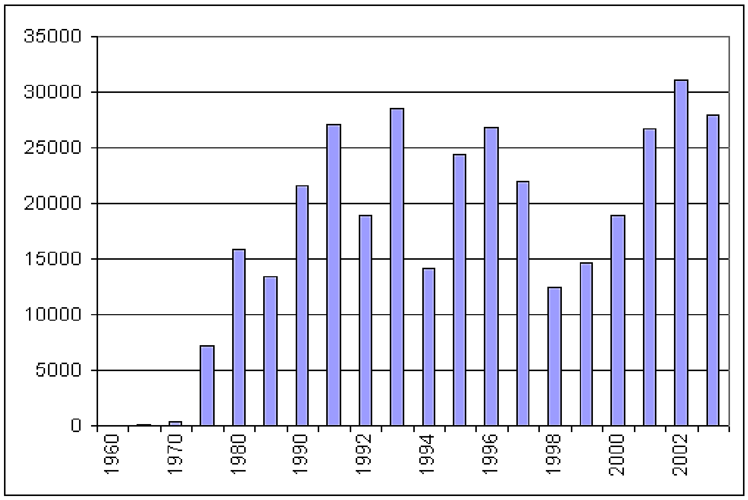
Country	Production (Billion Kilowatt Hours)	% of Country's Energy	Country	Production (Billion Kilowatt Hours)	% of Country's Energy
Argentina	6.9	6.2%	Korea RO (South)	144.3	35.6%
Armenia	2.3	39.4%	Lithuania	9.1	72.9%
Belgium	43.4	53.8%	Mexico	9.4	4.0%
Brazil	13.2	3.1%	Netherlands	3.9	3.8%
Bulgaria	14.7	32.9%	Pakistan	1.7	1.9%
Canada	88.3	14.8%	Romania	10.3	17.5%
China	65.3	2.2%	Russia	152.1	16.9%
China: Taiwan	39.3	17.1%	Slovakia	15.5	56.4%
Czech Rep.	25.0	32.5%	Slovenia	6.0	41.7%
Egypt	0	0%	South Africa	12.8	5.3%
Finland	22.1	29.7%	Spain	56.5	18.3%
France	419.8	76.2%	Sweden	61.3	42%
Germany	140.9	28.8%	Switzerland	26.3	39.2%
Hungary	13.9	37.2%	Turkey	0	0%
India	13.2	2.0%	Ukraine	84.5	47.4%
Indonesia	0	0%	United Kingdom	48.2	13.5%
Iran	0	0%	**USA**	**806.7**	**19.7%**
Israel	0	0%			
Japan	241.3	24.9%	**WORLD**	**2,597.8**	**14%**
Korea DPR (North)	0	0%			

Hazard Analysis

With three commercial nuclear power plants currently operating in the state, emergency preparedness is required in all potentially affected jurisdictions. Michigan's three commercial nuclear power plants are 1) the Enrico Fermi-2 plant near Monroe; 2) the Donald C. Cook plant near Bridgman; and 3) the Palisades plant near Covert.

A fourth plant, the Big Rock Point plant near Charlevoix, was closed in 1997 and then decommissioned, but spent fuel is still stored on-site in dry casks and will probably remain there quite a while. The Davis-Besse nuclear power station near Toledo, Ohio has several Michigan counties within its Secondary Emergency Planning Zone (EPZ), requiring coordinated planning between Michigan and Ohio. The commercial power plant facilities are located on the map at the end of this section. The chart below shows the amount of nuclear power that Michigan has generated since 1960.

Nuclear Generation in Michigan, 1960 through 2003
(Million Kilowatt Hours)



Source: Energy Information Administration, State Energy Data Report 1999, Electric Power Annual (Volume 1, 2001), and EIA Survey Form 906.

Federal, state and local governments and utility personnel take extensive precautions to ensure that, should a nuclear accident occur, its impact on the safety and well being of the general public and the environment will be minimal. These precautions include the development and continual testing of emergency plans, training of response personnel, coordination of response actions, and development and dissemination of emergency public information. A regular series of large, interagency drills and exercises takes place for each nuclear plant, and each plant has two designated emergency planning zones—primary (within a 10 mile radius) and secondary (within a 50 mile radius)—to handle all possible incidents and response activities that could be anticipated, both in the short-term and the long-term.

Impact on the Public
A nuclear power plant accident would tend to pose limited threats, directly involving the environment and public over a distance typically no greater than 10 miles away, even in the most severe U.S. events. Evacuation and contamination may occur within this limited distance from the plant, and any more far-reaching effects (e.g. food chain contamination) would vary with weather conditions and the extent and type of radioactive release. This hazard has been extensively studied and prepared for, allowing the likely impacts on the public to be efficiently assessed and addressed, should an event occur.

Impact on Public Confidence in State Governance
A nuclear power plant emergency may severely affect public confidence in state government if it results in significant environmental harm, displacement, or casualties. Although the odds of this happening are slim, nuclear power is poorly understood by many U.S. citizens, many of whom may be expected to misinterpret both the nature of the industry as well as the effects of an accident, and to perceive that any significant failures are likely the result of inadequate governmental oversight and regulation.

Impact on Responders

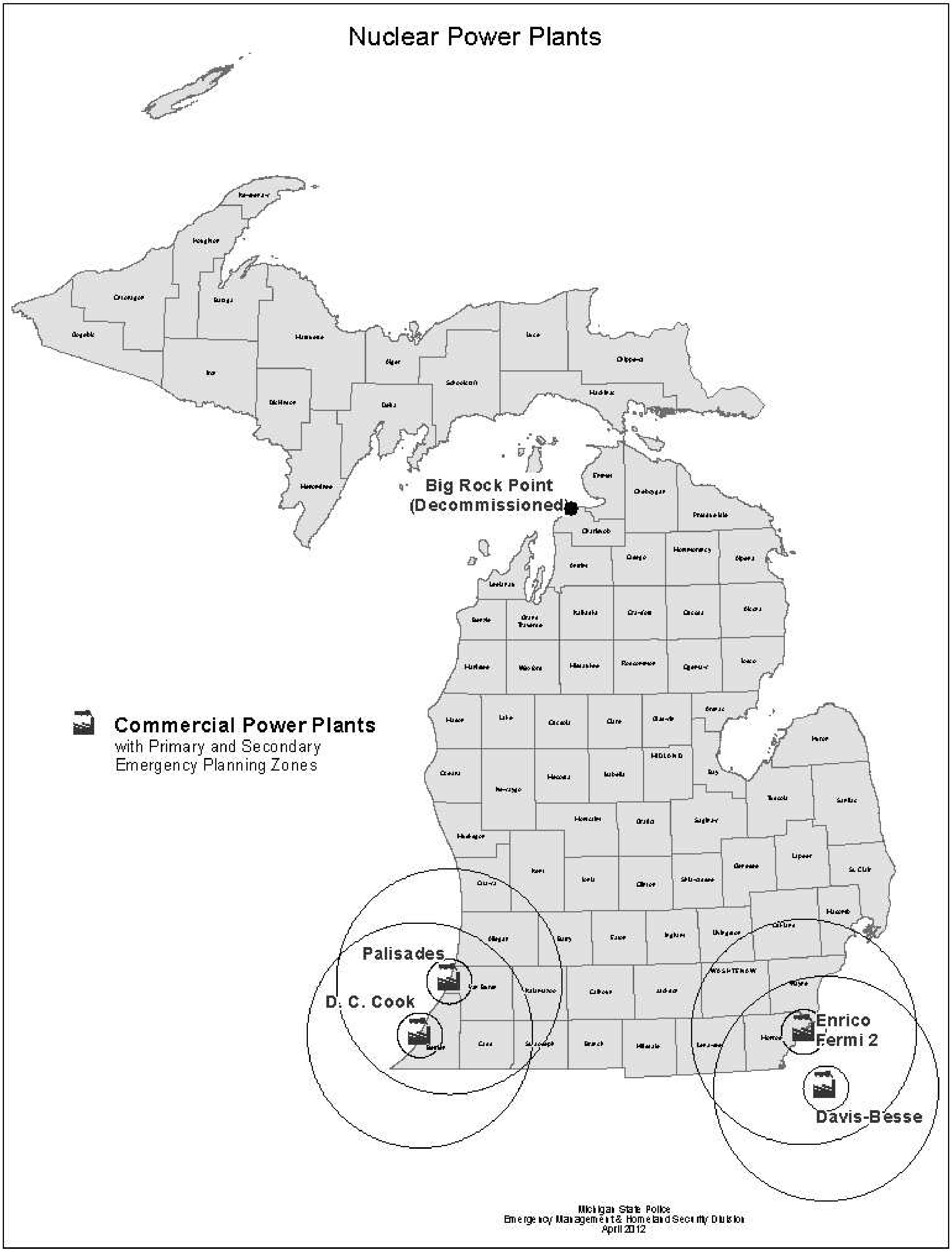
Due to pre-planning, training, and exercising, a nuclear power plant accident offers the opportunity to use planned staging areas, from which to handle equipment, protective clothing, medical treatment, decontamination, provision and sheltering needs. Responder exposure to radiation should not need to exceed amounts that have been mandated by law and by workplace regulations. (Extensive procedures and regulations are in place to minimize those types of risks.)

Impact on the Environment

A nuclear power plant accident could result in the release of potentially dangerous levels of radioactive materials both in the air and around the plant. Contamination may occur from radioactive gases, liquids or particles. Some possible accidents at nuclear power plants pose a risk for severe environmental contamination, and the degree and area of this contamination could vary greatly depending on the type and amount of radioactivity, and on the weather conditions.

An accidental release of large amounts of radioactive contamination could contaminate many areas of land for long periods of time, making it unusable for humans, wildlife species, and natural vegetation. The main reason is due to radioactive materials comprising unstable isotope elements that decay over a long period of time. Some isotopes can decay quickly, while others take a very long time to stabilize. Certain radioactive elements such as plutonium can remain hazardous for thousands of years, making re-use of an area difficult or hazardous. Nuclear reactors produce high level waste (an actual classification) in the reactor core that is highly reactive and thermally hot, presenting handling, transportation, and storage problems. Radioactive contamination may affect nearby water bodies, rivers, etc. and damage the environment and its aquatic life. Radioactive material has the potential to seep deep into the ground and water table.

Nuclear Power Plants in Michigan



HAZARDOUS MATERIAL INCIDENTS: TRANSPORTATION

An uncontrolled release of hazardous materials during transport, capable of posing a risk to life, health, safety, property, or the environment.

Hazard Description

As a result of the extensive use of chemicals in our society, all modes of transportation – highway, rail, air, marine, and pipeline – are carrying thousands of hazardous materials shipments on a daily basis through local communities. A transportation accident involving any one of those hazardous material shipments could cause a local emergency affecting many people.

Hazard Analysis

Michigan has had numerous hazardous material transportation incidents that affected the immediate vicinity of an accident site or a small portion of the surrounding community. Those types of incidents, while problematic for the affected community, are fairly commonplace. They are effectively dealt with by local and state emergency responders and hazardous material response teams. Larger incidents, however, pose a whole new set of problems and concerns for the affected community. Large-scale or serious hazardous material transportation incidents that involve a widespread release of harmful material (or have the potential for such a release) can adversely impact the life safety and/or health and well-being of those in the area surrounding the accident site, as well as those who come in contact with the spill or airborne plume. In addition, damage to property and the environment can be severe as well. Statistics show that almost all hazardous material transportation incidents are the result of an accident or other human error. Rarely are they caused simply by mechanical failure of the carrying vessel.

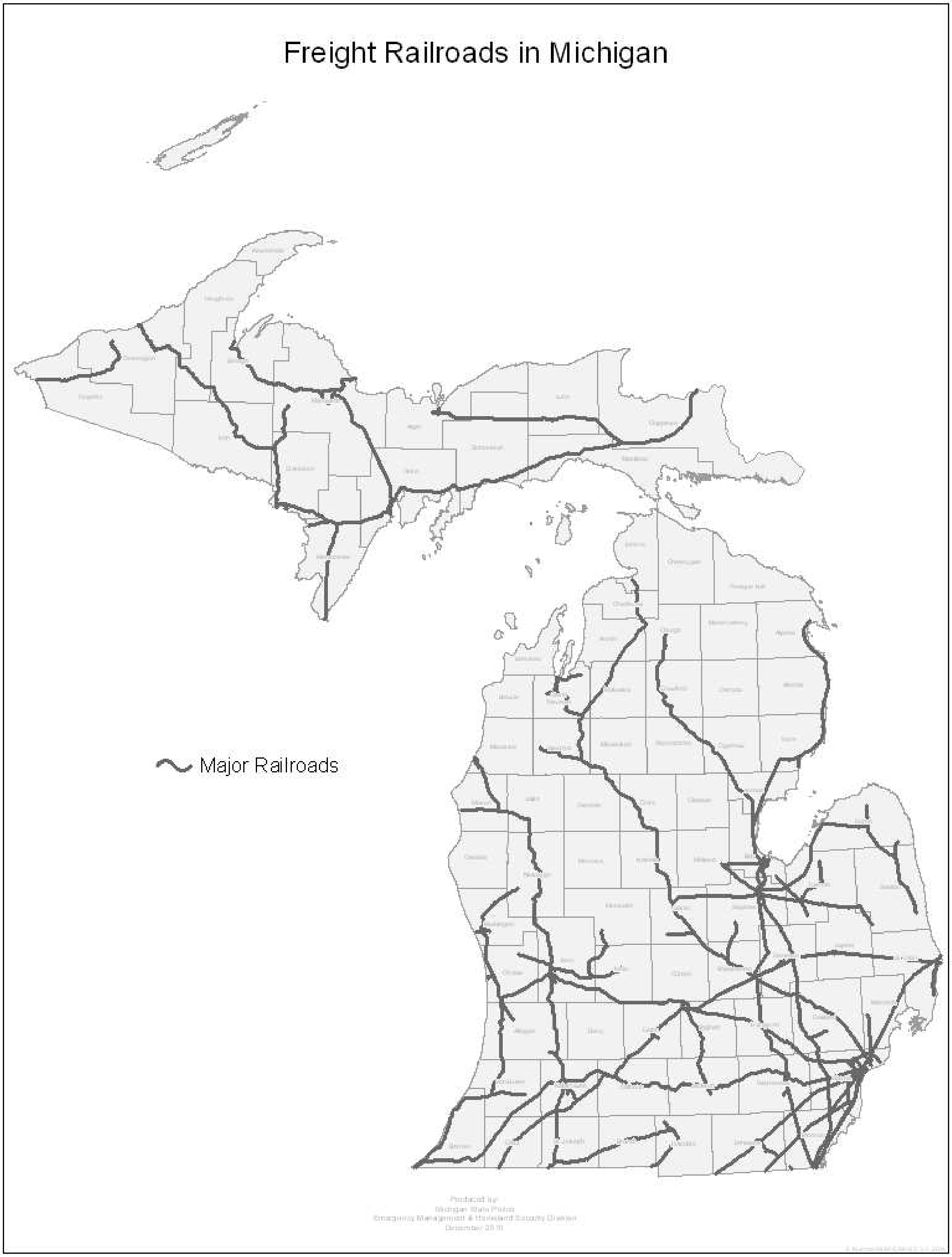
Being surrounded by the Great Lakes, one of the most dangerous hazardous material transportation accident scenarios that could occur in Michigan would be a spill or release of oil, petroleum or other harmful materials into one of the lakes from a marine cargo vessel. Such an incident, if it involved a large quantity of material, could cause environmental contamination of unprecedented proportions. Fortunately, the Great Lakes states, working in partnership with oil and petroleum companies and other private industry, have taken significant steps to ensure that a spill of significant magnitude is not likely to occur on the Great Lakes. (See the Programs and Initiatives section for more information.)

(Note: Pipeline transportation accident issues are addressed in the Petroleum and Natural Gas Pipeline Accidents section of this document. Refer to that section for specific information on that hazard. For an assessment of the various types of potential impacts from this hazard, please refer to the introductory section on hazardous materials, preceding the section on fixed site hazardous materials, earlier in this document.)

The maps at the end of this section illustrate the major railroads, highways, and Great Lakes ports in the State of Michigan. These transportation links and nodes have the greatest probability of experiencing a hazardous material transportation incident. Although the greatest risk involving hazardous materials comes from highway and rail shipments, a petroleum or chemical spill on the Great Lakes could have disastrous consequences for shoreline communities, recreational areas, tourism, and the environment. Fortunately, only about 3% of all shipments on the Great Lakes involve petroleum or chemicals, and most of those are through the Port of Detroit.

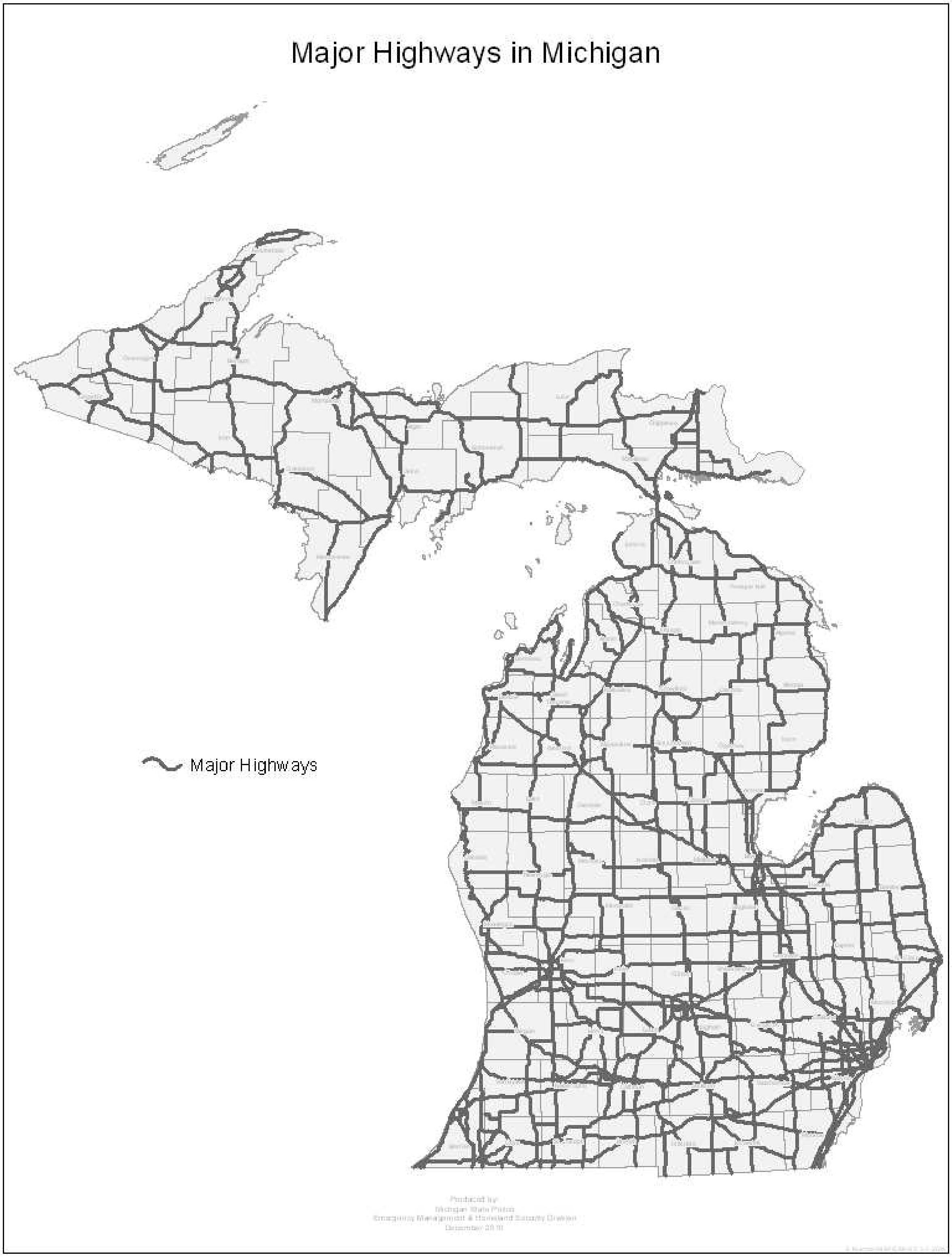
Freight Railroads in Michigan

Source: Michigan Department of Transportation



Major Highways in Michigan

Source: Michigan Department of Transportation



Great Lakes Commercial Ports in Michigan

Source: Michigan Department of Transportation

PETROLEUM AND NATURAL GAS PIPELINE ACCIDENTS

An uncontrolled release of petroleum or natural gas, or the poisonous by-product hydrogen sulfide, from a pipeline

Hazard Description

Though often overlooked, petroleum and natural gas pipelines pose a real threat in many Michigan communities. Petroleum and natural gas pipelines can leak or fracture and cause property damage, environmental contamination, injuries, and even loss of life. The vast majority of pipeline accidents that occur in Michigan are caused by third party damage to the pipeline, often due to construction or some other activity that involves trenching or digging operations. Many structures are located right next to pipelines and thus may be at risk. Pipelines can also cross through rivers, streams, and wetlands, thus posing the possibility of extensive environmental damage in the event of a major failure.

Michigan is both a major consumer and producer of natural gas and petroleum products. According to the federal Energy Information Administration, Michigan's consumption of petroleum products, particularly liquefied petroleum gases (LPG) is high; Michigan is the largest residential LPG market in the nation, due mostly to high residential and commercial propane consumption. The state has a single petroleum refinery but a large network of product pipelines. More than 78% of the overall home heating market uses natural gas as its primary fuel. With over one-tenth of U.S. capacity, Michigan has the greatest underground natural gas storage capacity in the nation and supplies natural gas to neighboring states during high-demand winter months. Driven largely by the residential sector, Michigan's natural gas consumption is high. Nearly four-fifths of Michigan households use natural gas as their primary energy source for home heating.

The State Energy Data System (SEDS) released data in August 2009 that describes energy consumption by source and total consumption per capita. Michigan ranks 13th in the nation in production of natural gas, with 264.9 billion cubic feet, and 7th in consumption, at 847.8 billion cubic feet. These figures underscore the fact that vast quantities of petroleum and natural gas are extracted from, transported through, and stored in the state, making many areas vulnerable to petroleum and natural gas emergencies. Michigan's gas and petroleum networks are highly developed and extensive, representing every sector of the two industries—from wells and production facilities, to cross-country transmission pipelines that bring the products to market, to storage facilities, and finally to local distribution systems.

While it is true that the petroleum and natural gas industries have historically had a fine safety record, and that pipelines are by far the safest form of transportation for these products, the threat of fires, explosions, ruptures, and spills nevertheless exists. In addition to these hazards, there is the danger of hydrogen sulfide (H_2S) release. These dangers (fully explained in the Oil and Natural Gas Well Accidents section) can be found around oil and gas wells, pipeline terminals, storage facilities, and transportation facilities where the gas or oil has a high sulfur content. Hydrogen sulfide is not only an extremely poisonous gas, but is also explosive when mixed with air at temperatures of 500 degrees Fahrenheit or above.

In 2010, Michigan suffered what may be the largest inland oil release in the country, when a pipeline in Calhoun County failed and released large quantities of crude which ended up in the Kalamazoo River and flowed downstream for many miles. Although a description of this event appears later in this section, it must be noted here that because the recovery activities for this disaster are still ongoing, an after-action report was not yet available for use in this analysis, to efficiently relay "lessons learned" and the final results of the extensive cleanup activities.

Hazard Analysis

The map at the end of this section shows the location of major petroleum and natural gas pipelines within Michigan. It is apparent from the map that petroleum and natural gas pipelines crisscross the entire state, from well heads to storage sites, through distribution to consumers. Major compressor stations that receive and redistribute natural gas are located at key points along the pipelines (but are not shown on the map). These stations monitor and maintain pressure levels within the pipelines. In the event of a pipeline rupture, the compressor stations shut down to stop the flow of product. Many smaller compressor stations are located across the state to complete the distribution process to consumers.

The state's major natural gas storage facilities are located in the central part of the Lower Peninsula. Natural gas is piped into those storage facilities from Michigan wells, and from large transmission pipelines that originate in Canada, the southwestern United States, and the Gulf of Mexico area.

Petroleum pipelines carrying crude oil, fuel oil, propane, butane, gasoline, and other petroleum products have their heaviest concentrations in central Lower Michigan and between Detroit and Toledo. Many of the refineries, terminals, and storage areas are located in urban areas where the potential for extensive damage, and threat to lives and property, is greatest. The largest concentration of these facilities is found in the Detroit metropolitan area.

Petroleum and natural gas pipeline accidents are on the rise, due to the aging of the underground infrastructure (much of which was laid over 50 years ago) and an increase in construction excavation. According to studies conducted by the General Accounting Office (GAO), an average of 22 people died annually from 1988 to 1998, when the number of accidents was increasing by four percent per year. The GAO also found that the USDOT/OPS has not adequately enforced many safety regulations passed by Congress since 1988 and is instead relying more on industry self-regulation as an enforcement tool.

Increased pipeline safety regulations again came to the forefront in 2000, after deadly pipeline explosions occurred in Bellingham, Washington in June 1999 (three deaths) and Carlsbad, New Mexico in August 2000 (11 deaths). In 2004, the Pipeline and Hazardous Materials Safety Administration (PHMSA) was signed into law. The purpose of the Act was to provide a more focused research organization and establish a separate operating administration for pipeline safety and hazardous materials transportation safety operations.

The Pipeline Safety Improvement Act of 2002 mandated significant changes and new requirements in the way that the natural gas industry ensures the safety and integrity of its pipelines. The law applies to natural gas transmission pipeline companies. The law places requirements on each pipeline operator to prepare and implement an “integrity management program” that, among other things, requires operators to identify so-called “high consequence areas” (HCA) on their systems, conduct a risk analysis of these areas, perform baseline integrity assessments of each pipeline segment, and inspect the entire pipeline system. Companies were required to identify all HCAs and submit specific integrity management programs to the Office of Pipeline Safety (OPS), the Research and Special Projects Administration, and the U.S. Department of Transportation. All pipeline segments within HCAs were to be inspected and remediation plans completed by December 17, 2008, while non-HCA segments must be inspected by 2012. All segments must be re-inspected on a 7-year cycle, with certain exceptions.

Because petroleum and natural gas pipeline accidents will occur eventually, affected local communities must be prepared to respond to the accident, institute necessary protective actions, and coordinate with federal and state officials and the pipeline company emergency crews to effectively manage and recover from the accident. That can best be accomplished through the collaborative planning, training, and exercising of emergency procedures with all potentially involved parties.

Impact on the Public

Severe events may cause shortages of, and higher prices for, petroleum and other fuels. Some residents with low incomes or fixed budgets may find higher prices to be unaffordable, and may face problems involving heating and other energy needs being used to maintain their homes and health. Transportation and fuel costs may become too expensive to allow business profits to be maintained, when such businesses rely on fuel-driven transportation or functions. Those in the vicinity of the pipeline break itself may suffer from health problems, unpleasant odors, evacuations, and damage/contamination of their property. Some pipeline accidents result in explosions that cause extensive damage, injury and even loss of life. Gas leaks in particular can cause surprising amounts of damage from sudden explosions, without any advance warning to those nearby.

Impact on Public Confidence in State Governance

As with the oil and gas well hazard, there may be a sense that inadequate regulation, authorization, or oversight was maintained by the state, if there is an event of significant size or impact. The nature of the transported materials also causes concern about environmental and health impacts.

Impact on Responders

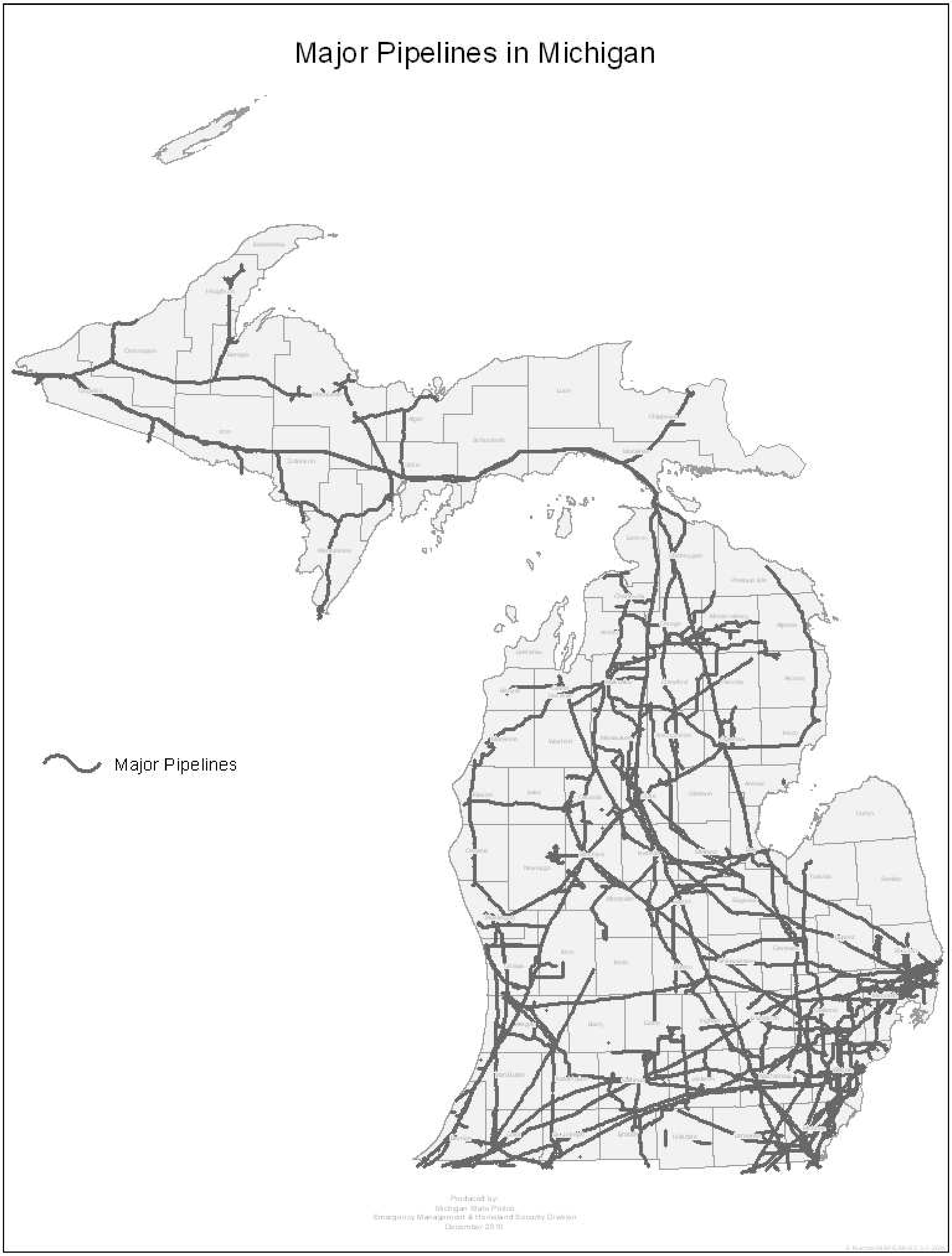
Special expertise is often needed, and the cooperation of the utility provider is often critical to an efficient and successful response. Enclosed areas may be involved in these incidents (e.g. those occurring in a densely populated urban area), and thus may require special equipment, personnel, and training in search and rescue.

Impact on the Environment

Petroleum and natural gas pipelines pose a real threat in many Michigan communities because they can lead to leaks, fractures, fires, explosions, ruptures, and spills that cause environmental contamination. The danger of hydrogen sulfide (H_2S) release can occur where the gas or oil has a high sulfur content. Hydrogen sulfide is not only an extremely poisonous gas, but is also explosive when mixed with air at temperatures of 500 degrees Fahrenheit or above. Atmospheric concentrations of greenhouse gases, especially carbon dioxide, methane, and nitrous oxide, can contribute to climate change, both regionally and globally. Adverse local consequences to ecological and socio-economic systems can result from a major petroleum or natural gas pipeline accident. Particulate pollutants may consist of metals, soot, or similar small substances. Soft sloping ground near waterway crossings can be susceptible to erosion or lateral spreading, which may cause significant pipe displacement or rupture.

Major Petroleum and Natural Gas Pipelines in Michigan

Source: Michigan Public Service Commission; pipeline company maps



OIL AND NATURAL GAS WELL ACCIDENTS

An uncontrolled release of oil or natural gas, or the poisonous by-product hydrogen sulfide, from production wells.

Hazard Description

Oil and natural gas are produced from fields scattered across 63 counties in the Lower Peninsula. From 1927 to January 2009, there have been 56,525 oil and natural gas wells drilled in Michigan, of which roughly half have produced oil and gas. To date, Michigan wells have produced over 1.4 billion barrels of crude oil and 6 trillion cubic feet of gas.

The petroleum and natural gas industry is highly regulated and has a fine safety record, but the threat of accidental releases, fires and explosions still exists. In addition to these hazards, many of Michigan's oil and gas wells contain extremely poisonous hydrogen sulfide (H_2S) gas. Hydrogen sulfide is a naturally occurring gas mixed with natural gas or dissolved in the oil or brine and released upon exposure to atmospheric conditions. Over 1,300 wells in Michigan have been identified as having H_2S levels exceeding 300 parts per million (ppm).

As the table below indicates, at concentrations of 700 ppm, as little as one breath of hydrogen sulfide can kill. Although hydrogen sulfide can be detected by a "rotten egg" odor in concentrations from .03 ppm to 150 ppm, larger concentrations paralyze a person's olfactory nerves so that odor is no longer an indicator of the hazard. Within humans, small concentrations can cause coughing, nausea, severe headaches, irritation of mucous membranes, vertigo, and loss of consciousness. Hydrogen sulfide forms explosive mixtures with air at temperatures of 500 degrees Fahrenheit or above, and is dangerously reactive with powerful oxidizing materials. Hydrogen sulfide can also cause the failure of high-strength steels and other metals. This requires that all company and government responders be familiar not only with emergency procedures for the well site, but also with the kinds of materials that are safe for use in sour gas well response.

Physiological Response to H_2S

10 ppm	Beginning eye irritation
50-100 ppm	Slight conjunctivitis and respiratory tract irritation after 1 hour exposure
100 ppm	Coughing, eye irritation, loss of sense of smell after 2-15 minutes. Altered respiration, pain in the eyes and drowsiness after 15-30 minutes, followed by throat irritation after 1 hour. Several hours of exposure results in gradual increase in severity of these symptoms and death may occur within the next 48 hours.
200-300 ppm	Marked conjunctivitis and respiratory tract irritation after 1 hour of exposure.
500-700 ppm	**Loss of consciousness and possibly death in 30 minutes to 1 hour.**
700-1000 ppm	**Rapid unconsciousness, cessation of respiration, and death.**
1000-2000 ppm	**Immediate unconsciousness, with early cessation of respiration and death following within a few minutes. Death may occur even if the individual is removed to fresh air at once.**

Source: American National Standards Institute, Standard: 237.2-1972

An unplugged abandoned well, also known as an orphan well, can be a hazard to the health and safety of the surrounding people and environment. There are many situations where an unplugged well can become dangerous. For example, a rusted-out casing in a gas well can let natural gas flow underground and accumulate in the basement of a nearby building, possibly causing an explosion. Occasionally, gas leaking from an old well can contaminate a nearby water well. An old well might also be a conduit for salt brine from deeper formations to pollute fresh groundwater, or to discharge at the surface. In some cases, oil leaks from abandoned wells, polluting soil and water. In the vicinity of a coal mine, an old well can be a conduit for explosive gas to enter the mine, a serious mine safety problem. Also, where coal mining has occurred, an old well can allow acidic mine water to discharge at the surface.

Hazard Analysis

Over the years, Michigan has experienced periodic upward and downward trends in oil and natural gas production as new reservoirs were discovered and older ones became depleted. However, oil production has been declining at 5-8% per year since 1990. Natural gas production peaked in 1998 and has also begun to indicate a decline in production. As the table and map indicate at the end of this section, a large number of Michigan's oil and natural gas wells are located in the western counties bordering on Lake Michigan, and in the central part of the Lower Peninsula. A thin band of fields also runs from Calhoun County to St. Clair County in the southern Lower Peninsula, and across the northern Lower Peninsula from Manistee County to Presque Isle County. Oil and natural gas wells are scattered around other Lower Peninsula counties, but the Upper Peninsula contains few productive oil and gas wells.

Michigan reaps tremendous economic and social benefits from oil and natural gas production. As with all industrial and commercial activities, along with those benefits come some risks as well. Despite the best efforts of the MDEQ Office of Geological Survey and the drilling companies to minimize oil and natural gas well accidents, it is inevitable that such accidents will occur from time to time. When they do, the affected local communities must be prepared to respond to the accident, institute necessary protective actions, and coordinate with state officials and drilling company emergency crews to effectively manage and recover from the accident. That can best be accomplished through collaborative planning, training, and the exercising of emergency procedures with all potentially involved parties.

Using revenues from oil and gas production taxes, the Michigan Department of Environmental Quality has plugged and restored at least 200 wells. Out of the 62,376 oil and gas wells drilled in Michigan since the 1920s, 26 orphan wells remain to be plugged as of 2012.

It can be difficult to accurately assess incident probabilities for oil and gas wells, but some indications might be gained from existing OSHA data. As related in the section on hazard identification, information about the location of wells is available since permits needed to be issued before they are dug or drilled. If permit sites are near developed or potentially sensitive areas, specific inquiries can then be made with MDEQ to see if the permit actually resulted in a well being created, whether the well is still open or has been capped, and whether open wells have been known to contain hydrogen sulfide. Wells that are open and potentially hazardous should be reconsidered if they are located very near to vulnerable populations or densely developed areas.

Impact on the Public

Those who are in or near a well site during a hazardous event (workers, inspectors, trespassers) may face severe injury or death. Those living in the close vicinity of such a well may potentially be affected by gases and thus require temporary evacuation, but these cases would be extremely rare.

Impact on Public Confidence in State Governance

An event of significant size or impact may provoke a perception that inadequate regulation, authorization, or oversight was maintained by the state.

Impact on Responders

Wells may contain poisonous hydrogen sulfide gas, and thus require responders to use special equipment when nearby. Special search and rescue skills may be needed for victim extraction. In this regard, the oil and gas well hazard may be considered to be similar to a fixed site hazardous materials incident (q.v).

Impact on the Environment

The process of getting oil and natural gas from underground to the end user has the potential to be environmentally destructive. The environmental impacts of oil and natural gas well accidents include the emission of air pollutants, leaks and spills, groundwater contamination, and the effects of well "blowouts." Many of Michigan's oil and gas wells contain extremely poisonous hydrogen sulfide (H_2S) gas. Productive natural gas wells and their associated utilities and access roads also "eat up" natural land, and many areas where gas is found are natural areas where drilling puts industrial facilities into rustic settings.

An unplugged abandoned well (orphan well) can be a hazard to the environment. For example, a rusted-out casing in a gas well can let chemical substances flow underground, and gas leaking from an old well could contaminate a nearby water well. An old well might also be a conduit that allows salt brine from deeper formations to pollute fresh groundwater, or to discharge at the surface. In some cases, oil leaks from abandoned wells may cause the pollution of soil and water.

Michigan's Oil and Gas Wells, by County
(As of 11/2006)

County	Wells	County	Wells	County	Wells
Alcona	**336**	Gratiot	**74**	Missaukee	**463**
Alger	**0**	Hillsdale	**64**	Monroe	**3**
Allegan	**502**	Houghton	**0**	Montcalm	**318**
Alpena	**773**	Huron	**4**	Montmorency	**2,318**
Antrim	**1,180**	Ingham	**105**	Muskegon	**23**
Arenac	**290**	Ionia	**0**	Newaygo	**290**
Baraga	**0**	Iosco	**9**	Oakland	**53**
Barry	**26**	Iron	**0**	Oceana	**64**
Bay	**452**	Isabella	**303**	Ogemaw	**523**
Benzie	**28**	Jackson	**23**	Ontonagon	**0**
Berrien	**0**	Kalamazoo	**0**	Osceola	**626**
Branch	**1**	Kalkaska	**346**	Oscoda	**343**
Calhoun	**120**	Kent	**175**	Otsego	**3,670**
Cass	**70**	Keweenaw	**0**	Ottawa	**175**
Charlevoix	**90**	Lake	**37**	Presque Isle	**44**
Cheboygan	**8**	Lapeer	**61**	Roscommon	**138**
Chippewa	**0**	Leelanau	**0**	Saginaw	**56**
Clare	**914**	Lenawee	**2**	St. Clair	**475**
Clinton	**0**	Livingston	**122**	St. Joseph	**0**
Crawford	**425**	Luce	**0**	Sanilac	**0**
Delta	**1**	Mackinac	**0**	Schoolcraft	**0**
Dickinson	**0**	Macomb	**149**	Shiawassee	**6**
Eaton	**20**	Manistee	**590**	Tuscola	**119**
Emmet	**0**	Marquette	**0**	Van Buren	**23**
Genesee	**27**	Mason	**22**	Washtenaw	**23**
Gladwin	**247**	Mecosta	**330**	Wayne	**33**
Gogebic	**0**	Menominee	**0**	Wexford	**13**
Gd. Traverse	**212**	Midland	**143**	**STATEWIDE**	**18,047**

Source: Michigan Department of Environmental Quality Office of Geological Survey

Michigan's Oil and Gas Fields

Source: Michigan Department of Environmental Quality, Geological Survey Division

II. Technological Hazards
B. Infrastructure Problems

The following list summarizes the broad types of infrastructure problems covered in this section:

1. Infrastructure Failures
2. Energy Emergencies
3. Transportation Accidents (air, rail, highway, marine)

A specific chapter is dedicated to infrastructure failures. Although various industrial hazards involve certain types of infrastructure (e.g. pipelines), and their breakdown, and this entire section of the hazard analysis relates to other types of infrastructure, the chapter specifically called infrastructure failures focuses upon interruptions in the provision of critical life-sustaining infrastructure, such as electricity and water supplies. As reported in a 2009 study by the National Academy of Sciences, an electrical blackout "has the potential to affect virtually all sectors of society: communications, transportation, banking and finance, commerce, manufacturing, energy, government, education, health care, public safety, emergency services, the food and water supply, and sanitation." Moreover, modern technological systems tend to be vulnerable to two trends that have been called "dependency creep" and "risk migration." These can be summarized as follows: "As systems become more complex, and as they grow in size, understanding and oversight become more difficult. Subsystems and dependencies may evolve that escape the close scrutiny of organization operators. Dependencies allow risk present in one part [of the] overall system to 'migrate' to others, with potentially damaging results. GPS and electric power systems have clearly accelerated dependency creep, and consequent risk migration. New technologies, such as nanoscale components, may not be adequately understood in the context of" existing risks to electric power systems.

One of the overarching patterns to be found within technical systems is the tradeoff between efficiency and vulnerability. Reserve capacity within a system can serve as a means for dealing with uncertainties and contingencies. In a competitive market environment, systems operate close to their full capacity and maximum efficiency during times when everything is functioning smoothly and predictably. Under such ideal conditions, "buffers shrink, costs fall, and profits rise," but when something in the operating environment breaks down, as in the case of a disaster or system failure, "unexpected developments perturb the system, finely tuned technical systems become brittle and have trouble operating outside relatively narrow parameters. Vulnerability can be the consequence of increased efficiency." Within this framework, solutions may involve the use of systems designed to include "excess capacity: costs are passed on to users and the society" as part of this operational design, rather than in the form of disaster response efforts after a failure has already occurred. Extra security may come at the expense of decreased efficiency, but the costs can be more fairly spread across the users of the technology, rather than concentrated in disastrous events. This problem of system management operates in an environment of "interdependencies, lack of knowledge, lack of slack, lack of trust, and lack of ways to overcome coordination problems." However, they key to the mitigation of problems in such complex systems can probably be found through addressing each of those conditions, point for point, and together as a whole.

"Systems can quickly become dependent upon new technologies in ways that are unknown and unexpected by both developers and users… vulnerabilities in one part of the broader system have a tendency to spread to other parts of the svstem."

(The information and quotations in the preceding two paragraphs and text box were primarily obtained from "Severe Space Weather Events—Understanding Societal and Economic Impacts: A Workshop Report – Extended Summary," the National Academies Press, Washington DC, 2009.)

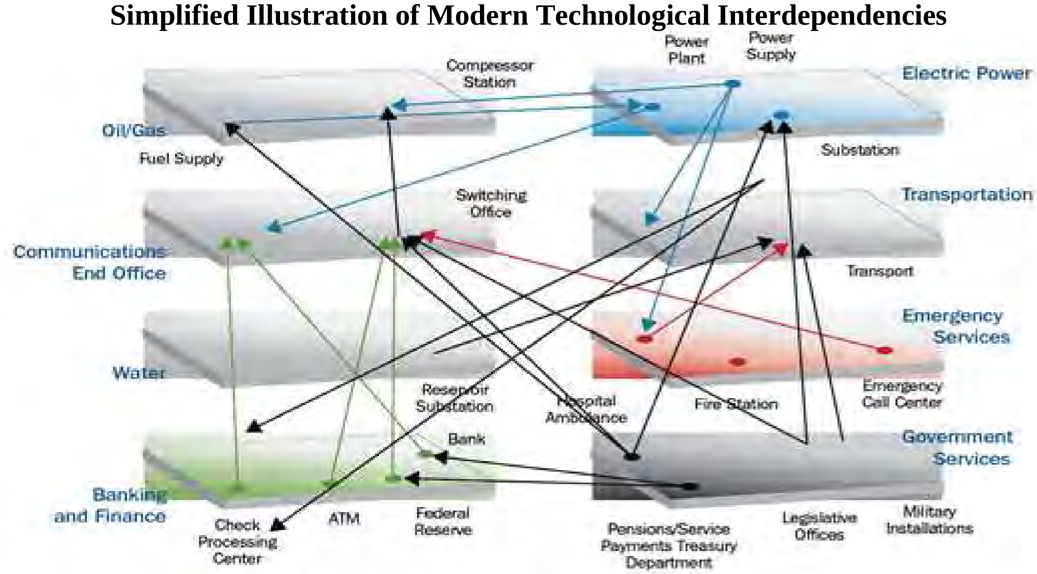
For the 2012 update of the MHA, new consideration has been given to aspects involving the safety and integrity of the built environment—bridges and structures—in addition to the traditional problems that had been covered in previous editions: broken water mains, sewage system breakdowns, and widespread and extended power failures. Energy emergencies are then discussed in a separate section, describing potential vulnerabilities involving breakdowns in the availability of key energy sources that power most of our modern activities—especially gasoline, electricity, natural gas. Finally, the last section deals with major transportation accidents that might involve any of the major modes of our transportation system.

Overlap Between Infrastructure Problems and Other Sections of the Hazard Analysis

Some specialized forms of infrastructure are addressed in other sections of this document—dam failures appear in the Hydrological Hazards section because they can be a direct cause of flooding. Urban flooding is closely related to failures in the drainage infrastructure, and is included in the Hydrological Hazards section, as part of the Riverine Flooding chapter. Many of the ordinary means that enable weather hazards to be regularly endured (winds, storms, and extreme temperatures) involve the provision of adequate means of safely sheltering and transporting people, goods, and services in spite of such weather events. Storm events are a major cause of infrastructure failures, which then expose people more directly to the severe weather extremes that occur in Michigan's climate. Hail, ice, lightning, and strong winds have all caused breakdowns in electrical supply, for example, which in turn may expose persons to extreme cold or heat. Floods are often prevented through the use of drains and pumps and structures, and a breakdown in the functions of such infrastructure can lead to extensive flood damages.

There are cases in which various industrial accidents and technological hazards might arise from failures in the electrical or water supply system, which may be needed for the maintenance and cooling of complicated processes, and without which some disastrous fire, explosion, or release of hazardous materials might occur. Infrastructure failures may lead to energy shortages, a breakdown in vital health care, transportation, and communication services, thus having not only a costly economic impact but also putting lives at stake. Public health emergencies, in particular, may arise from the effects of a breakdown in sanitation infrastructure, or power failures that cause breakdowns in food supply and preservation chains (refrigeration, processing, and storage conditions). In addition to being able to hinder emergency response capabilities, infrastructure failures can also make it more difficult to maintain the effectiveness of law enforcement services, and thus enable criminal activities (e.g. looting) to increase. Certain types of civil disturbance or terrorism might be more likely to arise in circumstances involving lengthy power failures. Many types of catastrophic incidents would be expected to disrupt energy supplies or infrastructure in some way. Some types of hazards (e.g. earthquakes, space weather) are most likely to cause damage through their effects on Michigan's infrastructure, rather than in direct harm to humans. The space weather hazard in particular (addressed in the chapter on Celestial Impacts) needs to gain new recognition, because satellites have now become a type of critical infrastructure.

Simplified Illustration of Modern Technological Interdependencies



Source: Department of Homeland Security, through the National Academies Press.

INFRASTRUCTURE FAILURES

The failure of critical public or private utility infrastructure that results in a temporary loss of essential functions and/or services.

Hazard Description

Michigan's citizens are dependent on public and private utility infrastructure to provide essential life-supporting services such as electric power, heating and air conditioning, water, sewage disposal and treatment, storm drainage, communications, and transportation. When one or more of these independent, yet interrelated systems fail due to disaster or other cause – even for a short period of time – it can have devastating consequences. For example, when power is lost during periods of extreme heat or cold, people can literally die in their homes if immediate mitigation actions are not taken. When the water or wastewater treatment systems in a community are inoperable, serious public health problems can arise that must be addressed immediately to prevent outbreaks of disease. When storm drainage systems fail, due to damage or an overload of capacity, serious flooding can occur.

These are just some examples of the types of infrastructure failures that can occur, and all of these situations can lead to disastrous public health and safety consequences if immediate actions are not taken. Typically, it is the most vulnerable members of society (i.e., the elderly, children, impoverished individuals, and people in poor health) who are the most heavily impacted by an infrastructure failure. If the failure involves more than one system, or is large enough in scope and magnitude, whole communities and possibly even regions can be severely impacted. (Note: Refer to the Dam Failures and Petroleum and Natural Gas Pipeline Accidents sections for more information on those particular types of infrastructure failures.)

Hazard Analysis

Infrastructure failures can affect hundreds of thousands of Michiganders when the conditions are "right" for a loss of critical systems. Melted transformers, ruptured pipes, crumbled bridges, and exploded transformers can cause inconvenience or havoc around the nation and the state, depending on the severity of the problem. The risk of infrastructure failure grows each year, as physical and technological infrastructure gets steadily more complex, and the interdependency between various facets of infrastructure (like pipelines, telecommunications lines, and roads) becomes more intertwined. Additionally, more vulnerable and aging infrastructure (rail lines, electrical components, bridges, roads, sewers, etc.) is in need of repair. Because of these reasons, large-scale disruptions in various components of infrastructure are likely. Major disruptions could lead to widespread economic losses, limit security, and altered ways of life.

Infrastructure failures can occur at any time and in any place in the state of Michigan. The metropolitan areas may be the most susceptible to interruptions in infrastructure, due to the additional volume of critical components of transportation, power, water, and telecommunication networks. Residents of these areas are also less likely to have adequate measures to "get through" infrastructure failures with generators, wood, and fireplaces. Economic losses from incapacitated business and industry are great in these areas. In northern regions of the state, there are fewer networks of infrastructure, but greater geographic areas are affected during infrastructure failures. Downed lines or blocked roads affect many more square miles than a similar occurrence around Detroit, but there are far fewer individuals and businesses at risk.

Although Michigan has in place many codes and standards that govern the design, construction and operation of public and private utility infrastructure, these codes and standards are often inadequate to protect the infrastructure from disaster-related damage. In many cases, the codes and standards call for the minimum level of structural integrity and operational performance recommended in accepted engineering practice, when a higher level would result in less disaster damage. Obviously, a balance must be reached between structural integrity, operational reliability, and short- and long-term costs associated with upgrading facility codes and standards.

It is possible to design and operate facilities that are virtually "disaster-proof." However, in many cases it is not economically feasible to do so. Too extensive of increases in integrity and reliability can result in prohibitive increases in cost. It is often too expensive to upgrade infrastructure codes and standards much beyond their current levels. However, in those cases where recurring, severe damage and system down-time occur due to natural or technological hazard events, it makes sense to explore the possibility of enhancing infrastructure design, construction, and operational codes and standards. The State of Michigan, in concert with public and private utility providers, is in the beginning phases of doing so through its statewide hazard mitigation efforts.

As Michigan's public and private utility infrastructure systems continue to age, infrastructure disasters will undoubtedly become more common. Because many of these systems were developed decades ago, the costs of repairing and replacing aging sections and/or components have greatly increased. As a result, many communities cannot afford to do the maintenance work necessary to keep the system in ideal operational mode. Increasing demands on the systems also lead to increased deterioration, and many components have far exceeded their useful service life. This creates a situation of increasing risk from infrastructure-related disasters, either as a primary event, or as a secondary event from floods, windstorms, snow and ice storms, or other natural or technological hazards. When those disasters do occur, they cause great inconvenience to the affected population and they can also create severe public health and safety concerns. Some urban deterioration includes missing manhole covers, sewer grates, chain link fences, and the occasional disappearance of signs from city streets. This type of issue is found more often in blighted neighborhoods. Cities already lacking in funds are forced to spend time and resources to mark the exposed manholes and sewers with construction barriers before they cause harm to vehicles and pedestrians. Workers also are forced to bolt down the covers and grates of cities' metal coverings.

The national economic downturn that began in 2007 has affected Michigan as much as any other state in the country, having the highest unemployment rate in the nation for many consecutive quarters. There will be less tax revenue, due to people leaving the state, the loss of jobs (particularly within the auto industry), and declines in property values, risking a loss of funding for construction/repairs. Michigan roads also suffer because of the fixed per-gallon gas tax (used to match federal funding and pay for road work) which stays constant, even when the costs of fuel and materials increase. Gas tax, diesel fuel tax, and vehicle registration fees collected in 2008 were the same as the amount collected in 1998. The effects of inflation contribute to a substantial reduction in the amount of (real) funds available for repairs. The 1946 to 1964 baby boom age cohort (defined by the United States Census) is currently approaching retirement age, or has already retired, and many may move to the southern United States for warmer weather, newer infrastructure, etc. which further threatens state tax revenue levels.

According to the Michigan Asset Management Council, the condition of 10,000 miles of Michigan's federal aid eligible roads went from either "good" or "fair" to "poor" between 2004 and 2007. According to the US Census Bureau, Michigan has been ranked in the bottom ten of all states for over 40 years in its level of funding. After a decade of stagnant revenues in road funding, the Michigan Department of Transportation (MDOT) showed an additional 15 percent decline in funding between 2008 and 2011. Another challenge for Michigan's roads and bridges is the annual winter freeze and thaw cycle that causes a continual breakdown of road and bridge surfaces. According to the July 2008 report by the Citizens Advisory Committee on Transportation Funding, Michigan's roads and bridges will require an estimated annual investment of $6.1 billion, which is nearly two times the current funding level, for basic improvements to its road and bridge system.

Transportation Funding Task Force (TF2)

The Transportation Funding Task Force was created in response to Public Act 221 of 2007 (P.A. 221 or Act 221), legislation which passed both the Michigan Senate and House of Representatives with a bipartisan majority and was signed into law in December 2007. The purpose of the Task Force, as defined by P.A. 221, is to "review the adequacy of surface transportation and aeronautics service provision and finance" in Michigan, review strategies for maximizing the returns on transportation investment, and evaluate the potential of alternative strategies to replace or supplement transportation taxes and fees. A major and consistent focus of the group has been the need to stimulate economic activity and enhance personal mobility.

What the Task Force ultimately determined was that Michigan is approaching a crisis of infrastructure funding caused by the steady erosion of purchasing power, continued inflation in materials costs, and a decline in fuel-tax revenues due to spikes in gas prices, reduced travel, and a slowed economy. The decline in revenues, and a corresponding increase in demand for travel alternatives, has exposed the structural problems within the current mechanisms for transportation finance. For the past several years, the transportation revenue stream has been enhanced with bond revenues to provide a more robust level of investment. As a result, Michigan has made progress, particularly in improving the condition of the most highly used highways and bridges, but that bonding cannot continue without additional revenue.

Based on the information at their disposal, the Task Force could only conclude that much more investment in transportation is absolutely necessary. The Task Force learned that transportation agencies have been relentlessly vigilant in stretching their shrinking revenue. Their efforts may go unnoticed, because cost-cutting measures are designed not to disrupt service or impose on customers. Given the current state of the national economy, there is no guarantee that the federal government will come to Michigan's transportation rescue. Even if they did, Michigan is not in a position to take advantage of new federal funding. 2008 was the last year Michigan had enough state and local matching funds to claim all the federal transportation funding made available to the state. Some local agencies are already unable to make use of all federal transportation funding. In 2010 this became true across all transportation modes. Michigan must increase investment in transportation or past investment will be put at risk, and necessary infrastructure and transportation services will deteriorate.

The National Surface Transportation Policy and Revenue Study Committee recommended that investment in transportation by all levels of government should be at least $225 billion per year, an increase of 161 percent compared to national capital investment today of $86 billion. Michigan may lose up to $1 billion in federal funds each year, if transportation agencies do not have enough revenue to provide the required matching funds. The condition of Michigan's infrastructure would deteriorate, with 30 percent of Michigan roads predicted to decline into poor or fair condition during the next decade. The condition of airport pavement will also decline, with the average airport pavement already needing rehabilitation as of 2012, and crucial aviation safety programs threatened with termination or reduction in scope. Existing local transit services and intercity passenger rail services will be reduced, and intercity bus service to rural areas might be eliminated.

Restoring Michigan's investment in transportation has the potential to accomplish valuable and much needed changes. According the referenced study, the "good" level of investment was predicted to sustain 126,000 Michigan jobs, attract new businesses, and open new global markets for Michigan products and services. It will yield roughly $41 billion in other economic benefits for all sectors of the Michigan economy. For highways, roads and bridges, "good" investment will ensure that the most frequently used roads and bridges remain largely in good condition. For passenger transportation, a "good" investment level will allow transit agencies to begin replacing aging buses with greener, more fuel-efficient vehicles. It is estimated that congestion, poor pavement conditions, and crashes cost Michigan drivers and truckers $7 billion annually in wasted fuel, lost time, vehicle maintenance costs, medical costs, lost productivity, and property damage. Based on economic analysis conducted by the University of Michigan, the Task Force estimates that investment at the "good" level would provide an average Michigan household with an additional $2,000 per year in increased personal income and savings through reduced travel time and vehicle maintenance, and increased safety.

Two recent major engineering studies provide a glimpse of the extent of the infrastructure repair and rebuilding effort required just for Michigan to keep up with current and anticipated demand. The first study, completed by the American Society of Civil Engineers (ASCE) in 2009, found the results listed below.

Michigan's Top Three Infrastructure Concerns as of September 2008

1) Roads
2) Wastewater Infrastructure
3) Bridges

Key Infrastructure Facts

- 38% of Michigan's roads are in poor or mediocre condition, rated the 3rd worst state in the United States.
- In 2005, 39% of Michigan's urban highways were congested, compared to 23% in 2000.
- Michigan Department of Transportation will have a 15% decline in funding between 2008 and 2011.
- Michigan has the 8th worst road system in the nation, based on overall performance.
- Michigan is 6th in the nation in the total cost of road miles needed.
- A total of 23,000 road lane miles will need to be repaired or replaced by 2015, while expected funding will pay for only 876 lane miles, just 4% of what is needed.
- 25% of Michigan's bridges are structurally deficient or functionally obsolete.
- By 2030, unless additional roadway capacity is added, rush hour travel in major urban areas will take up to 50% longer to complete in Michigan.
- Driving on crumbling roads costs Michigan motorists a total of $2.6 billion per year.
- An additional 30% of Michigan roads will decline to fair or poor condition over the next decade.
- Under current funding mechanisms, Michigan stands to lose nearly $1 billion in federal funds each year, because its transportation agencies will not have enough revenue to provide the required matching funds.
- Michigan's drinking water infrastructure needs $11.3 billion over the next 20 years.
- Michigan's wastewater infrastructure needs $6 billion over the next 20 years.
- Michigan Department of Environmental Quality estimates that less than 40% of the State's stormwater infrastructure has even been reviewed for its impact on water quality.
- 52% of Michigan's schools have at least one inadequate building feature.
- There are 84 high hazard dams in Michigan. A high hazard dam is defined as a dam whose failure would cause a loss of life or significant property damage.
- A significant portion of the state's primary water distribution system is nearly 100 years old, with 80% of the city of Detroit's piping system having been installed before 1940.
- In 2007 alone, 26 billion gallons of raw or partially treated sewage spilled into surface waters in the state of Michigan, and 23 billion gallons, or 88% of the state total of sewage spilled into surface waters, were located in Detroit.

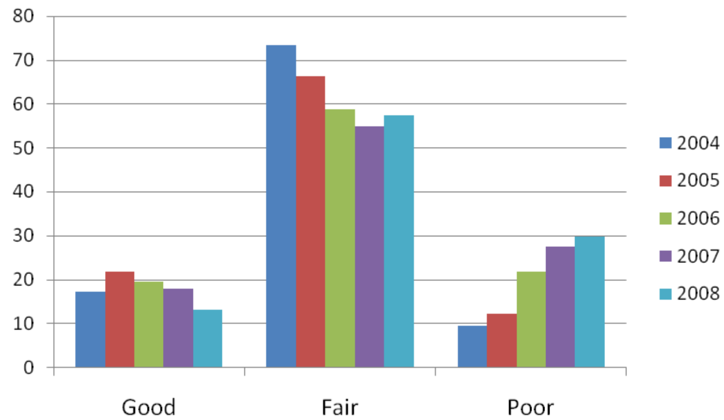
The ASCE study found a common thread nationwide of an increase in demands on public infrastructure without a corresponding increase in funding to perform the necessary maintenance and repairs on facilities, and to rebuild aging or dilapidated facilities.

Another study by the Southeast Michigan Council of Governments (SEMCOG), in 2005, estimated that the costs of replacing aging infrastructure and accommodating new growth in Southeast Michigan will likely top $26 billion over the next three decades, and may go as high as $70 billion when inflation and interest rates are added in. The study estimated that 60-70% of the region's sewers are more than 30 years old and will need extensive repairs or replacement to remain functional. (Nationwide, studies have shown it will cost $1 trillion to fix just the sewer problems alone in the United States over the next two decades.)

The Southeast Michigan Council of Governments (SEMCOG) showed survey data from 2004-2008 that documented a steady decline in the overall pavement condition of the major roads in Southeast Michigan.

Approximately 4,000 miles (10,660 lane miles) of the region's major roads were visually evaluated in 2008. Results of this survey indicate that 13 percent of the road network is in good condition, 57 percent is in fair condition, and 30 percent is in poor condition. SEMCOG also determined that gas tax revenues are declining in both the Federal Highway Trust Fund (HTF) and the Michigan Transportation Fund (MTF) because of higher gas prices causing people to drive less, increases in motor vehicle fuel efficiency and hybrid vehicles, and economic recession.

Road condition trends, 2004-2008, by percent of lane miles

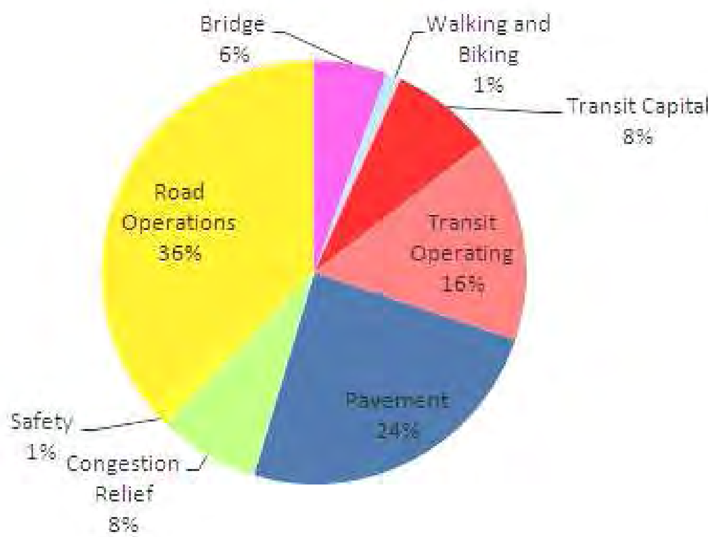


Southeast Michigan Council of Governments (SEMCOG): Direction2035

Direction2035 is the southeast Michigan region's long-range vision for transportation. It demonstrates how the transportation system can lend itself to improving the region overall by contributing to transportation goals, economic recovery, environmental health, community revitalization and stability, and quality of life. It consists of 1,850 transportation projects anticipated over the next 26 years, as well as policies and initiatives to be carried out by both SEMCOG and its partner agencies to keep moving the region in the right direction.

It is estimated that the region would need approximately $2.8 billion per year to address all identified transportation needs; but unfortunately, the region anticipates having only $1.3 billion per year available, a more than a 50 percent shortfall. Direction 2035 shows a need to make sure the region is using its limited funding wisely by addressing the highest priorities first, focusing on preservation of the existing system and implementation of the regional transit vision, and making transportation serve higher regional ideals. Direction 2035 has established the following transportation goals and objectives: enhance accessibility and mobility for all people; enhance accessibility and mobility for freight while maintaining community integrity; strategically improve the transportation infrastructure to enhance community and economic vitality; promote a safe and secure transportation system; and protect the environment, both natural and built.

The mixture of projects is designed to maximize regional goals and improve performance in those areas deemed most important for the region, including bridges, biking and walking facilities, transit, pavement, congestion, and safety. Also, Direction2035 calls for developing a regional transit authority to oversee an advanced transit system, helping local communities become safer and more walkable, coordinating transportation with water and sewer infrastructure needs, and maintaining a high level of security at our borders, ports, and airports. Projects are funded with a variety of federal, state, and local funds.



Michigan is a highly developed state. As such, it is highly dependent on public and private utility systems for the provision of essential life-supporting services, for the movement of people and goods, and for communications and the transmission of information. As a result, the possibility of infrastructure failure must be addressed in every Michigan community through wise system design and community development practices, and through prudent emergency preparedness that takes into account the issues and needs specific to infrastructure failures. In addition, the State of Michigan needs to continue to push for greater system reliability through its infrastructure-related hazard mitigation efforts. Although the problem of infrastructure failure will never be completely eliminated, it can certainly be greatly diminished through proper planning, design, construction, and maintenance practices.

Impact on the Public

Many forms of infrastructure are relied upon by the public, to provide the essential components of a productive modern lifestyle. The supply of fresh water (for drinking, cleaning, washing, cooking, and other uses) may sometimes be interrupted by pipe freezes, breaks, or water main failures. In addition to the need for citizens to find alternative sources of water, there is the potential for certain types of water system failures to allow contaminated water to be delivered and consumed, causing negative public health impacts. Pipe or water main failures may also cause localized damage, erosion, and flooding.

A failure of electric power systems may cause severe problems for persons who rely on medical equipment for their very survival, or for the maintenance of good health. A properly functioning power supply is also essential to maintain the safety of citizens who are working, traveling, attending to domestic matters, or involved in certain types of recreational activities. A sudden power failure may cause (1) traffic lights to stop functioning, (2) traffic patterns to slow dramatically (resulting in traffic jams and delays in emergency response capabilities), (3) interference with important communication networks and needed machinery (including other important infrastructure, such as sewer lift stations and hospital equipment), or (4) sudden darkness when vital operations are taking place or dangerous activities are being performed as a part of people's ordinary occupations and activities. Food storage and safety relies heavily on an ongoing supply of electrical power. A great many community events, business operations, and tourist attractions are similarly reliant upon electrical infrastructure.

Communication systems are vital for emergency response and operations, as well as a great many business functions and personal matters. Failure of communication systems may include (1) an area's mass media (conveying important emergency, health, public awareness, educational, recreational, and economic information), (2) its emergency 9-1-1 systems (allowing residents to quickly call for emergency assistance or to report hazardous conditions), (3) its land-based and/or cellular telephone systems (inhibiting a great number of valuable communications), (4) the internet (an increasingly important means of communicating and running business operations), or (5) specialized radio communication systems (such as those used by police, EMS, and other vital service networks). The impacts include great inconvenience, lost personal and business opportunities, and various degrees of added risk throughout citizens' lives.

Drainage infrastructure failures may cause normally safe areas to become flood-prone, causing all the impacts of that hazard (described previously), but in locations beyond those that are recognized as floodplain and wetland areas. Often, "urban flooding" is the result, in which the drainage capacities of a built-up area are exceeded, and polluted waters back up into streets, basements, yards, parking areas, etc. This causes transportation and access problems, property damages, potential injuries and ill-health, cleaning costs and inconvenience, and the loss of irreplaceable records, artwork, photos and historic documents, and other personal articles. Another type of potential impact is environmental, when sewage processing capabilities cannot be adequately maintained and result in the deposition of untreated sewage into some part of the local environment, such as an area river.

The impacts of transportation infrastructure failures are dealt with in separate subsections elsewhere in this document, under categories such as transportation accidents, pipeline accidents, and hazardous material releases.

Impact on Public Confidence in State Governance

The failure of water systems, including "boil water" advisories or reports of actual or potential contamination, may have a disgruntling effect on some residents' confidence in government, although this would not necessarily be connected with Michigan state government unless it involves inadequate regulations or oversight of local utility providers. (Many water sources are private rather than public.) Some communities have decided to include water contamination issues as a hazard, in their local hazard mitigation plans.

Failure of the electrical power system would likely be similar to that of a water system in its effect, with some citizens being disgruntled and blaming "government," while others are served by private utilities that may be held responsible instead. So long as a power failure is very short and infrequent, most citizens probably have no problem overlooking it.

Failure of transportation systems, on the other hand, is generally considered to be an area of clear governmental responsibility, although the blame for failures will depend upon what kind of failure had taken place. Road maintenance can have local, state, and federal components. Transportation planning tends to involve both local and regional decisions, overseen by state and federal guidelines and regulations. When the safety of major bridges, highways, airports, and railroads comes into question, significantly more weight tends to be placed upon the role of higher-level (e.g. state and federal) agencies than local ones. A bridge collapse like the one that occurred in Minnesota would be expected to result in substantial amounts of dissatisfaction with government, and that event may have increased general concerns about the adequacy of bridges, nationwide. Otherwise, the public is probably more focused upon road conditions and individual driving behavior, rather than larger-scale transportation-related systems and regulatory issues (e.g. airlines, trains, ferries). Please refer to the Transportation Accidents subsection that follows.

Failure of communication systems is not likely to be extensively connected with confidence in government, due to the number of private firms involved, except where these systems are necessary for efficient emergency response and public warning functions during a hazardous situation.

Drainage and sewage infrastructure is most associated with local/county governments, and any dissatisfaction with the capacity of those systems is likely to be directed toward the appropriate agencies at that level, rather than toward the state and federal government. (Also see the subsections on dam failure and flooding, elsewhere in this document.)

Impact on Responders

Many forms of infrastructure are used by responders before, during, and after an emergency event. A good supply of water is needed for firefighting, and for certain types of hazardous materials response operations. Clean water is also used in the provision of emergency medical care, but special reserves of such water may have to be transported to the response sites (or special staging areas, in larger events), if the local water supply has been damaged or found to be insufficient. Water infrastructure failure may severely impede the normal operation of medical facilities, and may also lead to water contamination that poses the risk of public health emergencies.

Electrical power systems are used in most modern activities, and their failure may severely affect responders' notification, warning, and communications systems during an emergency event. Power failures that affect traffic signals can cause traffic jams that interfere with emergency response. Important equipment may need to be run by generator (or other alternative power sources) and thus cause certain types of operations to become more complicated to stage, and less effective. During nighttime events, extra difficulties may be created by the need to find alternative sources of artificial light, and the difficulties of dealing with looters may also be compounded.

Communication systems are vital for emergency operations and response, but are often very difficult to effectively sustain in an organized fashion during emergency events. An inability to convey messages between responders, officials, and the general public may cause preparedness, response, and recovery operations to be severely handicapped. Alternative means of communication are usually less effective and efficient, involving extra time and effort to be expended by responders who could otherwise be engaged in other productive activities.

Failures in drainage infrastructure may cause normally safe areas to become flood-prone, thus potentially causing flood hazards (described earlier) to interfere with responders' effectiveness, safety, and efficiency. The impacts of transportation failures are dealt with in separate subsections in this document (fog, transportation accidents, etc.)

Impact on the Environment

Public and private utility infrastructure failures can negatively impact the environment, as with wastewater collection and treatment facilities discharging various pollutants, contaminants, and raw sewage into the natural environment. Surface water and groundwater discharge facilities can negatively harm the environment with suspended soil sediments, dissolved chemical substances, or biological material, for example. Sewage disposal systems can back up or overflow, causing basement flooding. When sewage processing capabilities cannot be adequately maintained, it may result in the deposition of untreated sewage into some part of the local environment, such as an area river. Pollutants can lead to the poisoning of aquatic wildlife or the creation of vast dead zones, in receiving lakes and waters where there isn't enough oxygen for marine life to survive.

County and watershed drainage systems, and water conveyance and treatment systems, range from small agricultural drains to massive urban storm and sanitary sewer systems. These can contaminate the environment in the event of an infrastructure failure. Detention and retention basins, dams, flood pumps, irrigation diversions, and erosion control structures are also part of the infrastructure. These facilities vary from rural open channels, with drainage areas of several hundred acres, to large river systems with drainage areas of several hundred square miles.

Electric power and telecommunication facilities and systems can have environmental impacts stemming from tree trimming and clearance, the installation and maintenance of overhead lines, or when placing new distribution systems underground.

ENERGY EMERGENCIES

An actual or potential shortage of gasoline, electrical power, natural gas, fuel oil, or propane—of sufficient magnitude and duration to potentially threaten public health and safety, and/or economic and social stability.

Hazard Description

An adequate energy supply is critical to Michigan's (and the nation's) economic and social well-being. The American economy and lifestyle are dependent on an uninterrupted, reliable, and relatively inexpensive supply of energy that includes gasoline to fuel vehicles, and electricity, natural gas, fuel oil, and propane to operate homes, businesses, and public buildings. Energy emergencies became a serious national issue in the 1970s, when two major "energy crises" exposed America's increasing vulnerability to long term energy disruptions. Americans have always dealt with short term energy disruptions caused by severe weather damage (i.e., downed power lines and poles), broken natural gas and fuel pipelines, and shortages caused by the inability of the energy market to adequately respond to consumer demand and meet needed production levels. However, the Oil Embargo of 1973-74, the natural gas shortage of 1976-77, the 1979 major price increases in oil resulting from the Iranian Revolution, the Gulf War in 1991 (after Iraq invaded Kuwait and destroyed many of its oil fields), and the aftermath of the September 11, 2001 terrorist attacks all forced the country to recognize its vulnerability to energy disruptions. That vulnerability was again exposed during the Great Blackout of 2003, when about 50 million electric customers in the northeast United States lost power due to a power grid malfunction. The oil price increases during 2007 and 2008 pushed American gasoline prices to over $4 a gallon and caused major economic and energy related issues as well.

There are three types of energy emergencies. The first and most frequent type of energy emergency involves physical damages to energy production or distribution facilities, caused by severe storms, tornadoes, floods, earthquakes, or sabotage. Michigan has experienced a number of these short-term energy disruptions in recent history, mostly due to high winds associated with severe thunderstorms, or damage caused by ice storms. While there have been only a few incidents of sabotaged energy systems in this country, networks supporting terrorist activity exist throughout the world and the possibility of more frequent incidents in the United States is always present. This category of energy emergency also covers short-term disruptions caused by human error, accidents or equipment failure, such as the power outages that occurred in Detroit in December 1998 and the Summer of 2000, the Wolverine Pipeline Company pipeline rupture in Jackson County in June 2000, the Mackinac Island power failure in July 2000, and the Great Blackout of 2003 that affected over 50 million energy customers. (Refer to the Infrastructure Failures, Pipeline Accidents, Severe Winds, and Ice/Sleet Storms sections of this document for additional information on short-term energy emergencies caused by weather, accidents, and equipment failure.)

The second type of energy emergency involves a sharp, sudden escalation in energy prices, usually resulting from a curtailment of oil supplies. Michigan experienced this type of energy emergency in the 1970s, due to events in the world oil market, and in 1990, following Iraq's invasion of Kuwait. The winter of 2000/2001 saw a sharp spike in natural gas costs, due to reduced availability. However, many Michigan customers were unaffected, due to a price freeze on Michigan's major gas utilities. When oil reserves in Louisiana were blocked during Hurricane Katrina (August 2005), the effects were felt in Michigan and the Governor issued a State of Energy Emergency due to a gasoline shortage. Since 2001, energy costs for the average U.S. household have more than doubled, and sharply escalating gasoline prices have again strained the budgets of lower and middle class families. The summer of 2008 had the highest oil prices on record, following a dramatic rise in prices from 2007 to 2008, and gasoline prices peaked at more than $4 per gallon. This contributed to the economic downtown beginning in 2007, as well as a move toward more fuel-efficient vehicles.

The third type of energy emergency is a sudden surge in energy demand caused by a national security emergency involving mobilization of U.S. defense forces. National defense, in a time of crisis, will demand an increase in energy. Although the regulated natural gas and electric utilities have approved state and federal priority allocation systems that are in place, regulatory changes to introduce competition into natural gas and electric markets have not fully addressed how such shortages might be managed once these markets are fully opened.

Michigan uses coal, nuclear power, natural gas, renewable power, petroleum, and hydroelectric power for energy. The following table describes the usage of each type in Michigan, and compared to the rest of the United States.

Types of Energy Used: Michigan vs. U.S

Type	Michigan	U.S.
Coal	62.6%	51.0%
Nuclear	23.3%	20.1%
Natural Gas	10.2%	17.2%
Renewable Power	2.5%	2.1%
Petroleum	0.8%	2.8%
Hydro	0.6%	6.8%

Source: Michigan Public Service Commission

Hazard Analysis

America's early 21st Century energy situation is at a crossroads. Although energy issues came to the forefront in the aftermath of the 1970s "energy crisis," many energy issues still remain to be addressed. There have been tremendous strides in energy efficiency in homes and home appliances, and with automobile fuel efficiency, saving billions of dollars in energy costs, and our dependence on foreign oil imports has been decreasing, now roughly 45% of total oil consumption. World demand for oil is projected to increase 37% over 2006 levels by 2030, according to the 2007 U.S. Energy Information Administration's (EIA) annual report. Cars and trucks are predicted to cause almost 75% of the increase in oil consumption by India and China between 2001 and 2025. Auto sales in China have continued to grow and now match U.S. levels, resulting in part from economic growth rates around 10 percent for many years in a row. Although the Strategic Petroleum Reserve and other mechanisms have been put in place to reduce the negative consequences of another oil embargo or similar supply disruption, the possibility always remains for an event of near-equal magnitude and impact.

Total U.S. energy consumption has increased by more than 28% since the early 1970s – due mostly to relatively healthy economic growth, changes in commuter patterns, and an increase in the use of home and office computers and other electronic devices. In addition, a commuter-oriented lifestyle has also increased in Michigan. However, during that same period, the U.S. share of world energy consumption actually decreased from 31% in the early 1970s to approximately 25% in the late 1990s. In the 1990s, Michigan's total energy consumption grew over 14%. While this growth was slower than overall economic growth in Michigan due to increasing energy efficiency, growing economies have usually required increasing amounts of energy.

On the electric energy front, electric power system restructuring efforts, currently ongoing in Michigan and across the country, may be considered experiments involving increased competition, lower electrical rates, and increased production and reliability. According to the MPSC's Semi-Annual Appraisal of Energy Markets, issued in September 2008, Michigan's peak electrical demand will grow by 1.2% per year for the next 20 years, but this calculation was made before the 2007-2009 recession, which reduced electrical demand. As economic recovery continues, the demand for electricity should rise. This growth requires at least one new power plant by 2015, and at least three more plants built at a similar frequency, if renewable energy mandates and energy conservation measures are not employed. On the natural gas front, increases in the price of natural gas in Michigan and elsewhere, coupled with spot shortages of natural gas, are likely to renew the emphasis on home, commercial, and industrial energy conservation measures for that energy source.

Despite all these efforts, Michigan still remains vulnerable to short-term energy shortages, as was evidenced by the sharp price increases and decreased supply of gasoline caused by the June 2000 pipeline break in Jackson County and Hurricane Katrina in September 2005. Although other factors contributed to the shortages and price increases, the pipeline break again demonstrated our dependence on an uninterrupted energy supply to sustain our economy. The frequent short-term utility outages caused by severe weather, accidents, or equipment failure are another reminder of our dependence on energy in our daily lives. Although we eventually recover from these short-term energy shortages, it often involves considerable inconvenience and expense. The energy shortages faced by California in 2000/2001, in the wake of its electrical deregulation plan, proved that the country is vulnerable to power deficiencies. While California made many mistakes that have not been duplicated in Michigan and elsewhere, its situation again proves how critically important energy is to our national and economic security. In 2003, the Great Northeast Power Blackout provided another example of the vulnerability of our energy supply system in the United States. The late 2000s oil price increases have played a major role in the worst economic recession since the Great Depression, as well as the move for the automakers to build more fuel efficient and electric/hybrid vehicles.

Michigan has an excellent energy emergency planning program through the Michigan Public Service Commission. Many mechanisms have been put in place to reduce the impacts caused by short- and long-term energy disruptions. Indeed, Michigan’s position as a major business, agriculture, educational, tourism, and industrial center requires that we continue to do so. However, even with those efforts, the threat of both short and long-term energy emergencies still exists in Michigan, due to our dependence on large-scale energy distribution systems to provide us with power.

Impact on the Public

Energy emergencies could cause the public, including small business owners and self-employed persons, to experience significant financial impacts from higher prices or limited/curtailed energy supplies. Business and commuting costs would be likely to increase temporarily. Persons with special medical needs may have difficulty traveling or otherwise having those needs met.

Impact on Public Confidence in State Governance

Portions of the public tend to infer government control and efficacy over market-related economic aspects of the situation. That is, many persons are unclear in their knowledge about limitations in the government’s authority, responsibility, and effectiveness in situations that are substantially defined and shaped by a competitive private sector.

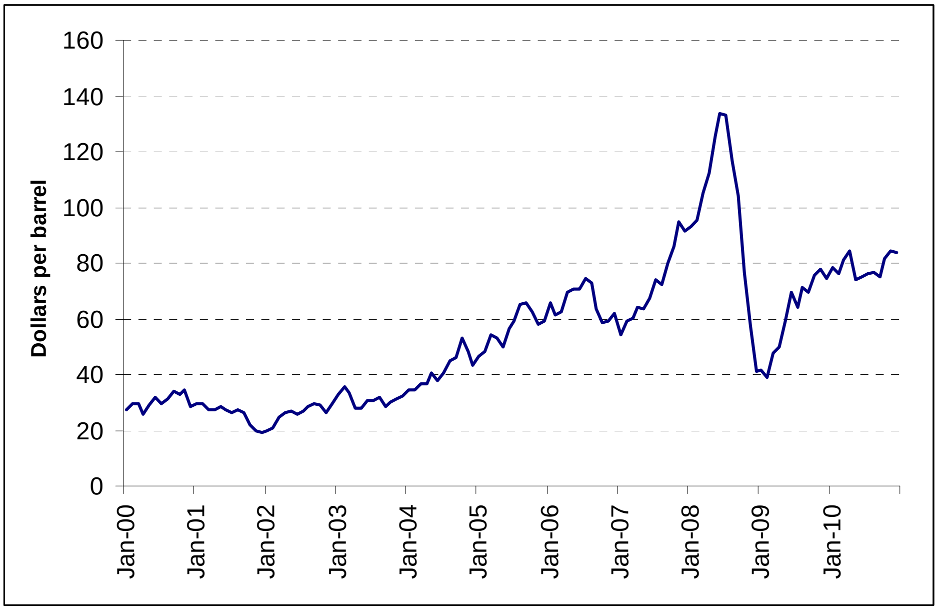
Impact on Responders

Energy emergencies may potentially affect response capabilities, through limitations or shortfalls in resources, and in the amount of expense associated with the use of such resources. A good example could be a shortage of fuel that is needed to operate fire trucks. The budgets of involved agencies may become overburdened. Resources may need to be carefully shared between agencies, or supplemented with special state or federal assistance.

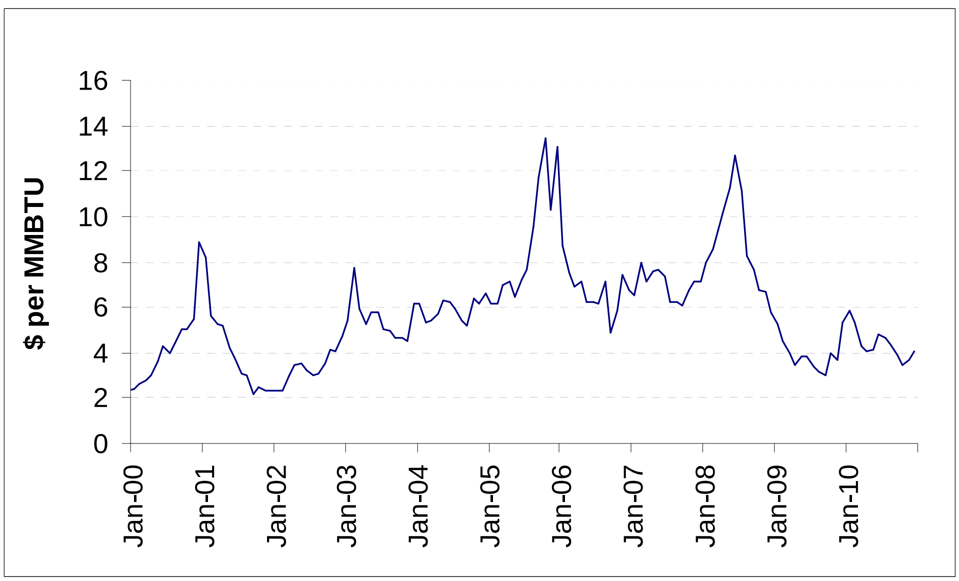
Impact on the Environment

Principal air emissions involve substances that could cause a negative impact on the environment, such as particulate matter, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide. Each of these pollutants varies in its emission rate and potential opportunities for reduction. Fossil fuel consumption is closely linked to greenhouse gas emissions and therefore climate change. The burning of fossil fuels results in the conversion of carbon to carbon dioxide, which contributes to the atmospheric greenhouse effect and global warming. Nuclear power plants generate radioactive by-products that can be harmful to the environment and must therefore be carefully stored in selected locations. The use of hydroelectric dams can also create negative consequences for aquatic wildlife, such as preventing fish from traveling upstream.

West Texas Intermediate Crude Oil Price
January 2000 – December 2010
(U.S. EIA Short Term Energy Outlook)



Natural Gas Prices (Monthly Average, 2000-2010)
(Henry Hub pricing point)



Midwest Energy Consumption Patterns

NOTE: Energy Market Maps, Energy Infrastructure Maps, and Renewable Energy Maps were no longer provided publicly on the Energy Information Administration (EIA) web site, for national security reasons, and thus are not included in this document.

TRANSPORTATION ACCIDENTS

A crash or accident involving an air, land, or water-based commercial passenger carrier.

Hazard Description

Air Transportation Accidents

There are four circumstances that can result in an air transportation accident: 1) an airliner colliding with another aircraft in the air; 2) an airliner crashing while in the cruise phase of a flight due to mechanical problems, sabotage, or other cause; 3) an airliner crashing while in the takeoff or landing phases of a flight; or 4) two or more airliners colliding with one another on the ground during staging or taxi operations. When responding to any of these types of air transportation accidents, emergency personnel may be confronted with a number of problems, including: 1) suppressing fires; 2) rescuing and providing emergency first aid for survivors; 3) establishing mortuary facilities for victims; 4) detecting the presence of explosive, radioactive, or other hazardous materials; and 5) providing for crash site security, crowd and traffic control, and protection of evidence.

Major Land Transportation Accidents

A major land transportation accident in Michigan has the potential to create a local emergency event, or to seriously strain or overwhelm local response and medical services. It could involve a commercial intercity passenger bus, a local public transit bus, a school bus, or an intercity passenger train. Although these modes of land transportation have a good safety record, accidents do occur. Typically, bus accidents are caused by the bus slipping off a roadway in inclement weather or colliding with another vehicle. Intercity passenger train accidents usually involve a collision with a vehicle attempting to cross the railroad tracks before the train arrives at the crossing. Unless the train accident results in a major derailment, serious injuries are usually kept to a minimum. Bus accidents, on the other hand, can be quite serious—especially if the bus has tipped over. Numerous injuries are a very real possibility in those types of situations. Sometimes, "ordinary" highway crashes can be of unusual significance, when they either involve a large number of vehicles or in some manner cause the entire shut-down of a major highway for a significant period of time. (For example, on July 3, 2010, in the City of Flint, a tanker accident and fire caused I-475 to be closed down for many hours, in both directions.)

Michigan's High Speed Rail Program

In 1999, Michigan began the implementation of its High Speed Rail Program. As one of the first projects, train speeds will be increased from 79 miles per hour to over 100 miles per hour on a segment of Amtrak's passenger train route between Detroit and Chicago. The existing rail corridor between Kalamazoo and Grand Beach has been upgraded with improvements to the track, the signal and communication system, and the at-grade crossing warning devices. The state-of-the-art signal and communication system uses advanced technology to communicate between the at-grade crossings and the train, and also uses a Differential Global Positioning (DGP) train location system. These improvements will ensure the highest level of passenger safety. The goal of Michigan's High Speed Rail Program is to reduce travel time on the entire Detroit-to-Chicago rail corridor from approximately six hours to three and one-half hours. Future plans also include an increase in trip frequencies along the corridor, from the current four daily round trips up to eight or possibly even 10 daily round trips.

The fastest passenger trains now operating in the United States are on the Northeast Corridor, traveling between Washington D.C. and New York City at approximately 125 miles per hour. Although this high-speed passenger rail service is relatively new to the United States, similar systems have been in place for quite some time in Europe and Japan, with an outstanding safety record.

From a hazard perspective, the higher-speed train service will provide new challenges for communities on the Detroit-to-Chicago rail corridor to address in their emergency planning and preparedness efforts. To ensure that all communities are adequately prepared, the Federal Railroad Administration (FRA), the Michigan Department of State Police (MSP), the Michigan Department of Transportation (MDOT), and the affected communities' emergency managers have all been working with the Operation Respond Institute to install an emergency information system along the corridor. This system is designed to quickly provide detailed railroad equipment information to emergency responders.

Water Transportation Accidents

A water transportation accident involving one of the 20 commercial marine passenger ferries operating from Michigan's Great Lakes shoreline communities could have significant life safety consequences. Most of these marine ferry services operate on a seasonal basis (typically May through November). Vessel sizes vary, but it is not uncommon for 100-200 passengers or more to be on board many of the ferries at the peak of tourist season. In a typical year, these ferries make thousands of trips across Great Lakes waters. Although the vessels have an excellent safety record and must pass rigorous Coast Guard inspections, the potential for an accident is always present. Accidents in other states or countries involving similar vessels validate the need for rigorous emergency preparedness actions to prevent loss of life in an open water setting such as the Great Lakes. For instance, the Ethan Allen tour boat that capsized in Lake George, New York, in 2005 took the lives of 20 senior citizens.

Hazard Analysis

The one commonality all transportation accidents share, whether air, land, or water-based, is that they can result in mass casualties. Air transportation accidents, in particular, can result in tremendous numbers of deaths and injuries, and major victim identification and crash scene management problems. Water transportation accidents, on the other hand, may require a significant underwater rescue and recovery effort that few local jurisdictions may be equipped or trained to handle. Michigan's fourteen Regional Planning Offices may have already performed an analysis of transportation in a particular area, and should be consulted for more information.

Air Transportation Accidents

Statistics from the NTSB and the airline industry show that the majority (over 75%) of airplane crashes and accidents occur during the takeoff or landing phases of a flight. As a result, developed areas that are adjacent to major airports, and along airport flight paths, are particularly vulnerable to this hazard. Accordingly, the greater the number of landings and takeoffs, the greater the probability of a crash or accident. The challenge for jurisdictions with a passenger air carrier airport is to develop adequate procedures to handle a mass casualty incident that could result from an airplane crash or accident.

The map at the end of this section shows the locations of Michigan's airports. Those airports are classified as transport airports, which are the most highly developed facilities in the state and have paved runways capable of handling jet aircraft. According to MDOT statistics, in 2010 these airports collectively handled over 28.2 million passengers (24.4 million from Detroit Metro alone). Nineteen airports have a greater probability of experiencing a commercial passenger airplane crash or accident, either at the airport or in the immediate vicinity of the airport, since these are the main takeoff and landing spots for such commercial flights.

Land Transportation Accidents

More than 130 certified intercity carriers provide passenger, charter, commuter, and special bus service directly to 220 Michigan communities. Of these carriers, six offer regular route service. Michigan's intercity rail passenger system consists of 568 route miles, along three corridors, serving 22 Michigan communities. (See the maps at the end of this section.)

Although these modes of land transportation have an excellent safety record, the combination of large numbers of passengers, unpredictable weather conditions, potential mechanical problems, and human error always leaves open the potential for a transportation accident involving mass casualties. Such an incident could occur with any of the aforementioned transportation modes, in any of the communities served by these systems. Nationally, an average of about six persons die each year in charter and commuter bus crashes, and 11 school children die in school bus accidents. About 8,500 children are injured each year in school bus crashes. Communities served by any of these systems should plan for a land transportation-related mass casualty incident in their emergency preparedness efforts.

<u>High Speed Rail: Future Challenges</u>

The new high speed rail service between Detroit and Chicago will provide special challenges for communities located along that rail corridor. Although the rail infrastructure will be greatly enhanced and state-of-the-art safety improvements will be instituted, the possibility of a high speed collision between the train and an automobile or truck will still exist. Of special concern are the 360 public and private at-grade crossings in place along the 279 mile corridor. An at-grade crossing always involves the potential for a collision between the train and a vehicle attempting to drive across the tracks.

The U.S. Department of Transportation, through the Federal Railroad Administration, regulates the speed at which trains operate over highway/railroad at-grade crossings. These regulations allow trains to operate at up to 110 miles per hour over highway-railroad at-grade crossings with conventional warning devices only (cross buck signs, side of street and/or overhead flashing lights, and/or gates). At speeds between 110 and 125 miles per hour, positive barriers must be installed at highway-railroad crossings. At speeds above 125 miles per hour, all highways and railroads must be grade separated. These regulations were developed by evaluating the risk of accident damage, using the following philosophy:

- Up to 110 miles per hour: The highway vehicle occupant is most at-risk.
- 110 to 125 miles per hour: Possible injury to the train's occupants, due to rapid deceleration.
- Above 125 miles per hour: Greater likelihood of injury to train occupants, and the train may be derailed.

Amtrak, and high speed train manufacturers, have done computer simulations of accidents that could cause a significant rapid deceleration (similar to a highway vehicle-train accident). These simulations predict only minor injuries to the train's occupants. Based on the passenger train accident history in the state, the FRA regulations, and the computer simulations, the likelihood of a serious passenger rail transportation accident that results in significant casualties appears to be low. However, any collision between a train and a vehicle could result in casualties. Over a 10 year period from 2000 to 2009, there were 787 collisions in Michigan between trains and vehicles. It is only prudent that communities along the rail corridor be prepared to handle a mass casualty passenger rail accident as a worst-case scenario, and to plan for that contingency in their emergency preparedness efforts.

<u>Water Transportation Accidents</u>

A map at the end of this section shows the locations of Michigan's 20 marine passenger ferry services. These services have a good safety record, having never suffered a serious accident that resulted in loss of life or property. Nonetheless, given the large number of trips that are made over Great Lakes waters every year, the possibility of a water transportation accident involving one of these vessels is still a possibility. Furthermore, should such an accident occur, the often-turbulent Great Lakes waters, coupled with the potentially large number of passengers on board, could pose tremendous obstacles to carrying out an effective water rescue and recovery operation.

The U.S. Coast Guard, local law enforcement marine safety units, and the ferry operator would provide primary rescue response to a Great Lakes marine passenger ferry accident. These agencies are highly trained and skilled in water rescue operations, but their resources may not be sufficient or their efforts timely enough to save everyone should a fully loaded ferry sink. Even with on-board life saving equipment, some loss of life might be inevitable—especially in inclement weather and/or rough lake waters. In addition, hypothermia is a real concern—even in balmy Great Lakes waters in the middle of summer.

Impact on the Public

Although automobile crashes tragically kill many hundreds of Michigan residents each year, this analysis necessarily focuses on the types of accidents that are large enough in scale to potentially cause an emergency or disaster-level situation. Airplane crashes and train derailments pose the largest problems, with the potential to cause mass casualties and significant local property destruction—especially since these modes of transportation pass through densely populated urban areas. On a smaller scale, but still potentially devastating to smaller or rural areas, would be major highway accidents involving passenger buses that result in heavy casualties, with the potential to overwhelm smaller emergency medical systems in those areas. An event that might go almost unnoticed in a large and wealthy metropolitan area might easily overwhelm the resources of a poor or rural community. In certain cases, power equipment or other infrastructure may be damaged by such accidents, causing additional impacts (please refer to the section on infrastructure failures). Marine accidents have the most direct impact on human life, but may also discourage water-related tourism, if they receive enough negative publicity. Certain types of marine accidents may also involve a release of hazardous or environmentally damaging industrial materials (see hazardous materials section).

Impact on Public Confidence in State Governance

There may be a sense that improper regulation, authorization, or oversight was maintained by the state, following an event of significant size or impact involving mass transit providers such as trains, airplanes, ships, buses, or trolley/monorail systems. In the case of major accidents involving the highway system, there is often a perception that roadway capacities are too limited—either by design, lack of sufficient funding, or the effects of annual construction projects. Some may perceive that greater enforcement of laws and regulations (e.g. motor carrier) might have prevented a major incident from taking place.

Impact on Responders

Routine “fender benders” or personal vehicle accidents are usually handled by law enforcement officers and are not considered to be community-level emergency events (although they may cause traffic jams and delays that impede emergency response). Only when large numbers of vehicles or persons are involved would motor vehicle accidents be considered large-scale events with the need to engage community-wide response efforts. In very small or rural communities, an overturned bus could be considered a major transportation accident, if such an incident caused enough injuries that local emergency medical capabilities could not adequately handle the situation. Thus, in many ways, this sort of incident is an example of a “mass casualty” event that local and state emergency management programs train to handle.

The impact on responders in highway events is usually limited to the risks of being in and around moving traffic streams, and the diversion of limited resources into the handling of a single large incident. Larger-scale and more unusual events involve the crashing or breakdown of large air, rail, or marine transportation vehicles. A bridge or tunnel collapse, or huge interstate pileup involving dozens of vehicles, may also cause an emergency-level event to occur. In the case of large plane crashes or train derailments, responders may be exposed to fires and hazardous materials, and may encounter problems with looters. In cases involving marine transportation accidents, special rescue operations may occur under perilous weather and lake conditions, in a time-sensitive effort to rescue persons stranded in (usually chilly or freezing) lake waters before they drown or suffer harmful effects from hypothermia or exposure. In all major transportation incidents, which take place in the outdoors, responders will be exposed to the elements and may be plagued by extreme temperatures, hail, winds, or lightning for extended periods of time, when managing these events. (Each of these hazards is described more fully in other subsections of this document.)

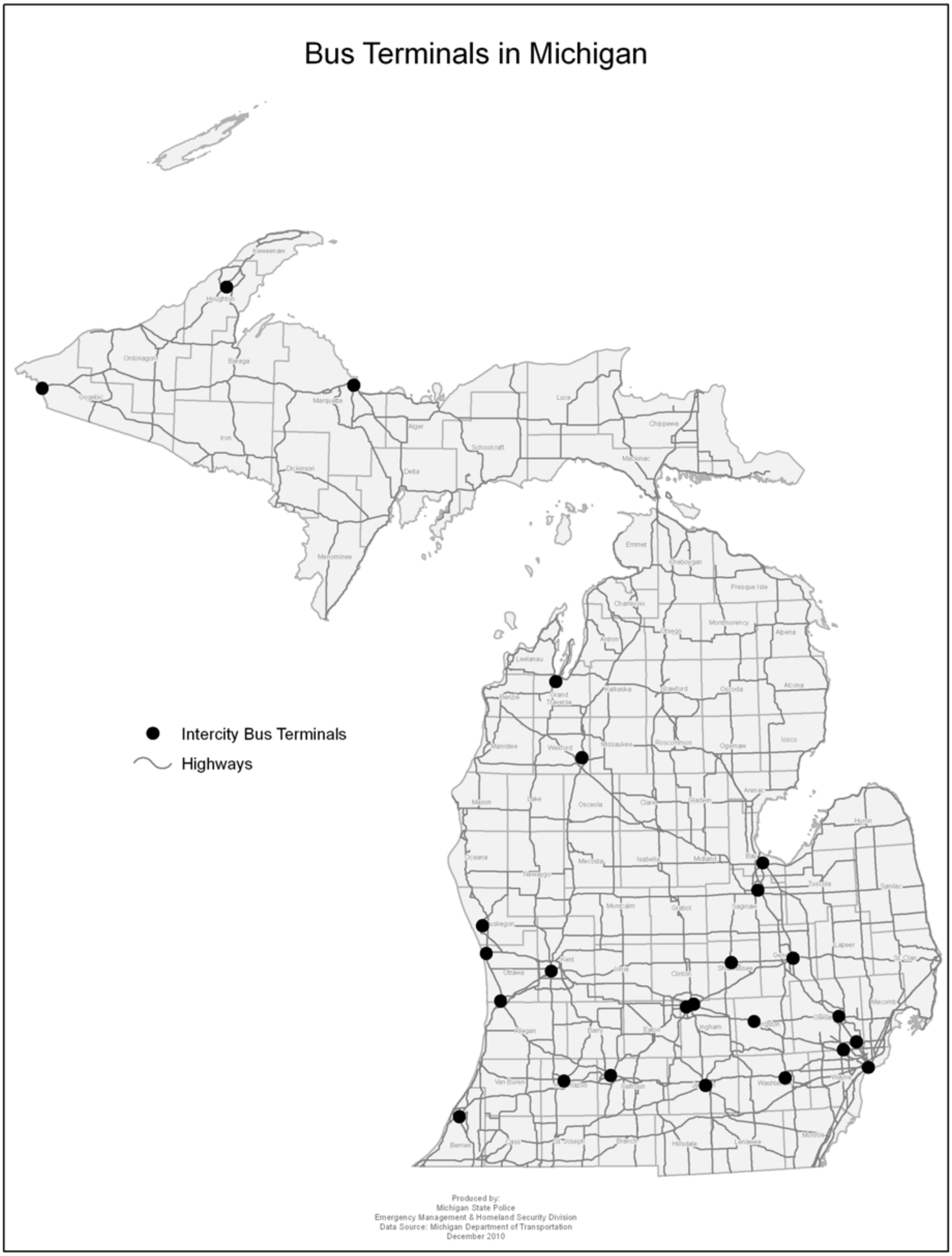
Impact on the Environment

Transportation accidents on land, in air, or in water may impact the environment if toxins or chemicals are released. The burning of petroleum, in an accident that involves an explosion, will quickly release sulfur dioxide, oxidized nitrates, and carbon monoxide into the air. These gases contribute to climate change, ozone depletion, and acid rain. Accidents involving watercraft may also cause a chemical release to occur. Similarly, an aircraft accident could spread petroleum and debris on land or in water.

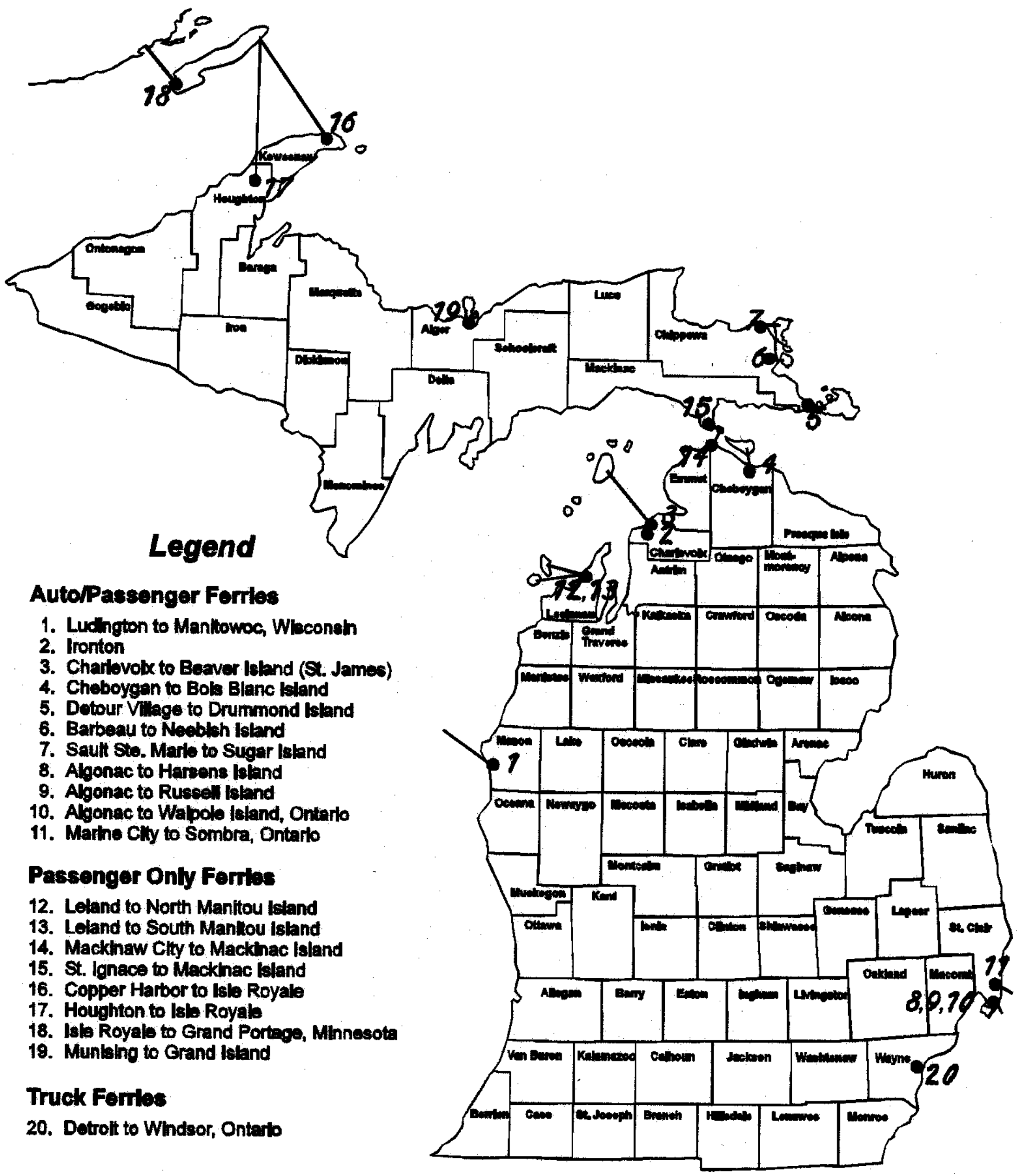
Michigan's Airports

Michigan Intercity Rail Passenger Transportation System

Michigan Intercity Bus Passenger Transportation System



Michigan Marine Passenger Transportation System



Source: MDOT, Bureau of Transportation Planning, Travel Demand & Intermodal Services Section, Modal Services Unit

Principal Ports in Michigan

III. HUMAN-RELATED HAZARDS

The following list summarizes the significant human-related hazards covered in this section:

1. Catastrophic Incidents (National Emergencies)
2. Civil Disturbances
3. Nuclear Attack
4. Public Health Emergencies
5. Terrorism and Similar Criminal Activities

These hazards all tie in with each other in various ways, and by placing them all in the same section of this document, this updated 2012 edition of the Michigan Hazard Analysis intends to make it easier for planners and emergency management personnel to learn about and consider the many aspects of these threats, risks, activities, conditions, and incidents.

The new hazard section, Catastrophic Incidents (National Emergencies), was primarily inspired by some of the states of alert and response activities that Michigan had to adopt in the past decade for incidents that primarily took place outside of its own borders. The main examples were the 9/11/2001 terrorist attacks (and subsequent anthrax incidents and threats), and the Gulf Coast disaster involving Hurricanes Katrina and Rita in 2005. It makes sense to consider, in advance, these types of incidents as well as other types of large-scale disasters that could occur in the future, which require a large-scale national response even though the actual incident itself may occur only within the borders of a few states outside of Michigan's immediate environment. Preparedness, planning, exercising, and mutual aid arrangements are the main "mitigation" activities proposed for this hazard during its initial phase of consideration in this 2012 edition of the Michigan Hazard Analysis. Some catastrophic incidents may involve other types of human-related hazards. Some of the possibilities that led to the addition of this hazard as a new section include recent considerations of a major pandemic, terrorist attack, or nuclear strike—all of which are covered in more detail in subsections herein.

Although civil disturbances are usually handled at the level of local or state governments alone, some types of unrest may be related to broader patterns of criminal activities, or even terrorism. The civil disturbance hazard has been given broader treatment, to shift farther beyond the emphasis on prisons that had been a part of its original concept in earlier state planning documents. Although prison disturbances are still considered a hazard, several additional types of incident have been more extensively discussed and compared. Although consideration was given to a type of civil disturbance that could be called "disruption," it was decided that such a concept was already partially covered by the discussion of catastrophic incidents and other hazards. "Disruption" would have described human collective responses to large-scale catastrophes, such as warfare, widespread conflict, or disasters, that disrupt ordinary lifestyles and force people to cope using relatively spontaneous or grassroots activities to provide for social needs. There were few examples that were clearly relevant to today's contemporary circumstances, however, except for those already suggested in other sections, and so the idea was not included as a full consideration within this edition. Consideration was also given to economic and criminal problems, but these were not considered relevant enough to an emergency management planning perspective to include. Emergency management deals with recognized disasters and emergency events, rather than social problems more broadly, and therefore throughout this plan decisions had to be made about where the line might be drawn between specific disaster/emergency events and circumstances that are ongoing social, economic, political, and environmental issues in any society.

Although warfare and other types of conventional military attack were not given specific treatment here, the nuclear attack hazard has been retained, yet almost entirely rewritten to reflect post-Cold War geopolitical circumstances. In addition, a greater connection is now exhibited between the nuclear attack hazard and that of terrorism. Public health emergencies have taken on new importance recently, with the rise in concern about global pandemic illnesses. Travel is so rapid and widespread today that quickly detecting and containing outbreaks of serious, even lethal, contagious diseases has been considered necessary and given higher priority by numerous levels of government, and their partnering agencies. Terrorism is one of the potential causes of widespread threats to public health, as well as nuclear attack and certain types of civil disturbances. The terrorism and similar criminal activities section has also been almost entirely rewritten in this 2012 edition of the Michigan Hazard Analysis, to reflect more recent knowledge about the involved topics. In many cases, it may not be immediately clear whether an incident was motivated by political causes, some other form of protest, criminal enterprises, or personal neurosis. A bomb blast event, for example, may have its origin in a hostile terrorist group, a riotous uprising, a murderous act involving organized crime, or the misguided activity of a mentally unbalanced individual. The act itself, and its effects, might constitute an emergency event regardless of the reasons that caused it to happen. In many cases, the determination of who organized such a bombing, and why, may take weeks of subsequent investigation, and may place the event (after the fact) within different hazard classifications, as they have been presented here. For that reason, it is recommended that the human-related hazards be studied together. At the very least, the civil disturbances and terrorism sections should be studied together, and those who are interested in terrorism should also give consideration to the nuclear attack and public health emergencies that can be caused by terrorist attacks.

During certain historical times and places, it might seem to make sense to include large-scale or widespread criminal activities as a type of hazard in itself. Gang warfare can certainly impose a serious toll upon the health and safety of an area, for example, and such enterprises may be used to raise funds for international terrorist activities. At this time, however, it was decided not to include large-scale organized crime as a specific type of hazard in this analysis, except where the purpose of that crime relates to terrorist activities (rather than the profit-oriented activities that are typical of criminal enterprises). Organized crime exists to try to make its participants wealthy, but terrorism aims to cause specifically destructive effects upon society—usually without any expectation or desire for personal profit or wealth or the part of the perpetrator(s). Dedicated law enforcement resources already exist specifically to combat crime of various types, and these ongoing activities usually do not involve emergency management personnel, declarations of disaster, or the type of public involvement and planning used for the mitigation of natural disasters and other-types of potentially large-scale hazards.

Overlap Between Human-Related Hazards and Other Sections of the Hazard Analysis

Terrorist and nuclear attack events can cause widespread infrastructure failures, hazardous materials incidents, transportation accidents, energy emergencies, nuclear power plant emergencies, structural fires, and oil/gas pipeline failures. Therefore, there is extensive overlap with the Technological Hazard sections. It is also possible that terrorist and nuclear attack events may cause dam failures and flooding, as well as wildfire events—two of the hazards that are addressed in Natural Hazards sections in this document.

In a reverse direction of causality, various natural and technological hazards may be expected to cause significant public health concerns. These include weather hazards such as extreme temperatures, hydrological hazards such as flooding and drought (both of which may affect the quality of drinking water in an area, as well as exacerbate the risks of contagious illness and food quality/contamination), and the ecological hazard of wildfires. Any disaster that can cause widespread homelessness and power failures may have a serious impact upon public health. Similarly, various types of incidents involving hazardous materials (including radiological incidents) may affect public health. Disasters with an extensive impact upon the environment may involve contamination that is a threat to public health.

With regard to natural or technological events that may cause violent incidents, the most probable circumstances may involve civil disturbances in reaction to other emergency or disaster circumstances, if overwhelming to or poorly handled by responders or government agencies. There are very few historical records of such incidents escalating to the point of a civil disturbance emergency in Michigan, and even then, the connection between natural and technological hazards and such disturbances has tended to be indirect and open to alternative interpretations. Most civil disturbance events have been rooted in other human circumstances. One of the exceptions involves the potential for widespread infrastructure failures to develop into circumstances in which local citizens and police must take extra precautions against criminal activity such as looting. With a large enough event or over a long period of time, such conflicts may cause certain types of civil disturbances to occur. Another important scenario involves the handling of prisoners in correctional facilities, during incidents of any cause that may require the area's evacuation, or special in-place sheltering (as from a tornado or a severe hazardous materials incident). It is important for correctional facilities to have planned for how their institutions could handle such emergency events—providing an appropriate level of protection for the incarcerated while also maintaining the needed level of order, control, and surveillance over them.

CATASTROPHIC INCIDENTS
(National Emergencies)

A large-scale event that has severe effects upon large numbers of persons, across a wide area, and immediately overwhelms State, tribal, and local response capabilities. Such incidents are likely to require coordination activities from many states, including Michigan, even if the event took place in a distant location.

Introduction
Since 2000, the nation has been affected by disastrous events that have caused various states, including Michigan, to undertake significant actions to respond to, assist, or help accommodate the impact of events that took place well outside of their borders. Mutual aid agreements are in place between states to provide one another with supplemental resources and capabilities to respond to and recover from a disastrous event. It is also possible that certain types of events outside of U.S. territory may require coordinated response, as well.

The National Response Framework (aka Federal Response Plan) involves a recognition of, and reaction to, events of national significance. This was observed during the terrorist events of September 11, 2001—along with the federal government, all states went into a mode of heightened alert and exchanged various information and resources in a coordinated manner. More recently, Hurricanes Katrina and Rita caused such disruption in the southern states that nation-wide assistance and coordination was needed. Not only were resources deployed to the disaster areas themselves, but distant states such as Michigan also needed to accommodate large numbers of evacuees who were temporarily displaced from their homes, jobs, businesses, and even families. Some evacuees even chose to permanently change their residence to new homes in other communities across the U.S.

In some disaster scenarios, even if Michigan experiences some direct impacts, it may turn out that much greater effects in other states or nations (e.g. Canada) may require extensive additional actions to be taken by Michigan government and personnel. In recognition of these extra tasks, a Catastrophic Incident hazard is now identified, in addition to the many hazards that are known to potentially have a direct impact within Michigan.

FEMA has (in its Catastrophic Incident Annex of November 2008) defined the nature of the catastrophic disaster situation. It "will result in large numbers of casualties and/or displaced persons, possibly in the tens to hundreds of thousands…. The nature and scope of a catastrophic incident will immediately overwhelm State, tribal, and local response capabilities and require immediate Federal support…. A catastrophic incident will have significant international dimensions, including impacts on the health and welfare of border community populations, cross-border trade, transit, law enforcement coordination, and others."

Special aspects that may be part of catastrophic incidents include the possibility of occurrence without warning, the occurrence of multiple incidents over a wide-ranging area (or even without any clearly defined incident site), may involve large-scale evacuations (whether organized or self-directed), may cause widespread homelessness and displacement (either temporary or permanent), may overwhelm existing health-care systems, and may produce severe environmental impacts that exceed governmental abilities to achieve a timely recovery.

Catastrophic Incident Scenarios
There are a great many possible situations that can result in nationwide activation of mutual aid and other response and recovery mechanisms, so it is not intended that this section will provide an exhaustive list of everything that may happen. This subsection does, however, provide about ten "scenarios" designed to suggest the types of situations that may be considered a catastrophic incident. It is hoped that this will assist planners and responders in further developing their mutual aid arrangements at all levels, to accommodate a wider variety of needs, and to suggest some possible repercussions that may not have previously been considered in existing planning and exercise scenarios.

Major Hazardous Materials Incidents
An event of sufficient magnitude (like the Chernobyl nuclear power plant disaster or Bhopal hazardous materials release) may warrant a response even if located in another country. A good example for Michigan could involve a major "Chemical Valley" incident in Sarnia, Ontario. It has been reported that this one industrial area (located just across the St. Clair River from the City of Port Huron) involves 40% of Canada's chemicals, including the largest liquid natural gas storage facility in North America. Canada has national, provincial, and local regulatory frameworks that have allowed the "Chemical Valley" area to function effectively for many years, but if some sort of unlikely circumstance or deliberate terrorist activity causes a major problem in the area, its potential impacts could be great.

Energy Emergencies and "Great Blackouts"
Michigan does not need to be directly involved in a major event for it to have significant consequences that warrant the provision of State-level assistance or response. One of the most notable scenarios involves the possibility of an energy emergency. It has been reported that 28 pipelines run between the cities of Port Huron, MI and Sarnia, Ontario. These pipelines reportedly support 85% of the heating that Michigan and Ontario residents require to maintain a normal and productive lifestyle. Serious disruptions in energy supply (along with higher costs for available product) may result from a disaster that disrupts these supply lines. Such a circumstance would not need to occur specifically in Michigan in order to cause serious problems here.

The loss of electrical power for a long enough time would be expected to cause a certain proportion of affected persons to undergo serious hardships—particularly those who have special medical needs or disabilities. Shortages of certain types of goods or services may affect Michigan, even if the blackout itself is not directly experienced here. Similarly, gaps in communication, information, or service networks may have an effect well beyond the actual area that lacks electrical power.

A "Supervolcano" Event
A volcanic eruption of sufficient size could cause an incident of national significance. In 1980, the eruption of Mount St. Helens (in the State of Washington) caused about 540 million tons of volcanic ash to be scattered over an area of some 22,000 square miles. A massive eruption of a "supervolcano" would cause a much larger area of destruction and emit billions of tons of ash into the air. Several locations have been identified in the western United States where this type of event is possible, even if not especially likely in the near term. It has been calculated that volcanic ash from a "supervolcano" event could be transported through the atmosphere over a much broader area, and that significant quantities could be carried and deposited as far away as Michigan. The size of such an eruption itself would likely be considered to be a catastrophic incident and thus would probably warrant a Michigan response in providing assistance to the more heavily involved western states.

Warfare
Military action has the potential to create a catastrophic incident. The United States is potentially vulnerable to attacks on its own territory, including attacks by military nuclear weapons. Furthermore, war in other parts of the world could have significant impacts on Michigan due to economic repercussions and potentially serious drains on Federal government resources. Because of the interconnectedness of international trade, finance, and communications, harmful effects might be felt from wars fought in distant places. Michigan also is home to an ethnically diverse population and foreign wars can directly impact on the homelands and families of these citizens.

Major Terrorist Attack
Major terrorist attacks could create a catastrophic incident, particularly if those attacks use weapons of mass destruction or are targeted on critical national infrastructure. Large-scale terrorism may create economic and infrastructure damage similar to military attacks. In addition, terrorists usually choose their targets with the goal of creating as much fear and uncertainty as possible. Dealing with a major terrorist attack will require addressing the concerns of frightened and confused citizens. It is worth noting that the details and limits of a terrorist attack

are rarely understood immediately, complicating response efforts. For example, following the 9/11 attacks, confusing reports and uncertainly regarding possible additional targets caused the Federal government to take significant precautionary measures. These included shutting down the national air-travel system and evacuating senior officials. Similar dramatic steps (even if temporary) might be needed in response to future major terrorism events.

Major Earthquakes

Although a major earthquake involving the New Madrid Fault would likely have some effect on the southern portions of Michigan, it is probable that an even greater Michigan effect would stem from the massive damages, casualties, and human needs that would need to be addressed near the earthquake's epicenter (or the earthquakes' epicenters). Another possibility could involve a major earthquake along California's San Andreas Fault line, or at some other at-risk location. If the magnitude of the event is great enough, the incident may rise to the level of a catastrophic incident and thus prompt a significant response by Michigan's government, agencies, and residents.

Celestial Impact

An impact by an asteroid, comet, or meteorite has the potential to be a catastrophic incident if the object has sufficient mass and velocity to cause extensive harm. This may even be true if the impact occurs on the other side of the planet, for there may exist a relationship between celestial impacts and a rise in volcanic and earthquake activity. Approximately once per century, a major impact (over a land mass) has been observed that is of a scale comparable to a nuclear blast. The last two events were seen in Siberia, in 1908, and in the Arabian Peninsula, in 1870. The fear is that since the Earth's population is so much greater now, as is the scale of human settlement, it has become more likely that the next major impact could cause serious casualties and damage. Additional vulnerability stems from the increasing importance of electronic communications that can be affected either by a material impact, or by "space weather." (Please refer to the Celestial Impact section for more information.)

Hurricanes

Although hurricanes have little direct impact on Michigan (except for thunderstorm systems and precipitation that may stem from a distant hurricane), it has recently been seen that a sufficiently damaging event (i.e. New Orleans, Florida, New York, or other coastal states) can necessitate large-scale assistance from all states in the union. Hurricanes have the demonstrated ability to cause a catastrophic incident.

Tsunami Events

Whether it originates from a celestial impact, a seismic event, or a volcanic event, a tsunami has the potential to do severe and widespread damage. A tsunami of sufficient size/velocity has the potential to be a catastrophic incident, resulting in the type of damage and displacement seen in the 2005 Katrina/Rita Hurricane Events.

Pandemics or other Public Health Emergencies

These types of national emergencies may be purely natural in origin, or they may involve intentionally-caused bio-warfare or terrorist events, or some combination of the two. Naturally occurring pandemic influenza caused widespread precautions around the world during 2009. Although the impact of the novel influenza A (H1N1) virus in that case turned out not to be quite as bad as feared, many were still sickened throughout the country and state, and it was particularly challenging for our schools and health providers.

Some public health emergencies may be the secondary result of a damaging disaster or sabotage incident. In the case of the anthrax cases and scares of late 2001, it made sense to have a state of heightened national alert, despite the fact that most reports of "white powder" eventually turned out to be harmless. Despite the number of false reports and hoaxes, the presence of anthrax in the United States' postal system and key government/media offices was very real, and merited substantial prevention and mitigation efforts nationwide. Coming so soon after the September 11 terrorist attacks, there was initial uncertainty about whether the anthrax incidents were part of ongoing terrorist tactics.

Impact on the Public

These impacts primarily involve the diversion or sharing of Michigan resources to assist other states with major emergency events, such as the devastating impact of hurricanes upon the city of New Orleans. A couple of the most significant possibilities include a New Madrid earthquake (see the Earthquake section), the eruption of a super volcano whose ash may affect weather patterns and cause dusty debris to fall over Michigan, a large scale mass mobilization for purposes of warfare or civil defense (which may cause the dedication of various factories, resources, and infrastructure toward defense and emergency response operations), related mass tragedies involving nuclear attack or terrorism (see those sections), or a large-scale celestial impact (also covered in its own section).

Impact on Public Confidence in State Governance

Those national emergencies that arise from natural hazards, such as flooding, tend to evoke sympathy and generous helping behavior throughout the country. If there is a major shortcoming perceived by the public (usually through the media) in the government's role in such disaster, then significant discontent may arise. Hurricanes Katrina and Rita were a case involving this type of perception and discontent, raising questions about government preparedness and response, on more than one level of authority.

In many emergencies of technological origin, whether a major plane crash or a power failure, there is usually a question of the extent to which government regulation should have been able to prevent or minimize the impacts of the event. Similar issues exist with major human-related hazard events, although it is often recognized that in many such events it was not reasonably possible to anticipate exactly when and how things would go wrong. Matters of national security are often given the benefit of the doubt by citizens, although military operations are routinely treated with skepticism by a significant portion of the population. Prolonged military operations that result in casualties are more likely to raise widespread concern about whether the government is acting correctly and responsibly. However, these same cases also involve a rallying of some patriotic groups who approve of the seemingly direct nature of military action, compared to more abstract policy decisions and approaches. In a diverse democracy, it is normal that the government's authority in a particular area will be lauded by some and criticized (or even feared) by others.

Impact on Responders

National Emergency events would call for the coordination of emergency responders (and associated personnel) between states, and even from across the nation or between nations (e.g. Canada, or its Ontario province). The most direct impact of a national emergency upon responders would be dealing with the logistics of interstate mutual aid (or even its international equivalents). In an event such as the 9-11-2001 terrorist events, or the 2005 Hurricane events, numerous response personnel may have to juggle their time, resources, and efforts involving activities that assist other states or jurisdictions with disaster response and recovery, while simultaneously ensuring that their own state's (or local jurisdictions') preparedness and response needs are also adequately cared for. An additional potential impact may arise from events that occur in one's home jurisdiction after various aid has been granted to some other area—various staff, equipment, expertise, and funds may suddenly be needed "back at home" in the midst of complicated and important response or recovery operations abroad. Extra complexity would also be entailed in the tracking of expenses and the paperwork involved in reimbursement procedures, which might ordinarily be used on activities that are of clearer importance to the home jurisdiction's own emergency needs. One of the effects of national emergencies that does have an impact upon a state's own circumstances, even when not directly impacted by the national emergency event itself, is the potential need to deal with evacuees coming from an affected area, who would need food, shelter, and other types of assistance in living their lives under conditions of displacement and even duress. Such evacuees would tend to have numerous financial and material needs, since the emergency event may have caused severe material hardships for them (or at least temporarily denied them access to their homes and wealth). In addition, various disaster and emergency events tend to cause emotional, social, and psychological hardships as well as material and economic ones, since various trauma may have been experienced during the emergency events (including the loss of family and friends). The uncertainties and stresses of relocations, job loss, etc. would often require social and psychological support structures to be sought (and often provided by the host community) in order to restore a degree of security to the evacuees conditions and lifestyle. As a part of long-term recovery, such evacuees would ideally be able to restore their lifestyles to some sort of normalcy, perhaps even including successful relocation back to their original homes and the resumption of their previous, ordinary life circumstances.

Impact on the Environment

Depending upon the type of event under consideration, environmental impacts upon Michigan may vary widely, or may not directly be felt at all. A super-volcanic eruption, even in the Western United States, could deposit large amounts of volcanic ash across the state. Although superficially similar in appearance to a snowfall event, in some ways, such material would not be collected or dissipated as easily as snow. A major earthquake, tsunami, hurricane, meteorite, nuclear, or terrorist event that causes a wave of immigration into the state (even if only on a temporary basis) may require various forms of development and land use that, under the need to provide emergency services to many people, could be environmentally damaging by the inability to speedily undertake such actions in accordance with long-term comprehensive development plans.

CIVIL DISTURBANCES

Collective behavior that results in a significant level of lawbreaking, perceived threat to public order, or disruption of essential functions and quality of life.

Hazard Description

Civil disturbances can be classified within the following four types: (1) acts or demonstrations of protest, (2) hooliganism, (3) riots, or (4) insurrection. Since most of these types of disturbance share similarities with each other, and the classifications presented here are not absolute and mutually exclusive, **it is recommended that this entire section be studied as a whole**. The descriptions that follow, while roughly organized by type of disturbance, provide information of interest in evaluating and understanding all types of civil disturbance, and therefore should not be treated as independent subsections or read in isolation from each other.

The first type, protest, usually contains some level of formal organization or shared discontent that allows goal-oriented activities to be collectively pursued. This first category includes political protests and labor disputes. Many protest actions and demonstrations are orderly, lawful, and peaceful, but some may become threatening, disruptive, and even deliberately malicious (on the part of at least some of those involved either in the protest itself or in reaction to the protest). It is only the latter type of event that should properly be classified as a civil disturbance. The destruction of property, interruption of services, interference with lawful behaviors of ordinary citizens and/or emergency responders, the use of intimidation or civil rights violations, and threats or actual acts of physical violence may all occur during civil disturbance events. Actual Michigan events have included the willful destruction of property and impeded property access during labor strikes, and heated conflicts between opposing participants at political rallies or issue-driven demonstrations. Different risks and forms of disturbance are connected with the nature and perceived importance of the cause, the degree of organization among those who are active in the protest, and the amount of group cohesion among those who are involved.

The second category of civil disturbance, hooliganism, is relatively unorganized and involves individual or collective acts of deviance inspired by the presence of crowds, in which the means (and responsibility) for ordinary levels of social control are perceived to have slackened or broken down. Certain types of events, such as sporting events, "block parties," or concerts, become widely publicized and, in addition to normal citizens who merely seek entertainment, tend to also attract certain types of persons who seek situations in which anonymity, confusion, and a degree of social disorder may allow them to behave in unlawful, victimizing, or unusually expressive ways that would normally be considered unacceptable by most ordinary people. Examples include the disorder that has followed various sporting events and college parties. Although the majority of persons present are ordinary citizens (although many may have some level of intoxication), a minority of persons begins making itself known through unlawful or extreme acts of deviance, and it is from this part of the crowd that the hazard primarily stems. This minority may include persons affected by the use of illegal drugs and alcohol, and may include criminals and persons with mental illnesses (such as antisocial personality disorder) who may either be reacting with extreme hostility to the crowding, noise and disorder, or may have deliberately sought out such crowds and disorder so as to gain opportunities to behave in ways that ordinary circumstances would not allow. Common problems include the widespread destruction of property, numerous types of assault and disorderly conduct, and criminal victimization. It should also be noted that many persons who are normally law-abiding may temporarily behave in unusually aggressive ways during these events, often prompted by an understandably defensive anxiety about the disorder and behavior exhibited by the deviant minority, but also possibly exacerbated by a level of alcoholic intoxication as well as the temptation by some to engage in appealing deviant behaviors that under normal circumstances of social control would not be selected. Many citizens remain law-abiding, but may remain in the area of a civil disturbance either because they live in the area, have activities (including social and recreational ones) that they wish to continue engaging in, have legitimate business to conduct, or because they are curious or concerned and wish to observe or witness the situation as it occurs. The majority of such law-abiding citizens will leave the area in an orderly way when given clear instructions by a legally-recognized authority to do so. There are cases in which hooliganism may become combined with protest, and thus complicate the situation for law enforcement personnel. In some circumstances, elements of protest are added only by a small minority of participants after the disturbances have already begun, but in other circumstances, protest activity may arise out of concerns regarding the extent and nature of pre-emptive law enforcement activities that were intended to prevent a civil disturbance.

The third type, riots, may stem from motivations of protest, but lacks the organization that formal protests include. Although legitimate and peaceful protests may spontaneously form when people gather publicly with the perception that they already share certain values and beliefs, riots tend to involve violent gatherings of persons whose level of shared values and goals is not sufficiently similar to allow their collective concerns or efforts to coalesce in a relatively organized manner. Instead, there tends to be a diffuse sense of shared discontent, but relatively few norms to shape these strivings into clearly coherent action. For example, widespread discontent within a community that is sufficiently cohesive may quickly take on a set of shared leaders and clear organization, such as a march or chant that is clearly in the form of a protest or demonstration, but in an area that doesn't have the same cohesiveness and shared norms and values, a relatively chaotic form of expression may take place instead, involving assaults, intimidation, and unlawfully destructive expressions of discontent, possibly including the victimization of innocent citizens or businesses who have been selected by part of the crowd to function as scapegoats during their expression of discontent. In addition to the sentiments of discontent that may have sparked the initial activities, however, elements of hooliganism may emerge and even come to predominate, as certain persons may attempt to exploit the social disorder for their own individual ends. In other cases, elements of legitimate protest may also form within this type of civil disturbance, and pockets of organized protest may help to channel and contain the negative elements of hooliganism, looting, etc. that might otherwise threaten all area residents. The complexity of these events for law enforcement can be very great, demanding carefully calculated efforts to analyze the nature of the disturbance, and difficult decisions about how to approach and possibly involve the numerous types of persons, gatherings, groups, and behaviors that may have the potential to either mitigate or exacerbate the situation.

The fourth type of civil disturbance, insurrection, involves a deliberate collective effort to disrupt or replace the established authority of a government or its representatives, by persons within a society or under its authority. Some prison uprisings may fall into this category, although others may more properly be classified as riots or protests, depending upon the presence and extent of specific goals and organization, and the type of action used in achieving such goals. The map at the end of this section shows the locations of major correctional facilities in Michigan. An insurrection has the deliberate goal of either replacing established authorities with a new distribution of power, or with the destruction of established power structures in favor of (usually temporary) anarchy or a smaller-scale set of recognized criminal (gang), ethnic, or other group networks and power-structures. The latter circumstances tend to involve disturbances that exist on a relatively small scale, such as in a single local area or involving a prison network or "cult compound" (or any other similarly self-aware group or subculture with identified collective interests and a network that allows rapid communication and collective action). However, larger-scale insurrections are also possible, involving issues of class conflict or other widespread social inequalities, highly divisive political issues, or other important large-scale events that disrupt the social equilibrium because they illuminate areas in which cultural values are not sufficiently shared throughout the society or region that is experiencing the conflict, disruption, or strain. In many cases, this kind of large-scale social strain has developed gradually over time, and involves an entire series of compromises, concessions, and migrations that may temporarily relieve the disruptive social and value conflicts, only to re-emerge after another period of changes and population growth has caused a breakdown in previous arrangements. This description of the causes of social discontent applies to many protests and riots, as well as insurrection. In cases involving the formation or emergence of significant subcultures or counterculture, such as during the Vietnam era, or when dominant values break down or fail to be established on important key issues or mores, there is the potential for insurrection on a larger scale. The Civil War of 1861-1865 was one such instance, in which the authority of the federal government was either accepted or rejected by various states which then aligned themselves in opposition to each other. Between these two extremes (of a purely localized civil disturbance and a national civil war) are numerous other possibilities for regional, political, class, or ethnic conflicts that may involve one or more categories of citizen in conflict with others. Examples could include prisoners versus law enforcement personnel, a countercultural group versus the establishment, or a violent political activist group in conflict with selected representatives of a contrary viewpoint. (Some such actions may overlap with those of terrorism, q.v.)

Hazard Analysis

Violent protests, disturbances, and riots have occurred throughout our nation's history. The Stamp Act Riots in the American Colonies in the 1760s, the "Boston Tea Party," and the Revolution itself involved riots and insurrection, as discontent escalated into organized international conflict. Though these events have occurred in the past, they are not considered an acceptable part of ordinary modern life.

Although destructive civil disturbances are rare, the potential is always there for an incident to occur. It is possible that risks for future disturbances may be exacerbated today by the ability of modern mass media (television, radio, the Internet, and various wireless communication devices) to instantly relay information (factual or not), in real time, to large numbers of people. That coverage may help to spread awareness of protests, discontent, riots, disorderly "parties," or other incidents to other areas or interested groups and persons, potentially exacerbating an already difficult situation. For example, media coverage of certain events has, in the past, spurred uprisings inside prisons. Communications technologies were also important in swelling the numbers of "Cedar Fest" revelers in recent East Lansing disturbances. Real-time media coverage of unfolding events is a fact of modern life that is inescapable. As a result, law enforcement officials must be skilled in monitoring all forms of media coverage to anticipate public and perpetrator actions and event progression.

Civil disturbances might be separated into several sub-categories of disturbance that could affect a community.

1. <u>Disturbances that center around a particular facility</u>: the facility could be a prison, a courthouse or other center of government, a stadium or other public meeting place, where large numbers of people may at some point gather in a disruptive fashion that is threatening to the community, its businesses, residents, or quality of life. Typically, a risk assessment would examine the history of the facility, and similar facilities in other communities. Such historical information might identify particular conditions that may cause collective behavior to get out of hand. The degree to which a community contains facilities and conditions that have been associated with civil disturbances will indicate the amount of risk that it faces from civil disturbances. The map at the end of this section shows the locations of major correctional facilities in Michigan.

2. <u>Disturbances that arise in general areas experiencing conflict and hardship</u>: This refers to neighborhoods or regions that have experienced one or more economic, social, or political stresses such as poverty, ethnic intimidation, corruption, and/or the notable presence of illegal activities. These ongoing conflicts and challenges may sometimes flare up into more widespread and blatant conflicts and unrest. The important things to recall about these sorts of civil disturbances is that it is the presence of these conflicts and problems (rather than a particular ethnic or demographic composition) that eventually generates broader disturbances. Care must be taken not to inappropriately "profile" areas based on the characteristics of their residents.

3. <u>Disturbances that interfere with normal business functions</u>: Sometimes, protests are organized in a way that is deliberately designed to disrupt the normal operations of one or more businesses, and may also happen to disrupt surrounding business operations or traffic flows nearby. Many such incidents are political, and eventually addressed through court actions or legislative proceedings. Labor negotiations may have associated employee unrest, including strikes. Protesters may object to the existence of specific facilities or businesses, or their location in a specific area, and while seeking to make such a business or its associated activities illegal, may attempt to take more direct action against its employees or patrons. Typically, the perceived harm from such businesses are either from environmental impacts or injury to persons, or social impacts concerning the image or moral standards associated with an area. In other cases, a political

demonstration may not have anything to do with the sorts of facilities or businesses in an area, but merely seeks the most crowded and inconvenient location so as to maximize the attention that it receives.

There is no specific "formula" recommended here for analyzing civil disturbance hazards, but it is probably helpful to include a historical approach that specifically addresses the social conflicts and political controversies affecting disturbance-prone areas of a community. The various costs of past events (crowd control, vandalism, arson, business disruption and closures, injuries, diverted traffic, negative economic impacts) can be estimated along with their past frequency (e.g. three times in the past hundred years) so as to produce an estimated annual cost. The history of cities with similar conditions can also be analyzed in this way, because the risk of a disturbance may be present even though there have not yet been any historic local events. This is particularly true for communities with newly-developed facilities, in rapidly growing areas, or experiencing significant social and economic changes. Their risk of civil disturbance may be increasing but there is not yet a local history of incidents that can be generalized from.

Impact on the Public

Civil disturbance impacts may include deaths and injuries, disruption of services, and short- and long-term damage to a community's tranquility and reputation (which may also affect its property values). Temporary or permanent business closures may be caused by broken windows, looting, arson, etc. Fear (and its associated security costs) may discourage visitors, shoppers, and tourists, and further cause economic impacts on the area (and associated declines in its property values). Direct property damage can be expected to cause inconvenience, at the very least, to area residents and businesses, and there is a further problem of impeded access to the area's services, and to residents' own personal property.

Impact on Public Confidence in State Government

If discontent underlies a disturbance, some persons may generalize, displace, or attribute the source of their discontent to local or state governments. Some discontent may actually be aimed toward government policies involving the environment, housing, land use, wealth distribution, taxation, military conscription, foreign affairs, labor issues, infrastructure provision, civil rights, or other issues. Although government programs often exist that attempt to address these types of concerns and to ensure that particular values (e.g. civil rights) are respected and supported throughout the jurisdiction, widespread or widely publicized disturbances or demonstrations may undermine the effectiveness of governmental programs and thus weaken public confidence in government. Other types of civil disturbance, such as wild festivities after a sporting event, may undermine public confidence in government if a pattern develops in which illegal behaviors become repetitive and widespread.

Impact on Responders

Frustration and anger may be displaced toward responders, and many citizens may not understand the nature of the motivations, rights, or responsibilities involved in either protest or policing actions. Responders may face unwarranted hostility from citizens, for many reasons, and response activities may be impeded by disruptions taking place. Response, medical facilities, communications, or transport capabilities may be overwhelmed. Psychological impacts on responders may arise from role conflicts and the nature of some of the participants involved in the disturbance (which has some differences when compared with "ordinary crime").

Impact on the Environment

Civil disturbances that stem from labor unrest (or other problems with industrial relations) may involve sabotage that causes the release of harmful substances or otherwise damages the ecosystem in an area. Civil disturbances that involve disruptive forms of collective behavior may include the lighting of fires that release toxins, especially when non-traditional manufactured items are used as fuels. Damage to property may, accidentally or deliberately, include sites that contain hazardous materials. Unruly crowds may disrupt or prevent needed maintenance activities by utility repairmen or industrial workers and thus inadvertently cause environmental problems to occur because of resulting infrastructure failures.

General Comments about Urban Civil Disturbances

Various racial and ethnic bigotries have been expressed at numerous times and locations throughout Michigan, sometimes exacerbated by major news events (which can be local, state, or national). For example, anti-German sentiments were frequently expressed during World War I. Some of these ethnic and racial antagonisms were institutionalized and enforceable by laws, contracts, or other arrangements. One example of this would be the "restrictive covenants" that prevented the sale of designated properties to those in specified minority groups. The use of restrictive covenants became unconstitutional as a result of a court decision (Shelley vs. Kramer) in 1948, but similar de facto patterns of residential pressures and segregation would still be evident for many decades afterward.

During periods of turmoil, social change, and immigration, the challenges of these large-scale social patterns often correspond with the symptoms of social conflict—in the attitudes, behavior, and policies of individuals, groups, organizations, and institutions. The number of civil rights protection programs and options has increased over time, and the Michigan Department of Civil Rights was formed in 1965, but it is useful to be aware of the possibility that widely publicized (and sometimes poorly understood or misrepresented) events may cause surges in conflicts and problems. Stereotyping, scapegoating, and discrimination can lead not only to individual crimes, but also to the disruption of neighborhood residents and the escalation of mistrust, fears, and protests into riotous incidents. It is also possible for these tensions and incidents to endure and to form an ongoing pattern of social conflict (see the section on Terrorism and Major Criminal Incidents).

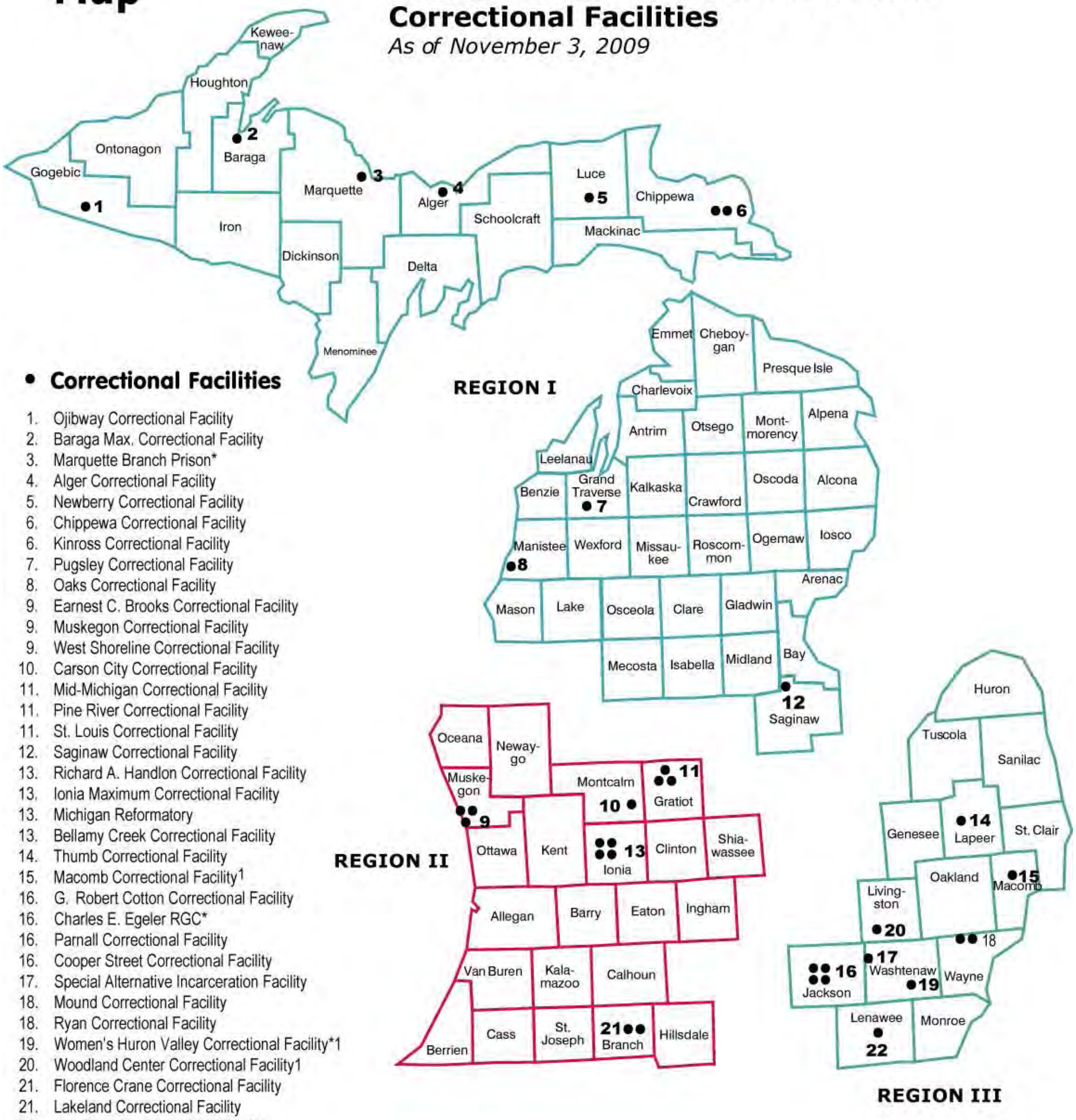
Further complicating the situation, particularly in urban areas, is that certain types of "illegitimate opportunity structures" (criminal organizations) have been known to give preferential treatment to those from particular family or ethnic backgrounds. Within the complexity and dynamics that are present in modern large cities, it has been very common for individuals to mistake or confuse their individual experiences of crime, poverty, etc. with larger-scale patterns of ethnicity, race, and social class, and to draw unwarranted conclusions about "all" persons who are perceived to be members of a particular class or group.

In actuality, social science has shown that within every large descriptive category of persons (age, race, gender, nationality, social class, etc.) there is a great deal of diversity. This diversity becomes apparent as an individual has more experience and interaction with a wide array of persons from a given background (e.g. ancestry or national origin), social situation (e.g. poverty), or socially defined category (e.g. ethnic identity), or with particular physical characteristics (e.g. sex). There usually turns out to be just as much diversity within any such large categories of persons as there is between them (to the extent that it is even valid to try to describe or define "them" collectively as a group). There is no quick shortcut to fairly and validly judge a person's character or motivations, based upon such large-scale classifications as gender, race, or social class—one must instead actually observe and get to know each person as an individual in order to start to make such assessments. (Gang-related clothing or the exhibition of countercultural symbols may be perceived as individual choices, rather than confused with a broader ethnic or other category, but even in such cases, it is often very difficult for a stranger to be able to judge the degree of authenticity and the actual meaning of such symbols for the persons who use them. On the other hand, an individual's decision to adopt a cautious or wary attitude in an unfamiliar setting or when meeting new persons is not quite the same as exhibiting deliberate prejudice, bigotry, or discrimination.)

Map

Michigan Department of Corrections Correctional Facilities

As of November 3, 2009



• Correctional Facilities

1. Ojibway Correctional Facility
2. Baraga Max. Correctional Facility
3. Marquette Branch Prison*
4. Alger Correctional Facility
5. Newberry Correctional Facility
6. Chippewa Correctional Facility
6. Kinross Correctional Facility
7. Pugsley Correctional Facility
8. Oaks Correctional Facility
9. Earnest C. Brooks Correctional Facility
9. Muskegon Correctional Facility
9. West Shoreline Correctional Facility
10. Carson City Correctional Facility
11. Mid-Michigan Correctional Facility
11. Pine River Correctional Facility
11. St. Louis Correctional Facility
12. Saginaw Correctional Facility
13. Richard A. Handlon Correctional Facility
13. Ionia Maximum Correctional Facility
13. Michigan Reformatory
13. Bellamy Creek Correctional Facility
14. Thumb Correctional Facility
15. Macomb Correctional Facility[1]
16. G. Robert Cotton Correctional Facility
16. Charles E. Egeler RGC*
16. Parnall Correctional Facility
16. Cooper Street Correctional Facility
17. Special Alternative Incarceration Facility
18. Mound Correctional Facility
18. Ryan Correctional Facility
19. Women's Huron Valley Correctional Facility*1
20. Woodland Center Correctional Facility1
21. Florence Crane Correctional Facility
21. Lakeland Correctional Facility
22. Gus Harrison Correctional Facility

*Includes reception centers

[1]Inpatient psychiatric units operated by the Michigan Dept. of Community Health

Source: Correctional Facilities Administration

NUCLEAR ATTACK

A hostile action taken against the United States which involves nuclear weapons and results in destruction of property and/or loss of life

Hazard Description

Nuclear weapons are explosive devices that manipulate atoms to release enormous amounts of energy. Compared to normal chemical explosives such as TNT or gunpowder, nuclear weapons are far more powerful and create harmful effects not seen with conventional bombs. A single nuclear weapon is able to devastate an area several miles across and inflict thousands of casualties. Although nuclear attack is an unlikely threat, the severe damage that would be caused by even one weapon requires the danger to be taken seriously.

The threat of nuclear attack has primarily been associated with the Cold War between the United States and the Soviet Union in the last half of the 20th Century. Although the Cold War is over, there remains a threat of nuclear attack. More nations have developed nuclear weapons and there is also the possibility that terrorists could use a nuclear weapon against the United States.

Understanding Nuclear Weapons

The following information about nuclear weapons is important for understanding the threat of nuclear attack: (1) types of nuclear weapons, (2) measures of weapon power, (3) forms of attack, and (4) types of delivery systems.

Nuclear weapons have been built in a wide variety of types for several different purposes. The first weapons relied on nuclear **fission**, or the splitting of heavy atoms to release energy and create an explosion. Later, new weapons were invented that used a combination of fission and **fusion**, which involves the creation of heavier atoms from lighter ones. Fusion bombs are also referred to as **hydrogen bombs** or **H-bombs**. For emergency planning purposes, the important differences are that (1) fusion bombs are more difficult to build and (2) that they can be much more powerful. Otherwise, all types of nuclear weapons create the same types of effects.

The power of nuclear weapons is measured by comparing the energy released by the weapon to the energy released by large amounts of conventional high explosive. The strengths of smaller weapons are measured in **kilotons** (or thousands of tons) of TNT explosive. A twenty-kiloton bomb produces as much energy as twenty thousand tons of TNT exploded all at once. The strength of larger weapons is measured in **megatons**, or millions of tons of TNT. A two-megaton bomb produces as much energy as two million tons of high explosive.

Smaller nuclear weapons are generally designed to be used against military targets on the battlefield. These are called **tactical** nuclear weapons. Larger devices designed to attack cities, infrastructure, and military bases are called **strategic** nuclear weapons.

Bombs can be set off at varying heights above the target. If the bomb is set off high in the air, its effects are spread out over a wider area and generally more damage is done. This is called an **air burst**. A bomb that is set off at or near the Earth's surface level wastes much of its energy against the ground. This is called a **ground burst**. Ground bursts have some specific military uses and terrorists may use ground bursts because they are unable to lift their weapons high enough to create an air burst.

Like any weapon, a nuclear device must be carried to its target by a **delivery system**. The first nuclear weapons were bombs dropped out of aircraft. Later, tactical weapons were made small enough to fire out of cannons or carry in large backpacks. **Intercontinental ballistic missiles** (**ICBMs**) are rockets that can carry one or more nuclear weapons across thousands of miles in less than an hour. Terrorists may lack sophisticated missiles, but they could create effective delivery systems by transporting a nuclear weapon in the back of a truck, aboard a cargo plane, or within a shipping container.

Effects of Nuclear Weapons

The effects of nuclear weapons are more complicated than those of conventional explosives. Nuclear devices cause damage through six major effects: (1) thermal pulse, (2) blast, (3) prompt radiation, (4) electromagnetic effects, (5) mass fire, and (6) residual radiation.

THERMAL PULSE is an intense flash of light and heat released within the first few seconds of a nuclear explosion. The damage from thermal pulse is almost instantaneous and covers a wide area. People and animals exposed to the pulse can be badly burned. Flammable objects such as buildings, vehicles, and trees may be set on fire. The flash is strongest close to the bomb and becomes weaker with distance. Even people located far away from the explosion may still be blinded by the intense light of the pulse.

BLAST is a powerful wave of force that moves out from the center of the explosion through the air and the ground. The farther the blast travels, the weaker it becomes. Very close to the bomb, the blast will destroy even the most strongly built buildings and will kill everyone not hidden deep underground. Farther away, buildings may survive, but with severe damage, and people will be injured by being picked up and smashed against objects. At still greater ranges, buildings will be less damaged and injuries will largely result from shattered glass and thrown debris. At all distances, a powerful wind follows the initial blast wave and adds to the destruction. The blast from a ground burst will dig a large crater into the ground, but this cratering will not occur with an air burst.

PROMPT RADIATION is the harmful blast of high energy radiation given off at the same time as the thermal pulse. Prompt radiation includes gamma rays and neutron radiation. This radiation is capable of killing or injuring living beings by damaging tissues and organs. Prompt radiation is quickly absorbed by the atmosphere and does not impact as wide an area as other nuclear weapons effects. In most instances, a person close enough to receive a harmful dose of prompt radiation is also close enough to be immediately killed by the explosion's thermal pulse or blast. However in unusual cases, some people who survive the immediate effects of the bomb may sicken or die days later, from radiation poisoning.

ELECTROMAGNETIC EFFECTS occur immediately after a nuclear explosion and may damage communications equipment, computers, and electronics. Radios, cell phones, and power lines are especially vulnerable. In most cases, the effects are limited to an area near to the explosion. Some equipment may recover after a period of time, while other devices will need to be replaced. One special type of nuclear attack might cause more widespread electromagnetic effects: a very large nuclear weapon carried high into the atmosphere by a missile is capable of damaging communications and electronics over a very large area.

MASS FIRE results from the ignition of thousands of individual fires by a bomb's thermal pulse, combined with widespread destruction from its blast. Over a period of hours, small fires merge and feed on damaged buildings and debris. Controlling these fires would be very difficult, due to damaged water mains, destroyed fire-fighting equipment, and blocked roads. The result is an extremely intense fire that can spread quickly and reach very high temperatures. Mass fire may significantly expand the area devastated by a bomb, destroying areas that might otherwise be only lightly damaged by other types of effects.

RESIDUAL RADIATION is unlike prompt radiation in that it lasts well after the nuclear explosion has ended. The ground immediately underneath the center of the explosion will be dangerously radioactive for several days due to "induced radiation." There will also be some radioactive dust and debris that will drift downwind of the explosion. This radioactive dust is called "fallout." Fallout will be a minor problem in the case of an air burst explosion, but will be very intense in the case of a ground burst attack. Regardless of the type of attack, the danger from fallout will tend to be greatest close to the site of the attack. The cloud of fallout will weaken the longer it lasts and the farther it travels.

Note that the effects of a nuclear attack will depend on the size of the weapon. A larger bomb will cause damage over a wider area. The importance of different types of damage will also vary with the weapon. Large strategic nuclear weapons will create most of their damage though thermal pulse and mass fires, while with small tactical bombs the blast effect and prompt radiation will be relatively more important.

The Nuclear Attack Threat

Nuclear attack against the United States would originate either as a strike by an enemy military or as a terrorist attack. Fortunately, nuclear devices are very difficult to build and this limits the availability of the weapons. A nuclear weapon more closely resembles a precisely built scientific tool then a simple, rugged bomb. Careful engineering and extremely rare materials are needed to make a working nuclear weapon.

At the end of World War II only the United States possessed nuclear weapons, but over time more nations have developed the necessary technology. At least eight countries now possess nuclear devices, while several more have secret nuclear weapons programs and may therefore be building bombs. While some of these "nuclear powers" are allies of the United States, others remain potential enemies. While unlikely, it is possible that an international crisis in areas such as the Persian Gulf, the Taiwan Straits, or the Korean Peninsula could escalate into an exchange of nuclear weapons. American cities are not invulnerable to attack.

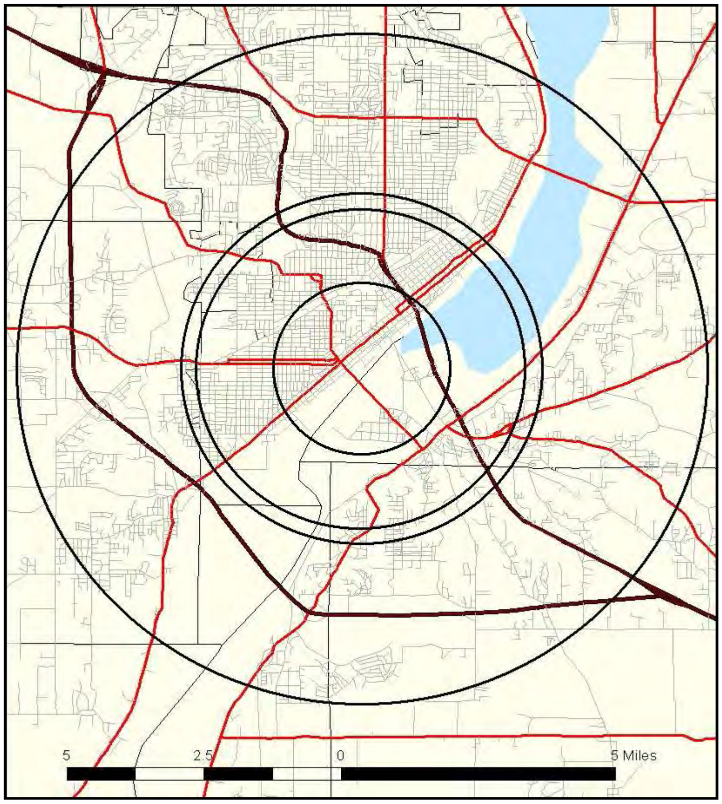
There also remains a risk from accidental, mistaken, or unauthorized launch of nuclear weapons. Even the most sophisticated technology may malfunction and even the best-trained personnel may make tragic mistakes. Once a missile has been launched there is no way call it back, and a nuclear warhead fired in error will do just as much damage as one launched in anger.

A strike by a nuclear power could consist of a single weapon or thousands, depending on the strength and intentions of the attacker. The most likely form of military attack would be the launch of intercontinental ballistic missiles fired from thousands of miles away. Although the United States now has a limited ability to shoot down incoming missiles, there are fewer than 30 interceptor missiles, of doubtful reliability. A very small attack or an accidental launch might possibly be stopped, but a larger attack would certainly strike the United States.

A nuclear power would have the ability to attack several locations at the same time. Multiple attacks across the United States would overwhelm national assets, forcing individual states or regions to rely on local resources. These attacks would probably be targeted on large cities and military bases and would use strategic nuclear weapons—each with a power of 100 kilotons or more. Cities would usually be attacked with air bursts, and military bases by the use of ground bursts.

The following map illustrates the effects of a typical military nuclear missile warhead. This example shows the effects of a 750 kiloton air-burst detonation at an altitude of 8,000 feet on a clear day above a mid-sized American city. Such an attack would be representative of an attack on Michigan cities such as Grand Rapids, Lansing, Flint, or Ann Arbor. The rings in the illustration show distances from the center of the nuclear explosion.

<u>Outer Ring: 6.3 miles across</u>
At this distance, the exposed skin of persons outdoors will suffer immediate 3rd degree burns (8 kcal/cm^2). With medical services destroyed or overwhelmed, almost all severely burned victims will die. Within this ring, mass fires can be expected to develop within hours. Eventually, most of this area will be destroyed by fire.



Second Ring: 3.3 miles across
At this distance, the blast wave will totally destroy light frame structures, such as most homes (5psi). Sturdier buildings will be severely damaged, with their interiors destroyed. Winds of 160mph would then follow the blast wave.

Third Ring: 3.0 miles across
At this distance, exposed persons will be affected by intense prompt radiation (5Gy). Between 50% and 80% of victims will eventually die from this exposure, unless first killed by blast or thermal effects.

Inner Ring: 1.6 miles across
At this distance, the blast wave will totally destroy even reinforced concrete buildings (20psi). Winds of 230 mph will follow the blast wave. Essentially everyone within this ring will be killed immediately.

Lighter damage will extend well beyond the area depicted in this map, mostly due to the effects of the thermal pulse.

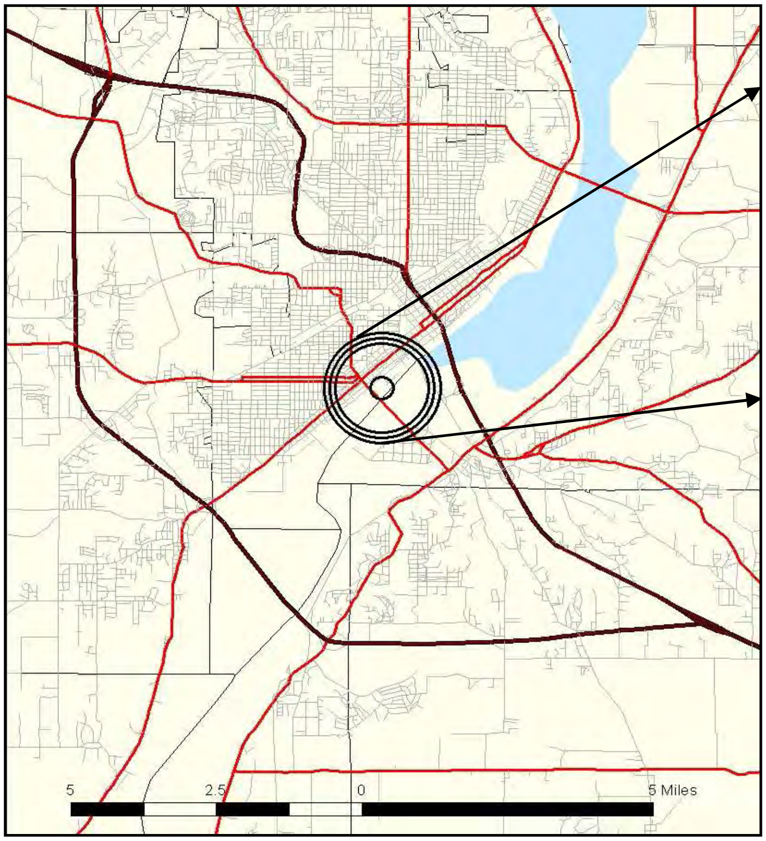
Nuclear Terrorism

As far as is known, no terrorist organization has ever managed to gain access to nuclear weapons. However, the great destructive potential of these devices make them very desirable for terrorist groups that wish to cause massive and indiscriminate casualties. It is known that several terrorist groups have actively pursued nuclear weapons capability.

Terrorists could acquire nuclear weapons as gifts from friendly governments, by stealing them from military stockpiles, or by building a crude device on their own. Each of these approaches is considered unlikely, but not impossible. A determined and well-financed terrorist group such as Al Qaeda may eventually be able to acquire a working nuclear weapon.

A nuclear attack by a terrorist organization would likely involve only a single weapon. An attack by only a single weapon would still be a major disaster, but resources could gradually be sent from the entire United States to aid the devastated area.

Because powerful strategic bombs are more difficult to steal or build, it is likely that a terrorist device would be of the less powerful tactical type. A rough estimate for the strength of this kind of nuclear weapon would be 25 kilotons or less. Even such a 'small' device would be approximately as powerful as the bombs that destroyed the Japanese cites of Hiroshima and Nagasaki at the end of World War II.



A terrorist nuclear weapon would be unlikely to arrive aboard a missile. It is much more probable that the bomb would be smuggled to the target, hidden inside the back of a truck or within a cargo container. Even a bulky improvised nuclear weapon could easily be carried in this way. The bomb could be detonated from inside its hiding place, creating a nuclear ground burst. There is a lesser possibility that terrorists could use a cargo plane to deliver a nuclear weapon as an air burst.

This map illustrates the effects of a possible terrorist nuclear bomb. This example shows the effects of a 25 kiloton nuclear weapon detonated at ground level on a clear day in a mid-sized American city. Such an attack would be representative of an attack on Michigan cities such as Grand Rapids, Lansing, Flint, or Ann Arbor. The rings in the illustration show distances from the center of the nuclear explosion.

Outer Ring: 1.0 miles across
At this distance, exposed skin will suffer immediate 3rd degree burns (8 kcal/cm2). With medical services destroyed or overwhelmed, most severely burned victims will die. Within this ring, mass fires can be expected to develop within hours. Eventually, most of this area will be destroyed by fire.

Second Ring: 0.9 miles across
At this distance, the blast wave will totally destroy light frame structures, including most homes (5psi). Sturdier buildings will be severely damaged, with their interiors destroyed. Winds of 160mph would then follow the blast wave.

Third Ring: 0.8 miles across
At this distance, exposed persons will be affected by intense prompt radiation (5Gy). Between 50% and 80% of victims will eventually die from this exposure, unless first killed by blast or thermal effects.

Inner Ring: 0.2 miles across
At this distance, the blast wave will totally destroy even reinforced concrete buildings (20psi). Winds of 230 mph will follow the blast wave. Essentially everyone within this ring will be killed immediately.

Lighter damage will occur out to a distance of approximately two miles, or twice the diameter of the outer ring on the map. This damage will be caused by a combination of blast and thermal pulse effects.

The arrows in the diagram represent the area covered by a moving cloud of radioactive fallout. This cloud will drift downwind from the site of the explosion, but the size and direction of the area affected by the fallout will depend considerably on wind and weather conditions. For example, in clear weather with winds blowing at 15 miles per hour, lethal levels of radiation will be encountered several miles downwind from the site of the explosion and harmful levels will occur for up to six miles downwind. Fatalities are expected in persons continuously exposed for four days in the contaminated area. People finding shelter or evacuated immediately will suffer substantially less harmful effects.

Note the significant differences between the two examples. The terrorist bomb directly impacts a much smaller area, but it creates a dangerous cloud of radioactive fallout. The lethal thermal pulse from the air burst missile explosion covers an area much greater than the area of heavy blast damage, while in the case of the terrorist bomb those two effects are more equal. In the case of the missile explosion, the area of effect for prompt radiation is much smaller than that for blast and thermal effects, but in the case of the terrorist bomb, lethal radiation extends almost as far as the other effects.

Global Consequences of Nuclear Attack

A final consideration for the nuclear attack hazard is the impact of a nuclear attack outside of Michigan's borders. An attack elsewhere in the United States or elsewhere in the world would have serious negative economic consequences. Such an attack would also result in a global call for emergency response resources, including those in Michigan. Finally, a large scale nuclear war involving many nuclear weapons could have damaging effects on climate worldwide. A nuclear attack would have serious consequences for Michigan, regardless of where that attack occurred.

Impacts of Nuclear Attack

Impact on the Public

A nuclear attack would cause catastrophic damage over a wide area. Attacks on populated areas would inflict massive loss of life, destruction of property, environmental damage, infrastructure failure, and public health impacts. In the case of a ground burst weapon, some areas would remain uninhabitable for an extended period of time. A nuclear war, even if occurring far from the United States, would have serious economic and environmental consequences, resulting in additional harm to the public. Although unlikely to occur, nuclear attack potentially poses a very great threat in terms of fatalities, property damage, and size of impact area.

Impact on Public Confidence in State Governance

Public confidence in state government following a nuclear attack is difficult to predict. It is likely that public reaction would depend on the perceived effectiveness of government response to the disaster. Given the extensive damage caused by nuclear weapons, and the limited available resources, it is very likely that government services would be overwhelmed. An especially serious problem would be insufficient medical resources for the treatment of injured victims. It is conceivable that the unmet needs of survivors could result in a significant loss of confidence in state government. On the other hand, anger at the perpetrators of the attack and feeling of patriotic solidarity might increase popular support of government, at least in the short term.

Impact on Responders

A nuclear attack would pose extensive risks and challenges for responders. In any attack on a populated area, many responders would be immediately killed or injured in firehouses, police stations, hospitals, etc. affected by the explosion. Surviving responders would face serious and unfamiliar challenges, including widespread infrastructure failure, high levels of radiation, mass urban fires, and the disruption of command and communications systems. Responders would also face an unprecedented level of need from thousands of injured or dying citizens. In the short term, emergency resources would unavoidably fall far short of requirements. Help could only be provided to a limited percentage of the total number of victims. Extensive casualties would be expected among responders. In the long term, responders and emergency managers would face massive challenges in sheltering, evacuation, medical care, and public order.

Impact on the Environment

A nuclear attack would cause significant environmental damage. In addition to the immediate destruction from blast and thermal effects, continuing damage would be expected due to toxic smoke clouds from mass urban fires, hazardous materials released from damaged storage facilities, and waste from wrecked water treatment systems.

Radioactive contamination would occur, with the extent depending on the specific details of the attack. At worst, large areas would be poisoned by fallout, and a crater at the site of an explosion could remain heavily contaminated for years. Use of numerous nuclear weapons might cause environmental damage on a regional or global scale, far beyond the effects created by a single weapon or small number of weapons. Such damage could occur during an extensive nuclear war. Specific effects would depend on the size and number of weapons used, as well as their specific targets. Global environmental impacts might include a drop in global temperature, reductions in food production, damage to the Earth's protective ozone layer, and an increase in background radiation levels.

Additional Nuclear Attack Guidance Information

During the Cold War, the nuclear attack hazard was not customarily analyzed at the local level. The large numbers of weapons available to the United States and Soviet Union threatened destruction on an enormous scale, and few plans could attempt to adequately address the hazard. Even communities not directly attacked would have been profoundly or fatally impacted by the effects of a superpower exchange.

Today, the threat of nuclear attack is very different, and local planning may again be appropriate for this hazard. The possibility of attack still exists, but the principal threat is the use of an individual nuclear weapon or a small number of weapons. Cold War planning scenarios may need to be updated to reflect the fact that the nature of the threat has changed. Not only are there far fewer nuclear weapons than in past decades, but the individual weapons are, for the most part, far less powerful.

When considering the hazard of nuclear attack by a foreign power, local vulnerabilities would be assessed in terms of proximity to possible high-priority targets. These might include military bases, large power plants, oil refineries, and major population centers. Targets identified in Cold War plans may no longer be relevant, as closed military bases and shut-down power plants are no longer likely targets. Since there is no way to accurately assess the probability of nuclear war, most mitigation strategies would be prompted by, and originate from, federal initiatives and defense priorities. The "risk" part of a local hazard analysis on this topic would therefore probably be missing, due to lack of information, but the "vulnerability" portion can still be assessed in terms of the presence of potential targets.

Also worthy of consideration is the possibility that one or more nuclear weapons might be used in an attack by a terrorist organization, especially in light of the ongoing threat posed by international terrorist groups. The section of this plan dealing with Terrorism and Similar Criminal Activities should be freely referred to, particularly in regards to potential terrorist targets. When planning for a terrorist nuclear attack, consider that the effects of a terrorist weapon are likely to be very different than those caused by a nuclear missile attack.

For any nuclear attack planning, the presence of fallout shelters, or makeshift substitute shelters, might be a key factor of analysis. When considering mitigation and response strategies, the ability to shelter or evacuate people would clearly be important. The ability to maintain government functions and social services would be similarly important. Protection of critical computer and communications systems from the effects of electromagnetic pulse would also be worth considering. The presence of redundancies (backup systems) in an area's infrastructure and critical services would be another means to assess local vulnerability to a nuclear attack.

Summary

Nuclear attack is an unlikely hazard, but even a single weapon could cause death and destruction on a massive scale. Nuclear weapons inflict damage over a wide area and through a variety of effects, including thermal pulse, blast, fire, and radiation. Despite the end of the Cold War, nuclear attack by foreign nations remains a real possibility, and this danger has been joined by the threat of terrorist nuclear attack. It makes sense to continue to prepare for the nuclear attack hazard as part of an overall emergency management strategy.

PUBLIC HEALTH EMERGENCIES

A widespread and/or severe epidemic, incident of contamination, or other situation that presents a danger to or otherwise negatively impacts the general health and well-being of the public.

Hazard Description

Public health emergencies can take many forms—**disease** epidemics, large-scale incidents of food or water **contamination**, extended periods without adequate water and sewer **services**, harmful exposure to chemical, radiological or biological agents, and large-scale infestations of disease-carrying insects or rodents, to name just a few. Public health emergencies can occur as primary events by themselves, or they may be secondary events to another disaster or emergency such as a flood, tornado, or hazardous material incident. The common characteristic of most public health emergencies is that they adversely impact, or have the potential to adversely impact, a large number of people. Public health emergencies can be statewide, regional, or localized in scope and magnitude.

Perhaps the greatest emerging public health threat would be the intentional release of a radiological, chemical, or biological agent with the potential to adversely impact a large number of people. Such a release would most likely be an act of sabotage aimed at the government or at a specific organization or segment of the population. Fortunately, Michigan has not yet experienced such a release aimed at mass destruction. However, Michigan has experienced hoaxes and it may only be a matter of time before an actual incident of that nature and magnitude does occur. If it does, the public health implications—under the right set of circumstances—could be staggering.

Hazard Analysis

Michigan has had several large-scale public health emergencies in recent history, but fortunately nothing that caused widespread severe injury or death. The 1973 PBB contamination incident is unprecedented in U.S. history, but the long-term implications of contamination may be less than was feared. Similarly, the northern Michigan water and sewer infrastructure disaster of 1994 is also unprecedented in scope, magnitude, and public health and safety implications for the affected communities. These events, though unusual, have heightened awareness of the broad nature of threats that can result in a public health emergency. Such emergencies no longer simply involve the spread of disease, but rather can arise out of a variety of situations and circumstances.

In 2001, Michigan health officials were introduced to the emerging health threats posed by foot-and-mouth disease and the West Nile encephalitis virus. Although foot-and-mouth disease is a highly contagious disease that only affects animals, a widespread outbreak such as that which occurred in parts of the United Kingdom in the spring of 2001 could have significant public health implications for humans as well, due to the potentially large numbers of dead animal carcasses that would have to be disposed of to prevent disease outbreaks. The Michigan Department of Agriculture and Rural Development, in conjunction with numerous other federal, state and local agencies and the agriculture industry, continues to monitor the foot-and-mouth disease situation and take the necessary steps to prevent the introduction and spread of the disease in the United States.

The West Nile encephalitis virus, which arrived in Michigan in August 2001, presents an equally challenging scenario for public health officials. Transmitted to humans by the bite of an infected mosquito, the West Nile virus is commonly found in Africa, West and Central Asia, and the Middle East. Health officials do not know how the virus was introduced to the United States. However, in 1999 and 2000, it caused an outbreak of human encephalitis in and around New York City that created a national stir and raised fears across the country that it would cause a full-blown public health emergency. The virus eventually spread to Michigan in 2001. It peaked in Michigan in 2002 with 644 reported cases, including 51 deaths. There has been a decline in reported cases every year since then.

Although no area in Michigan (or elsewhere) is immune to public health emergencies, areas with high population concentrations will always be more vulnerable to the threat. In addition, the more vulnerable members of society—the elderly, children, impoverished individuals, and persons in poor health—are also more at risk than the general population.

Michigan is fortunate in that it has an excellent public health system that constantly monitors the threats that could lead to a widespread or significant public health emergency. However, even the best monitoring and surveillance programs cannot always prevent such incidents from occurring. When they do occur, Michigan's public health agencies have shown the ability to effectively muster the resources necessary to identify and isolate the problem, and mitigate its effects on the population. In addition, if the problem is such that a multi-agency and multi-jurisdictional response is required, the emergency management system in Michigan can be utilized to enhance coordination and effectiveness of the response and recovery effort.

Impact on the Public

The primary types of public health impacts involve the threat or presence of either disease, contamination, or sanitation problems. Disease epidemics or pandemics have the potential to cause widespread debilitation or loss of life, associated medical expenditures, and decreases in productivity and quality of life. Contamination can at least temporarily lower property values, as well. Sanitation problems require effort and expense to resolve. Contamination and sanitation issues increase the probability and variety of diseases that may affect the population. Facilities may be shut down, as a means of preventing disease transmission or of containing contamination, and thus cause a loss of the services being provided to the public (by schools, for example). Medical resources may become overwhelmed and unable to deal with any additional needs. As traditional medical services become increasingly difficult to access (or if their quality declines due to overwork or understaffing) then increasing numbers may turn to less responsible and effective alternative means of treatment (or may forego treatment entirely).

Impact on Public Confidence in State Governance

The PBB incident of the mid-1970s caused part of the population to perceive a "cover up" by the state, or suspicions of faulty research involving the amount and nature of PBB risks. Although it took time for the cause and nature of the incident to be understood, and the detection of long-term health risks from PBB eventually became clearer, the public and the mass media's understanding of the nature of scientific research tends to be prone to misjudgments, hasty conclusions, and an abundance of speculation.

Food-borne illnesses, including the contamination of products during manufacture, is another type of public-health emergency that is likely to be associated in the public mind with the effectiveness of government policies and regulatory agencies. Widespread illness that is associated with public infrastructure (e.g. water, sewer, electrical) or with conditions that are overseen by government inspectors (e.g. air conditioning and ventilation systems) are more likely to cause a loss of public confidence in government when it occurs. Maintenance-related and environmental issues that may affect public health in an area (such as urban blight and insect/rodent infestations, contaminated brownfield sites, scrap tire piles, industrial or nuclear accidents) are also ones for which some level(s) of government will be held accountable by the media and the public. Post-disaster conditions that allow the spread of illness (or the breakdown of public health services) will also have a great potential to cause dissatisfaction with and loss of confidence in government.

There are also cases (e.g. a cluster of lethal meningitis infections on a large university campus) in which the public is unfamiliar with epidemiological methods and data, and believes that a problem exists despite government assurances that there is not yet sufficient evidence to reach that conclusion. The result would be that, unless offsetting information is proactively provided to the public, various persons will feel that abstract analysis techniques (or bureaucracy) are preventing government workers from seeing conditions that certain citizens consider to be "obvious." This mismatch in understanding and perception often results in citizen criticism of "government."

Impact on Responders

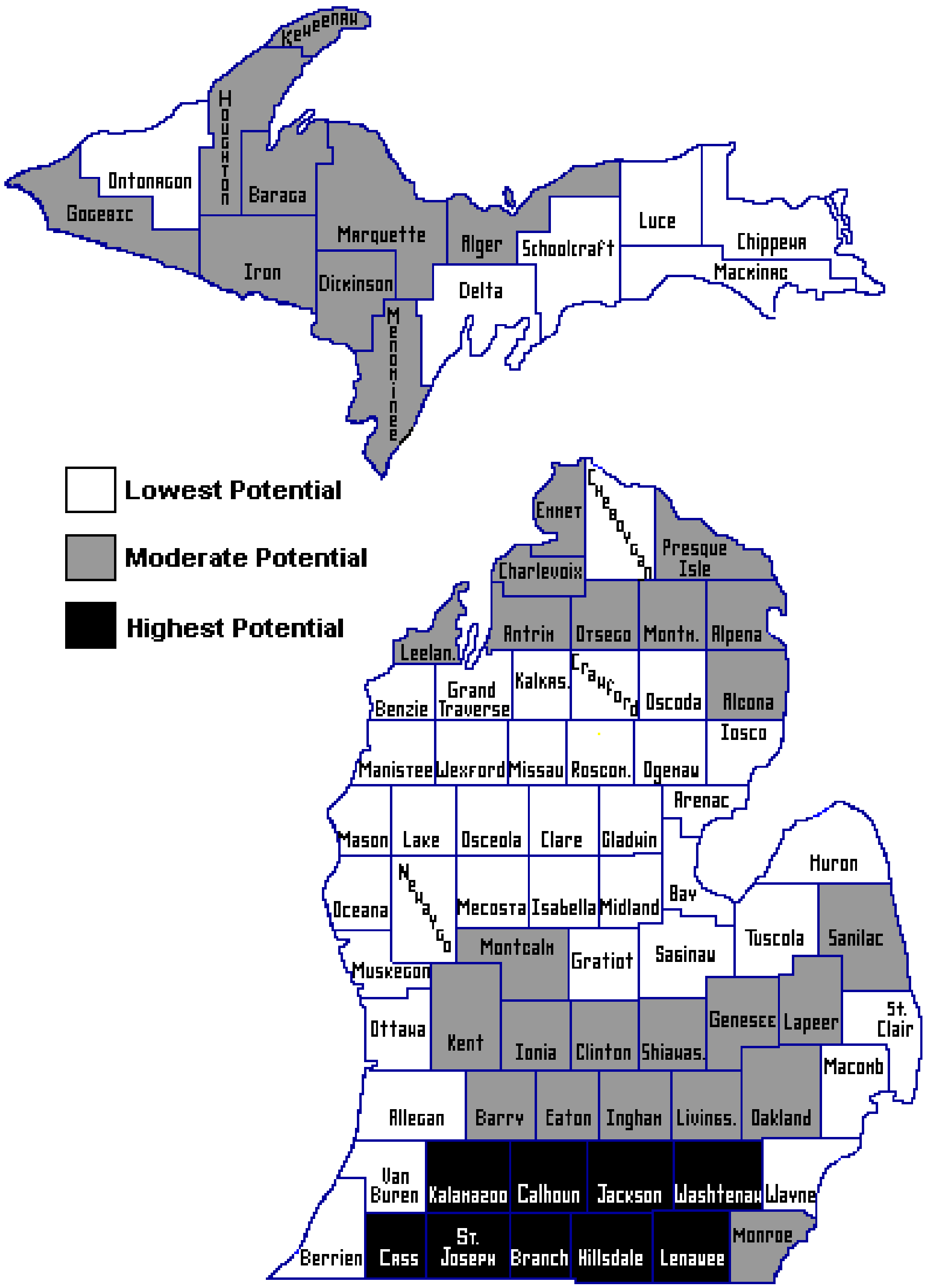
The primary types of emergency public health concerns involve the threat or presence of either disease, contamination, or sanitation problems. Certain types of contamination issues are similar to hazardous materials (q.v.) in their impact on responders, in that special measures, expertise, and precautions may be required when dealing with an incident. A similar approach may be taken with sanitation issues, in which special crews may need to be called in to deal with the problem, and the measurement and monitoring of the problem may require specialized equipment and expertise. On the other hand, issues of contagious disease tend to call for different response and precaution procedures, since there are many human-related transmission vectors that can seem more diffuse and unclear. Unless special training and equipment is obtained and employed, responders may be found to have an increased risk of succumbing to the contagious illness being responded to. (Even with the use of equipment and training, responders may still be more at risk, due to increased exposures to bacterial and viral threats.)

Impact on the Environment

A public health emergency tends to primarily affect people, but in a severe, large-scale event, decontamination centers, quarantine buildings, or additional medical facilities might need to be developed quickly, disregarding land use laws. This type of development may result in the loss of an area's natural wildlife habitat and could also impact the environment by causing nearby properties to flood.

Radon Zones in Michigan

This map was developed by the U.S. Environmental Protection Agency (EPA) using five factors to determine radon potential: indoor radon measurements, geology, aerial radioactivity, soil permeability, and foundation type.



Source: Adapted from an Environmental Protection Agency map

(Note: Consult the EPA Map of Radon Zones document (EPA-402-R-93-071) for additional background information on this map. That document also contains information on radon potential variation <u>within</u> counties. The EPA also recommends that this map be supplemented with any available local data in order to further understand and predict the radon potential of a specific area.)

TERRORISM AND SIMILAR CRIMINAL ACTIVITIES

<u>Terrorism</u>: "…activities that involve violent…or life-threatening acts…that are a violation of the criminal laws of the United States or of any State and…appear to be intended (i) to intimidate or coerce a civilian population; (ii) to influence the policy of a government by intimidation or coercion; or (iii) to affect the conduct of a government by mass destruction, assassination, or kidnapping" Federal criminal code. 18 U.S.C. §2331

Hazard Description

Terrorism is the use of violence by individuals or groups to achieve political goals by creating fear. The political motives of terrorism distinguish it from ordinary crime. Terrorism is carried out for a cause; not for financial gain, personal revenge, or a desire for fame.

Terrorism is a long-established strategy that is practiced by many groups in many nations. The United States is threatened not only by international terrorists such as Al Qaeda, but also by home-grown domestic terrorist groups including racist, ecological, anti-abortion, and anti-government terrorists.

A wide range of techniques can be used by terrorists, including bombings, shootings, arson, and hijacking. Regardless of the specific tactics used, terrorists seek the greatest possible media exposure. The goal of terrorists is to frighten as many people as possible, not necessarily to cause the greatest damage possible. Media coverage allows terrorists to affect a much larger population than those who are directly attacked.

Non-terrorist criminal activity may resemble terrorism, but lacks a political objective. Emergency management is typically not concerned with routine, individual crimes, but does need to prepare for crimes that impact large portions of the population. Such attacks may require resources not available to local law enforcement agencies. Crimes of this sort include mass shootings, random sniper attacks, sabotage of infrastructure, and cyber-attacks. The types of criminal attacks considered in this section are those that resemble terrorism or that may cause widespread immediate disruption to society.

<u>Terrorism in the United States</u>

Terrorists intend to use fear as a weapon to achieve their goals. This approach allows a small, weak group to potentially influence the actions of an entire nation or government. Terrorists lack the power to achieve their ultimate aims through the direct use of force, but by staging relatively small attacks in a spectacular fashion, they hope to have a major political impact. Their goals are effectively summarized by the proverb "Kill one, frighten 10,000." Terrorism can be an effective strategy for a weak group to use when fighting a strong opponent.

Terrorism has been used for thousands of years, but modern terrorism developed in the 19th Century. The United States has suffered from terrorist attacks for more than a century: U.S. President William McKinley was assassinated by an anarchist terrorist in 1901, the Los Angeles Times building was destroyed in 1910, and Wall Street was bombed in 1920. Racial and religiously-motivated terrorism continued throughout the 20th century. A new wave of terrorism was instigated in the 1960s by left-wing radicals. This was followed by right-wing extremist terrorism in the 1980s and 1990s. All of these attacks were conducted by American domestic terrorists against other Americans.

The United States has also been the target of terrorists from other countries. Conflict in the Middle East led to many attacks on American targets overseas, primarily by Palestinian nationalist terrorists, as well as groups supported by Libya and Iran. Hijackings, kidnappings, and bombings of Americans occurred throughout the 1970s and 1980s, and into the 1990s. By the mid-Nineties the danger had shifted toward attacks by violent Islamic extremist groups such as al-Qaeda. Al-Qaeda successfully moved their terrorist campaign inside of the United States homeland with the World Trade Center bombing in 1993 and the devastating 9/11 attacks in 2001.

Types of Terrorists

Terrorists fall into five major categories, based upon the political cause that motivates their actions. These categories are: nationalist, religious extremists, left wing terrorists, right wing terrorists, and single-issue terrorists.

Nationalist terrorists act in support of a cultural or ethnic group. Typically they are fighting on behalf of national populations that wish to have an independent government, but are currently ruled by another country. Nationalist terrorists tend to direct their attacks against the "occupying power" that they wish to drive away, but may also attack other nations that support their enemies. Nationalist terrorists claim to speak for their entire national group, but usually only represent a small minority of extremists. Examples of nationalist terror groups include the Provisional Irish Republican Army (Northern Ireland), the Popular Front for the Liberation of Palestine (Palestine), and the Armed Forces of National Liberation (Puerto Rico).

Religious extremist terrorists are violent adherents of a specific religion. They may be violent extremists within a large, generally peaceful faith such as Islam or Christianity, or members of a small "cult" religion in which the entire group is extremist. These terrorists tend to be especially committed because they believe their violent actions are supported by their deity and because they may expect to be rewarded after death. Religious terrorists see themselves as fighting in a battle of ultimate good against pure evil, in which any action is justified. Examples of religious extremist terrorists include al Qaeda (International), Hezbollah (Lebanon), and the Aum Shinrikyo cult (Japan).

Left wing terrorists attempt to force society to change to match their goals and values. They tend to target the government, powerful institutions, and symbols of authority. Socialist and Communist terrorists of this type were a threat in the late 1960s and 1970s, but have weakened in recent decades. Examples of left-wing terrorist groups include the Weathermen (United States), the Red Army Faction (Western Europe), and Shining Path (Peru).

Right wing terrorists see themselves as fighting for traditional values against an invading group and/or against a tyrannical government. In the United States these terrorists are associated with anti-immigration, white supremacy, anti-government, and Christian Identity movements. Only the most extreme elements of these movements have become terrorists, but they have carried out a substantial portion of the recent attacks in the United States. Right wing groups tend to target members of hated ethnic or religious minorities, or government employees. In recent years, right wing terrorists have usually operated as violent individuals termed "lone wolves" and not in organized groups. Examples of right wing terrorist groups in the United States include "The Covenant, The Sword, and the Arm of the Lord" and "The Order." Examples of right-wing "lone wolf" terrorists include Timothy McVeigh (of the 1995 Oklahoma City bombing) and James von Brunn (of the 2009 National Holocaust Museum shooting in Washington, D.C.).

Single-issue terrorists are not committed to an all-encompassing belief system, but rather are intensely concerned with one particular cause. Frequently these issues are of interest to many members of society, but only small numbers of individuals convert this interest into terrorist action. Common causes for single issue terrorists in the United States include animal-rights, environmentalism, and opposition to abortion. These terrorists carry out the majority of terrorist attacks within the United States, but tend to target property or individuals rather than attempting to cause massive casualties. Examples of American single issue terrorist groups include the Animal Liberation Front and the Earth Liberation Front, but many single issue terrorists operate as independent lone wolves or in small informal groups.

Terrorists and terrorist groups tend to fall into one of these five categories, but there are examples of terrorists who fit more than one of these categories. For example, nationalist terror groups have often promoted radical left-wing political views while religious extremist terrorists frequently have extreme right-wing views.

The most effective terrorists tend to operate in groups of like-minded individuals. Such groups range from a few committed amateurs to sophisticated international paramilitary organizations. Even in the larger organizations, terrorist groups are structured into small "cells" with a handful of members each. This structure, combined with the intense personal commitment of many terrorists, makes these groups difficult to discover, infiltrate, and disrupt.

Non-terrorist Criminals

Terrorism is a crime, but not all criminals are terrorists. Most crimes impact only a small number of victims and are appropriately handled by local law enforcement. Rarely, a criminal event will impact a large number of people. Examples include mass-shootings at schools or workplaces, infrastructure sabotage, and cyber-attacks. Such major criminal events may resemble terrorist attacks, but there are important differences between terrorists and other criminals.

The principal difference between terrorism and other types of crime is motivation. Terrorists are motivated by a political cause, not by personal gain. Terrorism is not only defined by what an attacker does, but why he or she does it. This is an important distinction because it explains other characteristic differences between terrorism and non-terrorist crimes.

Non-terrorist criminals may be driven by a wide variety of purposes. These motivations are highly idiosyncratic and difficult to categorize or predict. Most criminals avoid major crimes with widespread impact because the chance of monetary gain is low and the risk of punishment is high. Occasionally a criminal will be willing to take that risk. Major criminal events have been conducted for reasons of personal revenge, monetary gain, desire for fame, and due to mental illness.

There are other important differences between terrorists and criminals, although these are generalizations that do not hold true in all cases. Terrorists tend to prioritize their mission over their personal safety and will often risk capture or death to achieve their goals. Criminals usually seek freedom to enjoy the rewards of their crimes and so plan to escape undetected after their attacks. American criminals, especially those who conduct large-scale attacks, tend to operate as individuals or small groups. The most effective terrorists belong to organizations or networks that coordinate multiple members and share extensive resources.

Criminal and Terrorist Weapons and Techniques

There are a wide variety of harmful weapons and tactics available to terrorists and criminals. The specific effects of a terrorist or criminal attack, as well as the emergency response required, are determined largely by the tools used.

Explosives are by far the most common terrorist tool and have also been used by particularly violent criminals. Bombs have many advantages for an attacker, including flexibility, availability, and ease of use. Explosives can be delivered in many ways, including massive car bombs, hidden suicide vests, assassination devices, and letter bombs sent through the mail. Bombs are effective at both destroying property and harming people. Explosive attacks also produce dramatic images of destruction guaranteed to receive the media coverage that terrorists seek out.

A wide variety of explosive materials are available. Military explosives are the most powerful, but are difficult for most terrorists and criminals to get. Commercial explosives are widely available for legitimate use by mines, farms, and businesses. With over 2.5 million tons used each year in the United States, commercial explosives are powerful and easy to acquire. Alternatively, terrorists and criminals may choose to make their own explosives. Effective bombs can be built from commonly available materials such as farm fertilizer, diesel fuel, and hydrogen peroxide.

Explosives are also relatively easy to use. This allows even untrained bombers to launch damaging attacks. Common terrorist tactics include anti-personnel bombs, packed with metal objects to increase injuries, and suicide bombs that can be set off at the most harmful possible time and place. For non-suicidal attackers, bombs can be left in place to explode long after the bomber has made an escape. One common explosives technique of particular importance to emergency responders is the secondary device. This tactic uses a pair of bombs, the first of which draws rescuers and bystanders to the scene and a second, hidden bomb is targeted to then kill these emergency responders.

Explosive attacks can be countered by careful law enforcement work to identify and disrupt possible attacks before they occur. Alert and properly educated citizens can provide important assistance by observing and reporting signs of a possible attack, such as an unwarranted purchase of explosive materials, or the presence of a suspicious package in a public place. Some high-risk areas such as airports can be equipped with explosives screening devices. Particularly high-risk facilities, such as government buildings, may be physically hardened to limit the damage from attack by explosives. If a bomb or potential bomb is detected, specially trained law enforcement bomb squads should be contacted to dispose of it.

Case: Bath School Disaster (1927)

On May 18, 1927, the Bath Consolidated School in Bath, Michigan, was the target of an attack with explosives. The bomber was probably motivated by personal revenge against the local school district (stemming from a taxation issue), and so this event is classified as criminal, rather than as a terrorist attack. Although many of the explosives failed to detonate, the bombs in the school killed dozens of students and teachers. The bomber also destroyed his home and farm with explosives. Immediately after the school attack, the bomber approached the rescue operations scene and detonated an explosive device carried in his vehicle, killing himself, local officials, and several bystanders. The final death toll was 45, with 58 additional persons injured. The Bath Disaster remains the second most deadly U.S. bombing attack, after the Oklahoma City Bombing, as well as the most lethal attack on an American school. This case also provides early examples of such tactics now in common use by terrorists, including a secondary device, suicide bombing, and car bomb.

Case: Oklahoma City Federal Building Bombing (1995)

On April 19, 1995, the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, was attacked by a large truck bomb. The attack killed 168, injured more than 680, destroyed the building, and caused widespread destruction over a sixteen-block area. Although initially suspected of being carried out by international terrorists, the attackers were in fact anti-government domestic terrorists, one of whom had extensive Michigan connections. This attack is an example of right wing anti-government terrorism. It also demonstrates the extensive destruction that can be caused to large buildings which lack adequate target hardening and security measures.

Case: Bali Bombing (2005)

On October 12, 2002 terrorists bombed the tourist district of Kuta on the Indonesian Island of Bali. The targets were several nightclubs frequented by Western tourists. An initial backpack suicide bomb was directed against patrons inside a dance club. Shortly thereafter, a large car bomb detonated on a busy street near the first attack, killing survivors of the initial bomb and would-be rescuers. The second bomb weighed over a ton and devastated several blocks of buildings. In total, 202 persons were killed, with a further 209 injured. The attack was carried out by Jemaah Islamiyah, an Indonesian extremist Islamist organization. This case is an example of the versatility of terrorist explosives, used at Bali as both a small suicide weapon and a massive remotely detonated car bomb. It is also an example of a large secondary device, intended to kill those responding to the initial bomb.

Case: Northwest Airlines Flight 253 Bombing Attempt (2009)

On Christmas Day 2009, Umar Farouk Abdulmutallab attempted to destroy Northwest Airlines Flight 253, approaching Detroit Metropolitan Airport. The weapon used was an explosive device provided by the “al-Qaeda in the Arabian Peninsula” terrorist group and hidden in his underwear. The device was small and easy to conceal, but was capable of damaging or destroying the airliner. The explosive failed to detonate properly and instead ignited and burned Mr. Abdulmutallab, who was then subdued by the plane’s passengers and crew. This attack demonstrates the potential effectiveness of even small bombs when used against vulnerable targets such as aircraft. It also demonstrates that international terrorism may be directed at targets in Michigan.

Suggested cases for readers’ further study: (1) 1993 WTC bombing (demonstrates the importance of terrorist planning), (2) London transit bombing (demonstrates the use of small improvised devices), (3) Airline insurance bombing (demonstrates a criminal attack against an airliner), (4) Madrid train bombings (demonstrates political benefits for terrorists).

Incendiaries are similar to explosives and share many characteristics. Incendiaries are used to start fires rather than to destroy through explosion. Generally they are targeted at structures and property rather than directly against people. This makes incendiaries appealing to groups such as animal rights terrorists that seek to minimize casualties. The devices can be as simple as a can of gasoline ignited on a porch, or as sophisticated as a military thermite bomb. The use of fuel-laden jetliners as suicide missiles in the 9/11 attacks can be considered a massive application of improvised incendiary devices.

Countermeasures against incendiary attack are very similar to those against explosive attacks. Effective law enforcement, good intelligence on potential attackers, surveillance of critical sites, and hardening of particularly vulnerable targets can all be helpful. Note that the construction of simple incendiary devices can be very difficult to prevent since there are no legal restrictions on incendiary materials such as gasoline and matches. Prompt fire detection and effective firefighting can limit the damage once an attack occurs.

Case: Michigan State University Agriculture Building Arson (1999)
On December 31, 1999, environmental terrorists affiliated with the Earth Liberation Front (ELF) set fire to the Agriculture Biotechnology Support Project, located in a classroom and office building at Michigan State University. The university was targeted because of its work on genetically modified crops. The fire was set when there were few people in the building. Damages to the building and research equipment totaled approximately $1 million. Four domestic terrorists from Michigan and Ohio were later tried and convicted in federal court for carrying out this attack. This attack, a similar attack against Michigan State in 1992, and an attempted attack against the Michigan Technological University Forestry Center in 2001 are all typical of attacks by environmental terrorist groups. These attacks generally are designed to cause property damage but few deaths and injuries. These attacks also demonstrate the vulnerability of universities and research centers to terrorist attack.

Case: 9/11 Airliner Attacks (2001)
On the morning of September 11, 2001, terrorists hijacked four commercial airliners originating from Boston Logan Airport, Newark International Airport, and Washington Dulles International Airport and then deliberately crashed the aircraft into the World Trade Center in New York City, and the Pentagon in Arlington, Virginia (with a fourth crashing in rural Pennsylvania), killing approximately 3,000 persons and causing billions of dollars in property damage. This coordinated attack was the deadliest act of terrorism in history. The attack would have been even worse had the fourth aircraft hit its intended target, which was presumed to be the White House in Washington, D.C. Instead, passengers attacked the hijackers, probably causing them to crash the aircraft into the open field in Pennsylvania.

Although these attacks began as hijackings, they may be classified as incendiary terrorism because most of the damage was caused by large fires started by the crashing airliners and their spilled jet fuel. It was these fires that caused the collapse of the three largest buildings at New York's World Trade Center, and of portions of the Pentagon building.

These attacks caused major disruption to airline travel, including a temporary ban on all civilian flights in the United States. Significant and expensive changes were made to improve security at airports and aboard aircraft. Substantial damage was caused to the overall U.S. economy, due to the direct and indirect costs of the attacks. With the 9/11 attacks as justification, the United States and its allies launched major military campaigns in Afghanistan, Iraq, and Pakistan that have cost tens of thousands of lives and trillions of dollars. This one terrorist operation, conducted by 19 men armed with knives, continues to have global repercussions years after the event.

The 9/11 attacks demonstrate the ability of terrorists to seek out vulnerabilities and to creatively exploit them. The attacks were incredibly effective because the terrorist tactics were unexpected, and terrorists will continue to attempt to surprise their targets with new weapons and techniques. These attacks also illustrate that a major terrorist attack can have repercussions that extend well beyond the immediate scene of the attack.

Suggested case for readers' further study: Alphabet bomber (example of multiple incendiary attacks as part of an individual's terror campaign).

Shooting attacks are a popular tactic for both terrorists and criminals. Firearms can be used to target a specific individual or to attack many people in a crowded place. Small arms such as pistols, rifles, and shotguns are easily available in the United States, including semi-automatic weapons with large capacity magazines. Shootings at schools and workplaces are among the most common types of major criminal attack.

An important drawback to the use of firearms, particularly in a mass shooting, is that the attacker is not likely to escape. Therefore shootings are usually carried out by suicide attackers, those expecting to be arrested, or criminals who are acting impulsively and without thought to consequences.

Countermeasures against shooting attacks are difficult, since attackers usually choose unprotected public areas. Protection against attacks has to be balanced against the public's need to use their schools, shopping malls, government buildings, and workplaces. Appropriate security measures and effective lock-down training can limit casualties in high-risk buildings such as schools. Rapid response by well-trained law enforcement officers and emergency medical personnel is also very important.

Case: Columbine School Shooting (1999)
On April 20, 1999, two students staged an attack at Columbine High School near Denver, Colorado. Although the criminals attempted to use explosives, all of the casualties were inflicted with small arms. Using a variety of handguns and shotguns, the criminals killed 13 teachers and students and wounded 24 others. By targeting crowds of students during lunch, the attackers were able to inflict all of the casualties within 23 minutes. The criminals expected to die during the attack and took their own lives at the end of their assault. This attack demonstrates the vulnerability of facilities, such as schools, where large numbers of victims can be founds in close proximity. It also illustrates the short duration of most mass shooting attacks and the need for a very rapid law enforcement response.

Case: Mumbai Attacks (2008)
On November 26, 2008, terrorists attacked the Indian city of Mumbai. The primary weapons employed were rifles and handguns, though small explosives were also used. Ten terrorists attacked six targets across Mumbai's downtown area, including hotels, a railway station, a hospital, a restaurant, and a Jewish community center. There were also shootings on the city streets and several diversionary attacks. In total, more than 160 persons were killed and more than 290 injured. Sixteen of the dead and many of the injured were law enforcement officers. The attack was conducted by Lashkar-e-Taiba, a Pakistani extremist Islamist group. The attackers intended to die during their mission, though one man was taken alive. This case demonstrates the large number of casualties that can be inflicted by firearms in a crowded urban environment. It also demonstrates the significant challenge for law enforcement when suddenly confronted with a number of heavily-armed and suicidal gunmen, and the substantial police casualties which may result.

Case: Fort Hood Shooting (2009)
On November 5, 2009, a single gunman launched a shooting attack at the Fort Hood military post, located near Killeen, Texas. The attacker was Major Nidal Malik Hasan, a U.S. Army psychologist. Using a single handgun, Hasan killed 13 military personnel and wounded 29 others before being subdued. Hasan is accused of terrorism; acting for political reasons related to his extremist Islamist beliefs. It is believed that he was radicalized though the Internet and specifically through contact with Anwar al-Awlaki, a member of the terrorist group "Al Qaeda in the Arabian Peninsula." This case demonstrates the potential lethality of a highly trained and well-equipped gunman. Maj. Hasan made far more effective use of his weapon than other mass shooters, which can be attributed to his high level of training and preparation. It also demonstrates the danger posed by "lone wolf" attackers (self-radicalized and acting outside of the direct control of an established terrorist organization). Finally, it is an alleged example of an American citizen acting on behalf of a cause typically identified with international terrorists. As an American and a member of

the military, Maj. Hasan does not fit the expected terrorist profile, which may have enabled him to avoid detection as a deadly threat.

Suggested cases for readers' further study: (1) Virginia Tech shooting (an example of heavy casualties caused by a single gunman, and of a university target), (2) D.C. Beltway Sniper (example of random attacks, the effectiveness of a small team, long-range shooting, and widespread public fear), (3) Beslan School attack (an example of massive casualties, terrorist targeting of young children, difficult rescue operations, and a large suicide team with military weapons).

Chemical weapons attacks involve the use of poisonous materials, usually toxic gases. This is a potentially dangerous type of weapon, but is difficult to use effectively. Poison gas tends to disperse quickly and unpredictably, which reduces casualties even when used on an unsuspecting target. Chemical weapons attacks are very similar in effect to the accidental release of hazardous materials.

As with explosives, there are many possible types of chemical weapons. Military gases such as nerve gases can be deadly, but are difficult to acquire or manufacture. Commercial gases such as chlorine and hydrogen cyanide are produced in massive quantities and easier to find, but they are less effective. One possible terrorist tactic is to attack chemical storage facilities in order to harm the surrounding communities.

Chemical attacks have been rare in practice. Despite their theoretical effectiveness, few terrorists or criminals have attempted to use chemical weapons and most of their attacks have failed.

Case: Tokyo Sarin Attack (1995)

On March 20, 1995, Japanese domestic terrorists launched a poison gas attack on the Tokyo subway system. The perpetrators were members of Aum Shinrikyo, a religious cult with extensive financial and scientific resources. The terrorists manufactured their own supply of the military nerve gas Sarin. This attack demonstrates that while it is difficult to create mass casualties with terrorist chemical weapons, it is comparatively easy to cause mass panic.

Although the nerve gases used in Tokyo were highly lethal, and the attackers intended to cause many casualties, the terrorists had difficulty in spreading the gas effectively. Twelve people died in the attack, approximately fifty were severely injured, and more than a thousand suffered more limited health effects. The attacks did cause considerable alarm, and medical facilities were overwhelmed by uninjured but frightened citizens. One lesson learned from this attack was the importance of preparing first responders and emergency room personnel to deal with chemically contaminated victims.

Suggested case for readers' additional study: Afghan girls' school attacks (an example of non-fatal uses of toxic gas, recent attacks, and schools as targets).

Biological weapons use disease organisms to cause illness and death. This type of attack is sometimes referred to as "germ warfare." Some biological weapon organisms, such as anthrax, will sicken victims that come in contact with weapon materials, but the victims cannot easily spread their disease to others. This type of attack resembles the use of a chemical weapon. Other germ warfare organisms, such as smallpox and plague, can pass from one victim to another, allowing an initially small attack to eventually infect a large number of victims.

Biological weapons may be attractive to terrorists and criminals because some varieties are relatively easy to produce. A widespread disease outbreak could potentially sicken many people and cause widespread panic. In addition, biological terrorism can be targeted against crops or livestock if the attacker wishes to causes significant economic damage instead of human casualties.

Biological weapons also possess drawbacks for potential attackers. The effects are hard to control and a disease released against a terrorist's enemies might very well spread to infect the attacker's friends and allies. Another problem is that the most deadly germ warfare agents, such as smallpox and breathable anthrax, are quite difficult to manufacture. In addition, standard infectious disease control techniques, such as patient isolation, antiseptics, hand washing, and antibiotics, can be very effective countermeasures against biological attacks, just as they are against natural disease outbreaks.

One major consideration for potential biological attacks is that germ warfare is often not recognized as an attack. Victims often do not show symptoms for several days and unlike a bomb explosion or mass-shooting, biological attacks are often mistaken for naturally occurring diseases. This may be an advantage for certain criminals who want their attacks to go unrecognized, but may be a major drawback for a terrorist who wants to use a biological attack to achieve political goals.

Case: Rajneeshee Salmonella Attack (1984)
During September and October 1984, followers of the fringe religious leader Bhagwan Shree Rajneesh deliberately attacked residents of The Dalles, Oregon, with the salmonella organism. Salmonella was spread by means of contaminated glasses of water and by spraying the organism on restaurant salad bars. A total of 751 people were sickened and 45 were hospitalized. None of the victims died.

The attack was an attempt to reduce voter turnout in a local election, allowing the Rajneeshee religious community to gain control of the Wasco County Circuit Court. The perpetrators did not intend for their attack to be recognized. They hoped that it would be mistaken for an accidental outbreak of food poisoning. Only after the group was investigated for other crimes was the outbreak recognized as a deliberate biological attack.

This attack is a creative example of the criminal use of biological agents. It demonstrates the difficulty in identifying a biological event as a deliberate attack.

Case: Amerithrax Anthrax Attack (2001)
In October 2001, several letters contaminated with anthrax were mailed to locations in Florida, New York, and Washington, DC. The intended targets were politicians and members of the media, but most of the victims were accidentally exposed. Twenty-two victims suffered a confirmed anthrax infection and five died. Several structures, including government office buildings and postal facilities, were contaminated by anthrax and required expensive decontamination before they could be reoccupied. Fortunately, anthrax does not spread easily from person to person and the disease outbreak was quickly contained.

The content of the contaminated letters had initially suggested that Islamic terrorists were responsible for the attack. Following shortly after the 9/11 terrorist disaster, the Amerithrax attack was the subject of considerable media coverage and caused great national concern. Public fear was heightened by a large number of “copycat” incidents which followed over the next several months, though fortunately all of these proved to be mere hoaxes.

Eventually federal investigations determined that the attack was conducted by a domestic criminal posing as a foreign terrorist. In 2008, a U.S. government anthrax researcher was identified as the likely source of the attacks. An indictment was sought by the United States Attorney’s Office, but the suspect committed suicide before his arrest. The likely motive was personal and professional gain, as the attacks increased funding for the researcher’s anthrax vaccine project.

This incident is an example of a criminal use of biological weapons. It demonstrates that it can sometimes be difficult to determine whether an attack is criminal or terrorist in nature. It also shows that attackers are not all foreigners or members of the radical political fringe; in this case the criminal was a highly trusted government employee.

Radiological weapons, sometimes called Radiological Dispersal Devices (RDDs) or “dirty bombs,” are weapons designed to spread hazardous radiological materials. These devices do not create a nuclear explosion. The most standard design for a radiological bomb surrounds conventional explosives, such as dynamite or gunpowder, with radioactive materials in the form of powder or scraps of metal. Such a bomb would do the same damage as a normal (non-radiological) explosive and in addition would spread radioactive materials around the area near the explosion.

No radiological weapon has even been used in an actual attack. However, based on U.S. government tests of dirty bomb designs, the health effects of this type of weapon would likely be quite limited. It is difficult to create enough contamination to make victims seriously ill and even more difficult to cause deaths through radiation. It is likely that more people would be killed by the normal explosives in a dirty bomb than would be seriously hurt by the effects of radiation. However, cleaning up an area once it has been contaminated by radioactive materials would be extremely difficult and expensive. In addition, radioactive threats tend to cause a great deal of fear in the general public. This makes radiological weapons potentially very useful for terrorists: they create little actual destruction, but considerable terror and disruption.

Radiological weapons are considered a serious threat because the components for a dirty bomb have legitimate civilian uses and can easily be stolen by terrorists or criminals. Hospitals, food processing plants, and research centers all possess radioactive materials that would be of use in making a weapon. There is a proven black market in radioactive materials, particularly involving sources stolen from Eastern European countries. Plans for radiological weapons have been discovered in the hands of several potential terrorists, including U.S. domestic terrorists.

Case: Goiânia accident (1987)
No actual radiological weapon has ever been used in a criminal or terrorist attack. However, one radiological hazardous material incident demonstrates the possible health effects of a major successful attack. On September 13, 1987, medical equipment was stolen from an abandoned hospital in Goiânia, Brazil. The thieves were seeking metal for salvage and were unaware that they had taken a powerful radioactive source. The protective casing for the equipment's caesium chloride source was cracked open with a hammer and the deadly material dispersed through homes and businesses. The victims, some of whom were children, and none of whom were aware of the danger, handled the radioactive caesium and in some cases painted it on their bodies or ate it.

The danger was not recognized for more than two weeks, when doctors identified the radioactive material. When the incident was made public, local medical facilities were then overwhelmed by approximately 130,000 persons seeking medical care. Eventually, 249 victims were found to be contaminated, four of whom died. Extensive clean-up work required widespread radioactive monitoring, demolition of a number of buildings, excavation of contaminated soil, and disposal of large amounts of radioactive waste.

The Goiânia accident represents nearly a worst case example of radioactive contamination. The material involved was especially dangerous and the danger was undetected for several weeks. Victims had ongoing close contact with the radioactive material, including ingestion. A dirty bomb attack would likely be detected immediately, and a much timelier and more effective response conducted. Despite the seriousness of this incident, there were only four deaths, although cleanup was difficult and expensive. Public fear of radiation led to large numbers of unexposed but concerned persons demanding medical treatment.

Nuclear weapons are potentially the deadliest terrorist tools. Unlike the radiological "dirty bombs" described above, nuclear weapons create very large explosions capable of creating widespread damage and many casualties over a large area. The great destructive potential of these devices make them very desirable for terrorist groups that wish to cause massive and indiscriminate casualties. Fortunately, nuclear weapons are difficult to build, especially because they require the use of rare and carefully guarded materials. Although several terrorist groups have actively sought to acquire nuclear weapons, no terrorist organization is known to have succeeded in doing so.

The importance of the terrorist nuclear threat is not that such an attack is likely, but that it is possible, and that the damage caused by such an attack would be immense. Nuclear weapons cause damage by releasing enormous amounts of heat, by creating powerful explosive shock waves, by releasing damaging radiation, by disrupting electronic devices, and in some cases, by creating radioactive dust, called fallout, that drifts downwind from nuclear explosions.

Nuclear weapons vary greatly in their power and effects: the weapons most likely to be used by terrorists are very dangerous, but are still far less powerful than the strategic nuclear weapons possessed by nations such as the United States, Russia, and China.

For more detail on nuclear weapons and their effects, see the Nuclear Attack section of this document.

Case: Bombings of Hiroshima and Nagasaki (1945)
Although the nuclear attacks against Japan at the end of World War II were military strikes rather than terrorism or criminal activity, these cases are included because these are the only examples of nuclear weapons used against populated areas. The attacks, each using one nuclear bomb, destroyed the centers of the cities of Hiroshima and Nagasaki, though not their outskirts. At Hiroshima, 4.7 square miles of the city were destroyed and approximately 100,000 residents were killed. At Nagasaki, 1.8 square miles were destroyed and approximately 60,000 died. In both cases, the greatest cause of damage and destruction was intense heat and fire. The weapons used against the cities of Hiroshima and Nagasaki were weak by modern military standards, but were approximately the strength of the most likely types of terrorist nuclear weapons. These attacks provide a very rough guide as to the damage and casualties to be expected from a terrorist nuclear attack against a medium-sized city.

Sabotage is the destruction of property or the disruption of operations in an attempt to harm a business, government, or other entity. Attackers who use sabotage are called saboteurs. Sabotage often overlaps with, and can be difficult to distinguish from, other terrorist or criminal tactics. For example, explosives can be used to destroy vehicles or infrastructure, or chemical poisons can be used to contaminate food and medicine. The principal identifying characteristic of sabotage is that the attack is unusually not intended to harm large numbers of people, but rather to cause economic harm or embarrassment to the target. Where deaths or injuries do occur, they are usually incidental, rather than the purpose of the attack. Past sabotage tactics have included the toppling of electrical power pylons, the burning of vehicles, destruction of railroads and bridges, and contamination of food and medicine.

Many single-issue terrorists, including ecological extremists and anti-abortion radicals, have used sabotage widely. These groups have usually preferred to destroy property rather than to kill people. Most other terrorists tend to avoid sabotage as they seek the media coverage that results from numerous casualties. Sabotage by non-terrorist criminals is difficult to characterize, as it ranges from planned campaigns by organized labor groups, to one-time extortion plots, to attacks by mentally disturbed individuals.

Case: Byron Center Meat Tampering (2003)
In January 2003, a disgruntled employee intentionally contaminated 250 pounds of ground beef sold at a local supermarket in Byron Center (Kent County), Michigan. The meat was poisoned with insecticide containing harmful amounts of nicotine. The attacker was seeking revenge on his supervisor, whom he hoped would be blamed for the illnesses. Although the ground beef contained potentially lethal doses of toxin, there were no fatalities resulting from the attack. Investigation did identify 92 individuals sickened by the poison. The attacker was convicted and sentenced to seven years in prison. This incident demonstrates the willingness of some saboteurs to endanger the lives of numerous bystanders in pursuit of their goals. In this case, the attacker had no specific interest in harming the poisoning victims, except to use them to embarrass a personal enemy.

Case: Pontiac School Bus Bombings (1971)
On August 30, 1971, ten Pontiac school buses were bombed and destroyed in response to a controversial, court-ordered busing plan to integrate Pontiac schools. Authorities believe that several individuals slipped through a hole cut in the wire fence that surrounded the Pontiac bus depot, and placed dynamite under the buses. The explosion and fire destroyed the buses and focused national attention on Pontiac and the school busing issue. Subsequent attempts to overturn the Pontiac busing plan failed, and eventually 70 other school districts across the country were ordered to implement similar busing plans to achieve racial integration in schools. The Pontiac bombers, later apprehended and convicted of the attack, were identified as members of the Ku Klux Klan.

Suggested case for readers' further study: Tylenol cyanide poisonings (an example of a major impact on industry, and an unknown perpetrator with an undetermined motive).

Cyber-attack is a new category of terrorist and criminal threat. Cyber-attacks involve the use of computers, electronic devices, and/or the Internet to attack computer systems. Examples of some types of cyber-attacks include computer viruses, which damage many infected computers, denial-of-service attacks, which shut down a targeted website, and hacking attacks, which damage sensitive information. These attacks may be used as part of extortion schemes, to undermine public confidence in the target's security, as a form of technological vandalism, or as military sabotage.

Early cyber-attacks were primarily conducted by amateur computer "hackers" operating individually or in small teams. More recently, well organized groups of profit-driven professional cyber-attackers have developed. These teams of cyber-saboteurs can operate globally, attacking targets anywhere in the world through the Internet. Their customers include organized crime, national governments, and possibly terrorist organizations. These professional cyber-attackers can be very effective because they control large networks of "zombie" computers called "botnets." These are computers taken over without their owners' knowledge and controlled remotely, often for criminal purposes.

Another possible source of cyber-attacks are "hacktivists," computer criminals motivated by a political cause rather than by a profit motive. Several global networks of hacktivists have been created, including "Anonymous" and "Lutzsec." These loosely organized groups include members in multiple countries who coordinate their efforts online. There are also a number of nationalist hacktivist organizations, some of which may be sponsored by national intelligence services. Hacktivists groups are difficult to disrupt, both because of the challenge in determining the real identity of group members, and because they may be located in countries which refuse to cooperate with international law enforcement. Hacktivists have generally confined their cyber attacks to vandalism of websites, denial of service attacks, and theft of personal information. There is however, the potential for extremist members of these politically-motivated groups to shift their activities to more destructive cyber-terrorism.

National governments are also developing sophisticated cyber-attack capabilities, both to support espionage programs and to damage the computer networks of enemies. Cyber-attacks backed by extensive national military and intelligence resources could be especially destructive and difficult to counter. One new cyber-attack capability which appears to have been deployed by government-sponsored programmers is the ability to cripple or destroy industrial machinery by taking over the software that controls the machines. Cyber-attacks on these "industrial control systems" could be used to damage critical infrastructure such as electrical grids, water treatment systems, and fuel pipelines as well as to attack industrial targets. National cyber-attack capabilities are also expected to include efforts to disrupt secure national networks such as those used for banking and by law enforcement. A cyber war between nations with sophisticated cyber-attack capabilities could be very damaging, even to innocent bystanders in the conflict.

An analysis of cyber-attacks usually requires special resources to identify and report details about ongoing or past significant incidents that involve attacks upon or exploitation of computer networks or communications system. The Michigan Intelligence Operations Center especially tracks any such operations that impact the U.S. homeland or national security interests.

Here are some examples of information that may be noted and reported about cyber-attacks:

- What type of activity occurred?
    - Data exfiltration
        - If data was exfiltrated, how much and what type?
        - To what IP address?
    - Malicious file infiltration
    - Malware detection
    - Botnet activity

    - Spear Phishing
- What attack vector was used?
- What vulnerability did the threat actors exploit/attempt to exploit?
    - Known vulnerability for which a patch exists (include Common Vulnerabilities and Exposures [CVE] number if known)
- Upon gaining access, what did the threat actors do?
    - Scan for vulnerabilities and attempt to move laterally across the network
    - Host malware on a system
    - Compromise Active Directory server / Domain controller
    - Create additional accounts
    - Exfiltrate username and password hashes
    - Exfiltrate specific types of documents (either by name/subject or file type)
    - Exfiltrate whatever files and information they could get access to
- IP addresses involved in malicious activity?
    - The number of times the IP was involved in an event on that given day
    - The country associated with the IPs
- What malicious websites or domains were involved?
    - Indicate what IP address the domain resolved to at the time of the incident
    - Domain/IP registration information if available, including country of origin
    - Other domains hosted by malicious IPs
- When did the activity occur?
    - In addition to the date, include the period of time (the hours) from when the activity was detected to when it stopped
    - Each day the IP was involved, if across multiple days
- Phishing and Spear Phishing
    - E-mail header information
        - Sending IP
        - Mail relays involved
        - True email address (if message was spoofed)
    - Subject line
    - Attachments (more information in the next bullet section for malicious attachments)
    - Hyperlinks in the email, including the actual destination for any spoofed links
    - Text from the body
    - For spear phished individuals, include how the malicious actor attempted to bait their target
- What malicious code/software was detected or what indicators were associated with malicious files?
    - File name
    - File size
    - Hash values (e.g. MD5, SHA-1, ssdeep)
    - Timestamps
    - Additional malware information
- What botnet(s) were associated with the incident?

Case: July 2009 Cyber-Attacks (2009)

On the 4th of July, 2009, a series of cyber-attacks were directed against computer systems in the United States and in South Korea. Targets included the websites of the U.S. State Department, the U.S. Department of Defense, the White House, numerous South Korea government agencies, a large bank, and a major South Korean media company. The attacks were designed to shut down the targeted websites by overloading them with traffic. This was accomplished with a "botnet" of computers infected by a computer virus. Thousands of computers were hijacked and used in these attacks without their owners' knowledge. The cyber-attack software was also designed to damage the computers in the botnet several days after the start of the attack. Some experts believe that the attack was sponsored by the government of North Korea, perhaps with the help of criminal networks operating outside of that country. As with many cyber-attacks, it has been impossible to definitively prove who was responsible for the attacks. This case demonstrates the significant economic and governmental disruption which can be caused by even primitive cyber-attacks. It also demonstrates that the geographic locations of the cyber-attackers and of their targets are largely irrelevant. Attacks can be launched from anywhere, to anywhere, through the use of the Internet.

Case: Stuxnet (2010-Present)
First discovered in June of 2010, Stuxnet is a highly sophisticated cyber-attack program. This “computer worm” software has been designed to infect industrial control systems created by the Siemens Corporation. On most computers, the Stuxnet worm stays hidden and does no damage. However, if the Siemens control software is connected to certain types of motors, the worm conducts a cyber-attack on the infected system. The targeted motor is ordered to rapidly change speeds, which will destroy certain types of connected industrial equipment. Meanwhile the safety mechanisms on the equipment are disabled, and monitors will show motor performance as completely normal, even as the equipment is being destroyed. It is believed that Stuxnet was designed specifically to damage uranium processing equipment operated by the government of Iran. Substantial harm was apparently inflicted on its processing facility at Natanz. The creators of Stuxnet are unidentified, but given the sophistication of the software, and the care with which only Iranian government systems were targeted, it is considered likely that at least one national intelligence service was involved in creating the worm. Several governments have expressed an interest in damaging Iran’s nuclear industry in order to stall the creation of Iranian nuclear weapons. The case provides an example of the sophisticated cyber-attack tools which may be deployed by national governments. It also provides the first example of cyber-attack software capable of causing physical damage, not merely theft or destruction of data.

Possible Terrorist/Criminal Targets

Terrorists typically select targets that will generate the maximum possible media coverage, but the specific types of targets selected by terrorists and criminals depend entirely on the goals of the attackers. For nationalist, left-wing, and right-wing terrorists, the preferred targets are usually buildings or people with strong symbolic meaning for their enemies. These terrorists may attack government buildings, strike public monuments, or assassinate well-known leaders. Single-issue terrorists tend to target facilities or individuals directly associated with their specific cause. For example, anti-abortion terrorists might target abortion clinics, anti-Jewish terrorists might target synagogues, and animal rights terrorists may target animal research centers. Finally, religious extremist terrorists tend to emphasize killing or injuring large numbers of victims in a spectacular manner. These terrorists might be expected to target schools, airports, mass-transportation systems, sporting events, places of worship, or entire cities.
Most terrorists will usually seek out targets that are poorly defended by law enforcement, security screening, or other protective measures. Such “soft” targets offer the opportunity to do the maximum possible damage. Even terrorists who do not intend to survive their attack want to accomplish their mission, and well-protected targets can make that difficult to achieve. Terrorists rarely feel the need to strike only one specific target, so they will examine multiple targets until they find one that is vulnerable.

Targets for non-terrorist criminals are difficult to identify because criminals may have a wide range of motivations, including financial gain, personal revenge, a desire for fame, or mental illness. Criminals are generally more likely to choose targets that they are personally connected with, as when criminal employees target their workplace or criminal students target their own school building.

Impacts of Terrorism and Similar Criminal Activities

Impact on the Public

The specific impact of terrorism or similar criminal activities would depend on the nature of the terrorist targets and the type of weapons used against those targets. Given the wide range of possibilities, it is difficult to generalize about damage or casualties. In a worst case scenario, a terrorist or criminal attack could cause significant damage to people, property, and to the economy. Infrastructure, such as transportation, computer networks, or communications might be damaged or overwhelmed by a fearful population. Worst case scenarios, however, are unusual. Most attacks will do little damage and only a very few will cause mass casualties. One likely impact of terrorism on the public would be an increase in fear, uncertainty, and inconvenience. Terrorism is, after all, intended to cause terror. In some cases, innocent citizens may suffer misguided retaliation if they are identified with an ethnic group or political movement held responsible for terrorism. Public impact may also be increased by the effect of government anti-terrorism programs, as demonstrated by the inconvenience created by increased airport security measures.

Impact on Public Confidence in State Governance

Public reaction to terrorist attacks would vary depending on the effectiveness of the attack and the type of target. It is possible that state government would be held accountable for failing to stop a terrorist plot, though counter-terrorism is generally considered to be a federal government responsibility. Governments may also be pressured to create new legal restrictions and law enforcement measures in response to a terrorist attack. Such measures would be expected to create public opposition from citizens who feel their rights violated by counter-terrorism efforts. Finding the correct balance between civil liberties and public security is likely to remain a difficult challenge.

Impact on Responders

Responders may face difficult and unexpected challenges following a terrorist or criminal attack, especially if the attack involves mass casualties or uses chemical, biological, radiological, nuclear, or cyber attack. Terrorists, and criminals who conduct terrorist-like violent attacks, may behave very differently from other types of criminals with which responders are familiar. Terrorist weapons may pose a direct hazard to the life and safety of responders, especially in the case of secondary devices specifically targeted on those responders.

Impact on the Environment

Terrorist and violent criminal attacks are very rarely targeted specifically on the environment, but environmental damage is possible as an indirect consequence of an attack. This would be especially true in the case of chemical, radiological, biological, or nuclear weapons which could contaminate a significant area for an extended period of time. Damage to infrastructure may also cause environmental problems, as in the case of an oil pipeline sabotaged with explosives or a metropolitan water treatment system disabled by cyber-attack. Please refer to the sections on dam failures, energy emergencies, fires, hazardous materials, infrastructure failure, nuclear attack, oil and natural gas pipeline and well accidents, public health emergencies, and transportation accidents for more examples of the type of impacts that may result from terrorism or major criminal incidents.

THIRA Hazard Analysis
August 2012 DRAFT
Step 3 (beginning)

This new section begins to address the many potential impacts of hazards upon the State of Michigan. Although the previous section, describing Michigan's hazards and providing descriptive context for them, is quite similar to material appearing in other Michigan planning documents, this new section is designed specifically to proceed with new types of threat and hazard assessment, according to FEMA's guidelines of April, 2012 (CPG 201: Threat and Hazard Identification and Risk Assessment Guide).

In order to prevent any specific Michigan vulnerabilities from being revealed and exploited by persons or groups that have harmful intentions, the following information has been expressed in fairly general terms. The Federal Emergency Management Agency has identified 47 categories of "core capabilities" across five general "mission areas" that are similar to the traditional "phases" of emergency management. These have been described in the National Preparedness Goal, and it is necessary to be familiar with these definitions in order to correctly interpret thae Michigan-specific information that follows.

Prevention: The prevention mission area includes those capabilities necessary to avoid, prevent, or stop a threatened or actual act of terrorism. It is focused on ensuring an optimal level of preparedness to prevent an imminent terrorist attack within the United States.

1. Planning
Conduct a systematic process engaging the whole community as appropriate in the development of executable strategic, operational, and/or community-based approaches to meet defined objectives.

2. Public Information and Warning
Deliver coordinated, prompt, reliable, and actionable information to the whole community through the use of clear, consistent, accessible, and culturally and linguistically appropriate methods to effectively relay information regarding any threat or hazard, as well as the actions being taken and the assistance being made available, as appropriate.

3. Operational Coordination
Establish and maintain a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders and supports the execution of core capabilities.

4. Forensics and Attribution
Conduct forensic analysis and attribute terrorist acts (including the means and methods of terrorism) to their source, to include forensic analysis as well as attribution for an attack and for the preparation for an attack in an effort to prevent initial or follow-on acts and/or swiftly develop counter-options.

5. Intelligence and Information Sharing
Provide timely, accurate, and actionable information resulting from the planning, direction, collection, exploitation, processing, analysis, production, dissemination, evaluation, and feedback of available information concerning threats to the United States, its people, property, or interests; the development, proliferation, or use of WMDs; or any other matter bearing on U.S. national or homeland security by Federal, state, local, and other stakeholders. Information sharing is the ability to exchange intelligence, information, data, or knowledge among Federal, state, local, or private sector entities, as appropriate.

6. Interdiction and Disruption
Delay, divert, intercept, halt, apprehend, or secure threats and/or hazards.

7. Screening, Search and Detection
Identify, discover, or locate threats and/or hazards through active and passive surveillance and search procedures. This may include the use of systematic examinations & assessments, sensor technologies, or physical investigation & intelligence.

Protection: The protection mission area includes capabilities to safeguard the homeland against acts of terrorism and man-made or natural disasters. It is focused on actions to protect the citizens, residents, visitors, and critical assets, systems, and networks against the greatest risks to our Nation in a manner that allows national and citizen interests, aspirations, and way of life to thrive, creating conditions for a safer, more secure, and more resilient Nation by enhancing protection through cooperation and collaboration with all sectors of society.

8. Planning
Conduct a systematic process engaging the whole community, as appropriate, in the development of executable strategic, operational, and/or community-based approaches to meet defined objectives.

9. Public Information and Warning
Deliver coordinated, prompt, reliable, and actionable information to the whole community through the use of clear, consistent, accessible, and culturally and linguistically appropriate methods to effectively relay information regarding any threat or hazard, as well as the actions being taken and the assistance being made available, as appropriate.

10. Operational Coordination
Establish and maintain a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders and supports the execution of core capabilities.

11. Access Control and Identity Verification
Apply a broad range of physical, technological, and cyber measures to control admittance to critical locations and systems, limiting access to authorized individuals to carry out legitimate activities.

12. Cybersecurity
Protect against damage to, the unauthorized use of, and/or the exploitation of (and, if needed, the restoration of) electronic communications systems and services (and the information contained therein).

13. Intelligence and Information Sharing
Provide timely, accurate, and actionable information resulting from the planning, direction, collection, exploitation, processing, analysis, production, dissemination, evaluation, and feedback of available information concerning threats to the United States, its people, property, or interests; the development, proliferation, or use of WMDs; or any other matter bearing on U.S. national or homeland security by Federal, state, local, and other stakeholders. Information sharing is the ability to exchange intelligence, information, data, or knowledge among Federal, state, local or private sector entities as appropriate.

14. Interdiction and Disruption
Delay, divert, intercept, halt, apprehend, or secure threats and/or hazards.

15. Physical Protective Measures
Reduce or mitigate risks, including actions targeted at threats, vulnerabilities, and/or consequences, by controlling movement and protecting borders, critical infrastructure, and the homeland.

16. Risk Management for Protection Programs and Activities
Identify, assess, and prioritize risks to inform Protection activities and investments.

17. Screening, Search and Detection
Identify, discover, or locate threats and/or hazards through active and passive surveillance and search procedures. This may include the use of systematic examinations and assessments, sensor technologies, or physical investigation and intelligence.

18. Supply Chain Integrity and Security
Strengthen the security and resilience of the supply chain.

Mitigation: The mitigation mission area includes those capabilities necessary to reduce loss of life and property by lessening the impact of disasters. It is focused on the premise that individuals, the private sector, communities, critical infrastructure, and the Nation as a whole are made more resilient when the consequences and impacts, the duration, and the financial and human costs to respond to and recover from adverse incidents are all reduced.

19. Planning
Conduct a systematic process engaging the whole community as appropriate in the development of executable strategic, operational, and/or community-based approaches to meet defined objectives.

20. Public Information and Warning
Deliver coordinated, prompt, reliable, and actionable information to the whole community through the use of clear, consistent, accessible, and culturally and linguistically appropriate method to effectively relay information regarding any threat or hazard, and, as appropriate, the actions being taken and the assistance being made available, as appropriate.

21. Operational Coordination
Establish and maintain a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders and supports the execution of core capabilities.

22. Community Resilience
Lead the integrated effort to recognize, understand, communicate, plan, and address risks so that the community can develop a set of actions to accomplish Mitigation and improve resilience.

23. Long-term Vulnerability Reduction
Build and sustain resilient systems, communities, and critical infrastructure and key resources lifelines so as to reduce their vulnerability to natural, technological, and human-caused incidents by lessening the likelihood, severity, and duration of the adverse consequences related to these incidents.

24. Risk and Disaster Resilience Assessment
Assess risk and disaster resilience so that decision makers, responders, and community members can take informed action to reduce their entity's risk and increase their resilience.

25. Threats and Hazard Identification
Identify the threats and hazards that occur in the geographic area; determine the frequency and magnitude; and incorporate this into analysis and planning processes so as to clearly understand the needs of a community or entity.

Response: The response mission area includes those capabilities necessary to save lives, protect property and the environment, and meet basic human needs after an incident has occurred. It is focused on ensuring that the Nation is able to effectively respond to any threat or hazard, including those with cascading effects, with an emphasis on saving and sustaining lives and stabilizing the incident, as well as rapidly meeting basic human

needs, restoring basic services and community functionality, establishing a safe and secure environment, and supporting the transition to recovery.

26. Planning
Conduct a systematic process engaging the whole community as appropriate in the development of executable strategic, operational, and/or community-based approaches to meet defined objectives.

27. Public Information and Warning
Deliver coordinated, prompt, reliable, and actionable information to the whole community through the use of clear, consistent, accessible, and culturally and linguistically appropriate methods to effectively relay information regarding any threat or hazard, as well as the actions being taken and the assistance being made available, as appropriate.

28. Operational Coordination
Establish and maintain a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders and supports the execution of core capabilities.

29. Critical Transportation
Provide transportation (including infrastructure access and accessible transportation services) for response priority objectives, including the evacuation of people and animals, and the delivery of vital response personnel, equipment, and services into the affected areas.

30. Environmental Response / Health and Safety
Ensure the availability of guidance and resources to address all hazards including hazardous materials, acts of terrorism, and natural disasters in support of the responder operations and the affected communities.

31. Fatality Management Services
Provide fatality management services, including body recovery and victim identification, working with state and local authorities to provide temporary mortuary solutions, sharing information with mass care services for the purpose of reunifying family members and caregivers with missing persons/remains, and providing counseling to the bereaved.

32. Infrastructure Systems
Stabilize critical infrastructure functions, minimize health and safety threats, and efficiently restore and revitalize systems and services to support a viable, resilient community.

33. Mass Care Services
Provide life-sustaining services to the affected population with a focus on hydration, feeding, and sheltering to those who have the most need, as well as support for reunifying families.

34. Mass Search and Rescue Operations
Deliver traditional and atypical search and rescue capabilities, including personnel, services, animals, and assets to survivors in need, with the goal of saving the greatest number of endangered lives in the shortest time possible.

35. On-scene Security and Protection
Ensure a safe and secure environment through law enforcement and related security and protection operations for people and communities located within affected areas and also for all traditional and atypical response personnel engaged in lifesaving and life-sustaining operations.

36. Operational Communications
Ensure the capacity for timely communications in support of security, situational awareness, and operations by any and all means available, among and between affected communities in the impact area and all response forces.

37. Public and Private Services and Resources
Provide essential public and private services and resources to the affected population and surrounding communities, to include emergency power to critical facilities, fuel support for emergency responders, and access to community staples (e.g., grocery stores, pharmacies, and banks) and fire and other first response services.

38. Public Health and Medical Services
Provide lifesaving medical treatment via emergency medical services and related operations and avoid additional disease and injury by providing targeted public health and medical support and products to all people in need within the affected area.

39. Situational Assessment
Provide all decision makers with decision-relevant information regarding the nature and extent of the hazard, any cascading effects, and the status of the response.

Recovery: The recovery mission area includes those capabilities necessary to assist communities affected by an incident in recovering effectively. It is focused on a timely restoration, strengthening, and revitalization of the infrastructure; housing; a sustainable economy; and the health, social, cultural, historic, and environmental fabric of communities affected by a catastrophic incident.

40. Planning
Conduct a systematic process engaging the whole community as appropriate in the development of executable strategic, operational, and/or community-based approaches to meet defined objectives.

41. Public Information and Warning
Deliver coordinated, prompt, reliable, and actionable information to the whole community through the use of clear, consistent, accessible, and culturally and linguistically appropriate methods to effectively relay information regarding any threat or hazard, as well as the actions being taken and the assistance being made available, as appropriate.

42. Operational Coordination
Establish and maintain a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders and supports the execution of core capabilities.

43. Economic Recovery
Return economic and business activities (including food and agriculture) to a healthy state and develop new business and employment opportunities that result in a sustainable and economically viable community.

44. Health and Social Services
Restore and improve health and social services networks to promote the resilience, independence, health (including behavioral health), and well-being of the whole community.

45. Housing
Implement housing solutions that effectively support the needs of the whole community and contribute to its sustainability and resilience.

46. Infrastructure Systems
Stabilize critical infrastructure functions, minimize health and safety threats, and efficiently restore and revitalize systems and services to support a viable, resilient community.

47. Natural and Cultural Resources
Protect natural and cultural resources and historic properties through appropriate planning, mitigation, response, and recovery actions to preserve, conserve, rehabilitate, and restore them consistent with post-disaster community

priorities and best practices and in compliance with appropriate environmental and historical preservation laws and executive orders.

The following pages, then, provide descriptive information about how all 47 of these core capabilities within Michigan might be affected by a "worst, most plausible" hazard incident. Following from the development of regional and state hazard scenarios through an involved community coordination and input process over recent years, the following five scenarios are here presented with descriptive impacts: severe winter storm, chemical attack, pandemic influenza, cyber-attack, and improvised explosive devices (IED).

Reviewers of this document are invited to submit suggestions or identify oversights in this impact assessment description. For example, capabilities that that have been marked as "N/A?" in this draft document may actually have relevance that has not yet been identified here. Suggestions for how the information in this impact assessment might be improved are welcome. (The capabilities, definitions, and general nature of the assessment have already been pre-defined by FEMA requirements, however, and are not as readily subject to amendment as the information this process has generated herein.)

Winter Storm – Capability Impacts (35/47)
(Region 1, 5, 6, 7, 8, and state Scenarios)

Prevention (0/7)

1. Planning	N/A (only relevant for terrorist threats)
2. Public Information and Warning	N/A (only relevant for terrorist threats)
3. Operational Coordination	N/A (only relevant for terrorist threats)
4. Forensics and Attribution	N/A (only relevant for terrorist threats)
5. Intelligence and Information Sharing	N/A (only relevant for terrorist threats)
6. Interdiction and Disruption	N/A (only relevant for terrorist threats)
7. Screening, Search and Detection	N/A (only relevant for terrorist threats)

Protection (6/11)

8. Planning	Yes - Planning for a major snow/ice event is beneficial
9. Public Information and Warning	Yes – Thousands of residents need to be warned
10. Operational Coordination	Yes – Storm activities require coordination
11. Access Control and Identity Verification	Yes - (Limit access to blocked roads and damaged sites)
12. Cybersecurity	N/A (No clear connection with storm impacts)
13. Intelligence and Information Sharing	Yes – Information can be very beneficial
14. Interdiction and Disruption	N/A (No clear connection with storm impacts)
15. Physical Protective Measures	N/A? (but may tie in with the Access Control capability)
16. Risk Management for Protection Programs and Activities	N/A? (Some connection can probably be found)
17. Screening, Search and Detection	N/A? (Storm impacts may inhibit this activity)
18. Supply Chain Integrity and Security	Yes – Transportation, infrastructure, energy supply impacts

Mitigation (7/7)

19. Planning	Yes – Staff time, expertise, and information needed for plans
20. Public Information and Warning	Yes – Information and warning to prevent injuries & harm
21. Operational Coordination	Yes – Coordinated mitigation activities
22. Community Resilience	Yes – Arrange for snow clearance & storage, school closures
23. Long-term Vulnerability Reduction	Yes – Pipe & main insulation, snow loads, power system resiliency
24. Risk and Disaster Resilience Assessment	Yes – Could be a part of a hazard analysis & mitigation plan
25. Threats and Hazard Identification	Yes – Plan for snow loads, road clearance, snow dumping sites, etc.

Response (14/14)

26. Planning	Yes – School closures, snow clearance, transportation access
27. Public Information and Warning	Yes – Snow warnings and associated information
28. Operational Coordination	Yes – Road, tree, and line clearance, infrastructure, closures, alerts
29. Critical Transportation	Yes – Mostly EMS & response vehicles, road & runway clearance
30. Environmental Response / Health and Safety	Yes – Snow with excessive soiling/chemicals, envir. effects of road salt
31. Fatality Management Services	Yes – Fatalities tend to either be isolated or transportation-related
32. Infrastructure Systems	Yes – Power supply, water mains, other pipes, transportation systems
33. Mass Care Services	Yes – Snowbound, stranded travelers, areas of power/water failure
34. Mass Search and Rescue Operations	Yes – Isolated snowbound areas, areas with severe infrastructure failure
35. On-scene Security and Protection	Yes – Law enforcement: areas with snow/ice and infrastructure failures
36. Operational Communications	Yes – Emergency response and mass care activities in affected areas
37. Public and Private Services and Resources	Yes – Alternative power sources, wireless communication, water/food
38. Public Health and Medical Services	Yes – Hypothermia, frostbite, other problems in snowbound areas
39. Situational Assessment	Yes – Identify areas with critical transportation/infrastructure issues

Recovery (8/8)

40. Planning	Yes – Snow clearance, infrastructure restoration, service provision
41. Public Information and Warning	Yes – Info about area access, service/infrastructure availability
42. Operational Coordination	Yes – Restore normal access to structures, services, infrastructure
43. Economic Recovery	Yes – From business/infrastructure closures, special event cancellation
44. Health and Social Services	Yes – Especially isolated snowbound, injured, bereaved, other trauma
45. Housing	Yes – Damages from ice dams, fallen trees, wind, snow loads, leaks
46. Infrastructure Systems	Yes – Restoration of power, water, communications, transportation
47. Natural and Cultural Resources	Yes – Risks from ice dams, snow loads, winds, water main break, etc.

Chemical Attack – Capability Impacts (47/47)
(UASI Region 2 Scenario)

Prevention (7/7)	
1. Planning	Yes – Preparing to prevent and handle this sort of terrorist incident
2. Public Information and Warning	Yes – Preparation and release of appropriate warnings & information
3. Operational Coordination	Yes – Include all appropriate agencies, refine protocols
4. Forensics and Attribution	Yes – Analysis of clues, identifying suspects & threats/opportunities
5. Intelligence and Information Sharing	Yes – Distribute and use information to address threats
6. Interdiction and Disruption	Yes – Actions to prevent or reduce threats and impacts
7. Screening, Search and Detection	Yes – Actions to locate and pinpoint threatening objects/agents
Protection (11/11)	
8. Planning	Yes – Planning for likely threats at known vulnerable locations
9. Public Information and Warning	Yes – Involvement of the whole community to guard against threats
10. Operational Coordination	Yes – Involvement of all relevant agencies to protect known targets
11. Access Control and Identity Verification	Yes – Prevent/limit inappropriate access to vulnerable target sites
12. Cybersecurity	Yes – Organizations with physical targets also receive cyber-attacks
13. Intelligence and Information Sharing	Yes – Distribute and use info to protect targets, reduce attack impacts
14. Interdiction and Disruption	Yes – Actions that reduce vulnerabilities and prevent/reduce impacts
15. Physical Protective Measures	Yes – Guarding and reinforcing vulnerable targets, reduce their access
16. Risk Management for Protection Programs and Activities	Yes – Compare the vulnerabilities of at-risk sites, enemy threats/power
17. Screening, Search and Detection	Yes – Scrutinize the access points and vulnerabilities of at-risk sites
18. Supply Chain Integrity and Security	Yes – Assess supply surpluses and redundancies, in case of disruption
Mitigation (7/7)	
19. Planning	Yes – Produce strategies to protect target sites and reduce access
20. Public Information and Warning	Yes – Involvement of the whole community to reduce harmful impacts
21. Operational Coordination	Yes – Advance coordination/training of agencies, develop strategies
22. Community Resilience	Yes – Work to reduce vulnerabilities and potential attack impacts
23. Long-term Vulnerability Reduction	Yes – Hardening physical targets, reducing target site accessibility
24. Risk and Disaster Resilience Assessment	Yes – Assessments and analyses of likely target sites and their environs
25. Threats and Hazard Identification	Yes – Identify likely targets, hostile groups, similar situations abroad
Response (14/14)	
26. Planning	Yes – Advance strategies to reduce impacts, apprehend hostile actors
27. Public Information and Warning	Yes – Information, activities & warnings to involve/protect community
28. Operational Coordination	Yes – Enhanced by training, exercises, procedures, advance coord'tion
29. Critical Transportation	Yes – Traffic rerouting and diversion, emergency responder access
30. Environmental Response / Health and Safety	Yes – Hazardous substance response procedures, info & capabilities
31. Fatality Management Services	Yes – Potentially hundreds of fatalities, including haz mat decon needs
32. Infrastructure Systems	Yes – Damaged/blocked roads, highways, pipelines must be overcome
33. Mass Care Services	Yes – Many evacuated/displaced persons need to be accommodated
34. Mass Search and Rescue Operations	Yes – Many trapped and injured persons require assistance
35. On-scene Security and Protection	Yes – Cordoning off areas, arresting suspects, crime scene handling
36. Operational Communications	Yes – Operation of wireless media (incl. radio), EOC, PIO, JIC, FTC
37. Public and Private Services and Resources	Yes – Affected/nearby persons & neighborhoods need water, food, etc
38. Public Health and Medical Services	Yes – Many hospitalizations and thousands of "worried well"
39. Situational Assessment	Yes – Need to establish EOC, connect with agency EMCs, etc.
Recovery (8/8)	
40. Planning	Yes – Plan for damaged infrastructure, housing, traffic diversion, etc.
41. Public Information and Warning	Yes – Notifications, household reunification, shelter/service locations
42. Operational Coordination	Yes – Coordinate EOC, FTC, JIC, Disaster Recovery Center, SEOC
43. Economic Recovery	Yes – SBA loans, disaster assistance, restore infrastructure/services
44. Health and Social Services	Yes – Many thousands of "worried well," relatives, displaced, etc.
45. Housing	Yes – Hundreds of displaced/evacuated residents in the attack area
46. Infrastructure Systems	Yes – Restore area energy, power, water, sewer, transportation systems
47. Natural and Cultural Resources	Yes – Area resource inventory to be developed and used

Pandemic Influenza – Capability Impacts (36/47)
(Region 7 Scenario) Terrorist connections are possible

Prevention (0/7)	
1. Planning	N/A (this capability is only relevant for terrorist threats)
2. Public Information and Warning	N/A (this capability is only relevant for terrorist threats)
3. Operational Coordination	N/A (this capability is only relevant for terrorist threats)
4. Forensics and Attribution	N/A (this capability is only relevant for terrorist threats)
5. Intelligence and Information Sharing	N/A (this capability is only relevant for terrorist threats)
6. Interdiction and Disruption	N/A (this capability is only relevant for terrorist threats)
7. Screening, Search and Detection	N/A (this capability is only relevant for terrorist threats)
Protection (9/11)	
8. Planning	Yes – Public health preparations and arrangements
9. Public Information and Warning	Yes – Prevention info, symptom recognition, use of medical system
10. Operational Coordination	Yes – Arrangements for inoculations, medical access, triage, etc.
11. Access Control and Identity Verification	Yes – Logging/tracking patients, staff, access to medicine, etc.
12. Cybersecurity	N/A? (No clear connection with pandemic influenza)
13. Intelligence and Information Sharing	Yes – Tracking and verifying cases, epidemiological assessment
14. Interdiction and Disruption	N/A? (No clear connection with pandemic influenza)
15. Physical Protective Measures	Yes – Possible quarantine enforcement, mass transit adaptations
16. Risk Management for Protection Programs and Activities	Yes – Quarantine and vector control in health care, public spaces, etc.
17. Screening, Search and Detection	Yes – Locate and verify cases involving pandemic strains, vectors
18. Supply Chain Integrity and Security	Yes – Possible food, purchased goods, HVAC, or transportation vectors
Mitigation (7/7)	
19. Planning	Yes – Population concentrations, vulnerable public spaces, vectors
20. Public Information and Warning	Yes – Info on disease prevention, transmission control, medical access
21. Operational Coordination	Yes – Agency coordination, info distribution, bolster medical capacity
22. Community Resilience	Yes – Public space and transit design that reduces transmission risks
23. Long-term Vulnerability Reduction	Yes – Public/transit designs; capacity for detection, analysis, treatment
24. Risk and Disaster Resilience Assessment	Yes – Assess medical, analytic, info, and disease transmission potential
25. Threats and Hazard Identification	Yes – Biologic, epidemiologic, demographic, design, & vector analysis
Response (13/14)	
26. Planning	Yes – Appropriate assessment and handling of cases/procedures
27. Public Information and Warning	Yes – Info about disease recognition, vector control, proper response
28. Operational Coordination	Yes – Process, verify, treat/contain cases; analyze trends/vectors
29. Critical Transportation	Yes – Safely transport patients, bio-samples, staff, equipment, police
30. Environmental Response / Health and Safety	Yes – Greater chemical use, combustion, and dumping are possible
31. Fatality Management Services	Yes – Certain strains have a great capacity to produce mass fatalities
32. Infrastructure Systems	Yes – Worker shortages, public transit risks, medical system capacity
33. Mass Care Services	Yes – Food/facilities during tests, triage, treatment, and quarantines
34. Mass Search and Rescue Operations	N/A? (No clear connection, unless "atypical" MSAR is considered)
35. On-scene Security and Protection	Yes – Especially quarantine areas, medical supplies, treatment centers
36. Operational Communications	Yes – Relay analytic and logistical info for analysis, EMS, security
37. Public and Private Services and Resources	Yes – Bolster staffing and safety at affected or at-risk workplaces
38. Public Health and Medical Services	Yes – Analysis, triage, transport, treatment, quarantine, and security
39. Situational Assessment	Yes – Case verification, tracking, epidemiology, vector analysis
Recovery (7/8)	
40. Planning	Yes – Restore staffing, normal medical frameworks, undo quarantines
41. Public Information and Warning	Yes – Information about reunification, quarantines, rehabilitations, etc.
42. Operational Coordination	Yes – Remove quarantines, restore normal staffing & medical ops
43. Economic Recovery	Yes – Address impacts of sick employee, reduced travel/spending, etc.
44. Health and Social Services	Yes – Strong psychological impacts, counseling, economic support, etc.
45. Housing	Yes – Increased homelessness, demand for improved HVAC supply
46. Infrastructure Systems	Yes – Bolster staffing, improve HVAC systems & supply
47. Natural and Cultural Resources	N/A? (No clear connection, unless staffing/fatalities are counted)

Cyber Attack – Capability Impacts (39/47)
(Region 2 Scenario) NEEDS INPUT FROM SUBJECT MATTER EXPERTS

Prevention (7/7)

1. Planning	Yes – Protection algorithms & procedures (Details need developing)
2. Public Information and Warning	Yes – Awareness/info about cyber impacts and security
3. Operational Coordination	Yes – System designs, redundancies, "legacy" backups, etc.
4. Forensics and Attribution	Yes – Attack detection and tracing, attribution to human agents
5. Intelligence and Information Sharing	Yes – Coordination between multiple monitors, nodes, targets
6. Interdiction and Disruption	Yes – Mostly performed electronically through automated processes?
7. Screening, Search and Detection	Yes – A combination of human/physical and computer vulnerabilities?

Protection (9/11)

8. Planning	Yes – Protection algorithms and procedures (distinct from #1 above?)
9. Public Information and Warning	Yes – Computer security info, computer literacy, scam alerts, etc.
10. Operational Coordination	Yes – (details need to be developed)
11. Access Control and Identity Verification	Yes – Protection of access points, passwords, system/user info, etc.
12. Cybersecurity	Yes – (but self-referential; details need to be developed)
13. Intelligence and Information Sharing	Yes – (distinction between #5 above?)
14. Interdiction and Disruption	Yes – Physical/human components of cyber-attack, computer elements
15. Physical Protective Measures	N/A? (unclear connection with hazard – needs SME evaluation?)
16. Risk Management for Protection Programs and Activities	Yes – (but details need to be developed by SMEs)
17. Screening, Search and Detection	Yes – (but details need to be developed by SMEs)
18. Supply Chain Integrity and Security	N/A? (disruptions seem possible, but likelihood is unknown)

Mitigation (7/7)

19. Planning	Yes – Protection algorithms and procedures (distinct from 1 and 8?)
20. Public Information and Warning	Yes – Cautions and procedures to prevent/discourage cyber-attack
21. Operational Coordination	Yes – But it's unclear how many parties might need to be involved
22. Community Resilience	Yes – But the array of potentially involved systems needs identification
23. Long-term Vulnerability Reduction	Yes – But methods of resiliency must be identified by SMEs
24. Risk and Disaster Resilience Assessment	Yes – But requires SME expertise to describe
25. Threats and Hazard Identification	Yes – But SME expertise is required to describe

Response (10/14)

26. Planning	Yes – Possibly involving back-up system and legacy systems?
27. Public Information and Warning	Yes – Procedures/recommendations for alternative systems
28. Operational Coordination	Yes – But it's unclear how many parties would be involved
29. Critical Transportation	N/A? (potential needs might be possible, but likelihood might be low?)
30. Environmental Response / Health and Safety	N/A? (environmental impacts might conceivably occur; but unlikely?)
31. Fatality Management Services	N/A? (fatalities might seem to be limited to indirect effects only?)
32. Infrastructure Systems	Yes – Perhaps the most serious impacts of cyber-attack involve this
33. Mass Care Services	Yes – Due to supply chain disruption and/or infrastructure failures
34. Mass Search and Rescue Operations	N/A? (not clearly linked with known cyber-attack effects?)
35. On-scene Security and Protection	Yes – Some cyber-systems involve protectable physical locations
36. Operational Communications	Yes – particularly media involving digital transmissions?
37. Public and Private Services and Resources	Yes – particularly involving infrastructure and supply chain failures
38. Public Health and Medical Services	Yes – if medical services are impacted by cyber-attack
39. Situational Assessment	Yes – Handling impacts, cascading effects, defenses, apprehension

Recovery (6/8)

40. Planning	Yes – Find alternate systems & resources, bolster cyber-security
41. Public Information and Warning	N/A? (same functions served under mitigation item 20?)
42. Operational Coordination	Yes – but it's unclear which agencies might be included in recovery
43. Economic Recovery	Yes – The economic impacts of cyber-attacks can be very great
44. Health and Social Services	Yes – Stresses related to loss of data, money, and system confidence
45. Housing	N/A? (unclear whether cyber-attack could affect housing stock)
46. Infrastructure Systems	Yes – Infrastructure impacts might be some of the most serious types
47. Natural and Cultural Resources	Yes – Many such resources are now digitally preserved

Improvised Explosive Devices – Capability Impacts (46/47)
(Region 1, 2, 3, 6, 8 Scenarios)

Prevention (7/7)	
1. Planning	Yes – Advance identification of vulnerabilities and protective strategies
2. Public Information and Warning	Yes – where appropriate for prevention activities
3. Operational Coordination	Yes – information exchange, mutual cooperation, training, synergies
4. Forensics and Attribution	Yes – Group/individual suspect ID, motives, M.O., capacity, etc.
5. Intelligence and Information Sharing	Yes – Track suspects' activities, opportunities, methods, motives, etc.
6. Interdiction and Disruption	Yes – Methods to act upon the attribution and intelligence info above
7. Screening, Search and Detection	Yes – IED tends to be amenable to physical searches and deactivation
Protection (10/11)	
8. Planning	Yes – whole community involvement in detection, subject ID, etc.
9. Public Information and Warning	Yes – relay protective information to reduce event probability/impacts
10. Operational Coordination	Yes – information exchange, mutual cooperation, training, synergies
11. Access Control and Identity Verification	Yes – Restrict vulnerable spots, discourage container/package planting
12. Cybersecurity	N/A? (not directly connected specifically to IED situations)
13. Intelligence and Information Sharing	Yes – Track suspects' activities, opportunities, methods, motives, etc.
14. Interdiction and Disruption	Yes – Methods to act upon the obtained intelligence information
15. Physical Protective Measures	Yes – Strengthening/hardening facilities, barriers, shields, shelters, etc.
16. Risk Management for Protection Programs and Activities	Yes – Compare estimated target vulnerabilities, then prioritize/protect
17. Screening, Search and Detection	Yes – An important means of addressing IED threats
18. Supply Chain Integrity and Security	Yes – Where IED may be used for this type of disruption
Mitigation (7/7)	
19. Planning	Yes – Target/vulnerability identification, develop protection strategies
20. Public Information and Warning	Yes – relay protective information to reduce event probability/impacts
21. Operational Coordination	Yes – information exchange, mutual cooperation, training, synergies
22. Community Resilience	Yes – Target/vulnerability identification and protection activities
23. Long-term Vulnerability Reduction	Yes – Target/vulnerability identification, protection, back-up, etc.
24. Risk and Disaster Resilience Assessment	Yes – Identify targets/vulnerabilities, mitigation/hardening strategies
25. Threats and Hazard Identification	Yes – ID threatening groups/interests and vulnerable sites/systems
Response (14/14)	
26. Planning	Yes – Targets will require evacuation, emergency response, security…
27. Public Information and Warning	Yes – Danger areas to avoid, reunification info, suspect search info…
28. Operational Coordination	Yes – Various teams to work together, crowded/chaotic conditions, etc.
29. Critical Transportation	Yes – EMS, evacuation, target site access, related site protection, etc.
30. Environmental Response / Health and Safety	Yes – Hazardous substance control, exposure limitations, containment
31. Fatality Management Services	Yes – Must handle mass fatality potential in multiple locations
32. Infrastructure Systems	Yes – Compensate for serious impacts on certain critical systems
33. Mass Care Services	Yes – Various persons temporarily displaced, family ID/reunification
34. Mass Search and Rescue Operations	Yes – Conditions of collapse, smoke, hazardous mat'l contamination…
35. On-scene Security and Protection	Yes – Site control needed for emergency ops, search & rescue, CSI…
36. Operational Communications	Yes – Public announcements, emergency responder coordination, etc.
37. Public and Private Services and Resources	Yes – Supply chain impacts may have occurred in multiple areas
38. Public Health and Medical Services	Yes – Mass casualty events, family & other inquiries about victims
39. Situational Assessment	Yes – Assess impacts, threat limits, response capabilities/resources, etc.
Recovery (8/8)	
40. Planning	Yes – Physical site/system, supply chain, psychological/social recovery
41. Public Information and Warning	Yes – Keep all informed about progress in restoring normalcy
42. Operational Coordination	Yes – Responding agencies, site/system repairs, debris management…
43. Economic Recovery	Yes – Many targets are economically important sites/systems
44. Health and Social Services	Yes – Mass casualty therapy, psychological trauma, cultural impact
45. Housing	Yes – Temporary displacement is likely, longer term homeless possible
46. Infrastructure Systems	Yes – Restoration of functions, relief of alternate/substitute systems
47. Natural and Cultural Resources	Yes – Culturally significant amenities are more likely targets