SECTION 3: WISCONSIN RISK ASSESSMENT

Risk assessments provide the factual basis for activities proposed in the strategy portion of the mitigation plan. Statewide risk assessments must characterize and analyze natural hazards and risks to provide a statewide overview of the greatest threats. This overview will allow the State to compare costs associated with potential losses and to determine their priorities for implementing mitigation measures under the strategy. Furthermore, it helps the State prioritize jurisdictions that receive technical and financial support in the development of more detailed local risk and vulnerability assessments.

3.1 INTERIM FINAL RULE REQUIREMENT

The Interim Final Rule found in 44 CFR Section 201.4 [c][2] states that "to be effective, the State Hazard Mitigation Plan must include the following elements:

i. An overview of the type and location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future hazard events, using maps where appropriate.

ii. An overview and analysis of the State's vulnerability to the hazards described in paragraph [c] [2], based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed.

iii. An overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State shall estimate the potential dollar losses to State owned or operated buildings, infrastructure and critical facilities located in the identified hazard areas."

3.2 OVERVIEW OF VULNERABILITY AND RISK ASSESSMENT

The State of Wisconsin has experienced thousands of hazard events, resulting in millions of dollars in losses and casualties, 29 Presidential Disaster Declarations, and six Emergency Declarations since 1971. As part of an overall effort to reduce future exposure to damages, the State of Wisconsin, in cooperation with FEMA, has developed the Wisconsin Risk Assessment. The Wisconsin Risk Assessment presents research on the potential impact of natural hazards throughout the state and its jurisdictions. The document was developed to comply with the Disaster Mitigation Act of 2000 (DMA2K). This report provides a foundation for Wisconsin's effort to develop strategies to mitigate future damages from hazards.

The Wisconsin Risk Assessment examines natural disasters on a statewide basis and for individual counties. Natural hazards include those caused by climatological, geological, hydrologic, or seismic events. The Risk Assessment relies upon information about past hazard events from published sources such as the US National Oceanographic and Atmospheric Administration (NOAA), National Weather Service (NWS), US Geological Survey (USGS), US Army Corps of Engineers (USACE), Wisconsin Department of Natural Resources (DNR), and Wisconsin Emergency Management (WEM), among others.

According to the DMA2K and supporting requirements in the Interim Final Rule (IFR), states must take actions to identify hazards and assess threats, as outlined in Section 4.1 of the State Hazard Mitigation Plan. The initial hazard identification catalogued potential hazards in Wisconsin and determined which hazards have the most chance of significantly affecting the state and its citizens. The hazards include those that have occurred in the past, as well as those that may occur in the future.

After the most significant statewide hazards were identified, a detailed Risk Assessment was developed. The process used to identify the most significant hazards was reviewed and approved by the Wisconsin Hazard Mitigation Team (WHMT). This qualitative rating is included at the end of each hazard discussed in the Risk Assessment, as a way to address the issue of probability without undertaking detailed studies for all the hazards.

Because it forms the basis of the State Hazard Mitigation Plan, the state-level Risk Assessment should be as comprehensive as possible. As discussed elsewhere in this section, the initial list of thirteen natural hazards was reduced to five, for a more detailed analysis of hazards posing the greatest threat and mitigation potential in Wisconsin: flooding, tornadoes, high winds, coastal erosion, and wildfire.

The DMA2K criteria require states first to identify hazards that may affect them and then to perform a comprehensive multi-hazard assessment, including a review of detailed information concerning hazard characteristics, past occurrences, and probability.

3.2.1 Hazard Identification: Methodology

The hazards profiled in the Wisconsin Risk Assessment were selected from the comprehensive list of natural hazards FEMA identified in the 1997 "Multi-Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy (MHIRA)" and the "Hazard Analysis for the State of Wisconsin" (Department of Military Affairs, Wisconsin Emergency Management, November 2002).

Although the IFR requires that all natural hazards affecting the state must be included in a detailed overview, it is not practical or desirable to perform in-depth risk assessments on all these hazards since many of them have a low probability of occurring and/or it is difficult to mitigate their effects. Because of this, the WHMT and WEM determined that it would be desirable to reduce the initial list of 13 hazards to those that:

1. Have the highest probability of occurring within the state; and
2. Have the greatest potential for mitigation.

To accomplish this, the WHMT and WEM used a qualitative system that ranked each of the thirteen hazards by both probability and mitigation potential. The ranking systems for are shown in Tables 4.2.1-1 and 4.2.1-2 below. This ranking is not intended to supersede the detailed risk assessment of each potential hazard type, but rather to allow time and technical resources to be focused on the most significant hazards.

TABLE 3.2.1-1 PROBABILITY RANKING AND CRITERIA

Ranking	Criteria
High	• The hazard has impacted the state annually, or more frequently • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations
Medium	• The hazard impacts the state occasionally, but not annually • The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs • The methodology for identifying events is not well-established, or is not applied across the entire state
Low	• The hazard occurs only very infrequently, generally less than every five years on a large scale, although localized events may be more frequent • The hazard is generally very localized and on a small scale (i.e. sub-county level) • A methodology for identifying event occurrences and/or severities is poorly established in the state, or is available only on a local basis

TABLE 3.2.1-2 MITIGATION POTENTIAL RANKING AND CRITERIA

Ranking	Criteria
High	• Methods for reducing risk from the hazard are technically reliable • The State or counties have experience in implementing mitigation measures • Mitigation measures are eligible under federal grant programs • There are multiple possible mitigation measures for the hazard • The mitigation measures are known to be cost-effective • The mitigation measures protect lives and property for a long period of time, or are permanent risk reduction solutions
Medium	• Mitigation methods are established • The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard • Some mitigation measures are eligible for federal grants • There is a limited range of effective mitigation measures for the hazard • Mitigation measures are cost-effective only in limited circumstances • Mitigation measures are effective for a reasonably long period of time
Low	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The State or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measures have not been proven cost-effective and are likely to be expensive compared to the magnitude of the damages caused by the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor

Table 3.2.1-3 below highlights important information considered for each of the initial hazards. The data sources used for assessment and the relative rankings for probability and mitigation potential are shown. The table also indicates the "disposition" of the hazard, which describes how the hazard was addressed, either by performing a basic profile as required by the IFR, or through a more comprehensive risk assessment that provides projections of future losses from the selected hazards.

TABLE 3.2.1-3 NATURAL HAZARD IDENTIFICATION AND DISPOSITION

Hazard	Data Sources	Probability	Mitigation Potential	Disposition
Hail	• NOAA: NWS • FEMA • WEM	High	Low	• General profile • Risk assessment at county level
Lightning	• FEMA • Centers for Disease Control and Prevention • NOAA: NWS • University Corporation for Atmospheric Research	High	Low	• General profile
Tornadoes and High Winds	• NOAA: NWS • FEMA • WEM	High	High	• General profile • Risk assessment at county level • Risk assessment for State-owned and –operated facilities • Separate assessments for tornadoes and high winds
Flooding	• FEMA • WEM • NOAA: NWS • DNR	High	High	• General profile • Risk assessment at county level • Risk assessment for State-owned and –operated facilities
Wildfires	• FEMA • WEM • DNR	Medium	Medium	• General profile • Risk assessment at county level
Drought	• FEMA • WEM • NOAA: NWS	Medium	Low	• General profile
Extreme Heat	• FEMA • WEM • NOAA: NWS	High	Low	• General profile
Winter Storms	• FEMA • Centers for Disease Control and Prevention • NOAA: NWS	High	Low	• General profile

TABLE 3.2.1-3 CONTINUED				
Hazard	**Data Sources**	**Probability**	**Mitigation Potential**	**Disposition**
Coastal Erosion	• USGS • USACE • FEMA • WEM • DOA: WCMP	High	High	• General profile • Risk Assessment at County level • Risk Assessment for State-owned and –operated facilities
Earthquakes	• FEMA • University of Wisconsin-Extension, Geological and Natural History Survey • University of Memphis Center for Earthquake Information • WEM	Low	Low	• General profile
Landslides and Land Subsidence	• FEMA • USGS • WEM	Medium	Low	• General profile
Dam Failure	• FEMA • WEM • DNR	High	Medium	• General profile
Climate Change		???	???	

The classification process provided a stratification of the hazards based on these criteria. The WHMT identified floods, tornadoes, high winds, wildfires, and coastal erosion, because these hazards present highest risk to the state and have the most potential for mitigation based on this assessment. In the following sections, these hazards are afforded detailed risk assessments to identify the areas of the state that are most at risk, and this information is in turn used as the basis for determining appropriate actions to reduce the risks.

Since the State re-evaluates and updates this plan every three years, it may be appropriate to revisit this ranking methodology and perform full risk assessments for additional hazards in future plan updates. In 2008, a more detailed assessment of wildfires was included than in the previous version of the Plan, as a result of analysis done by the US Forest Service and DNR. The final report is included in the 2011 update. Furthermore, a more detailed assessment for hail is included in the 2011 update, based on data provided by the NWS and analyzed by WEM.

Population growth and development also increase the risk and vulnerability of counties. Since most natural hazards, with the exception of floods, coastal hazards, and dam failure, are so wide-spread, it is difficult to project future risk based solely on population and growth. Increasing residential property value will also increase future risk from tornado damage, in general.

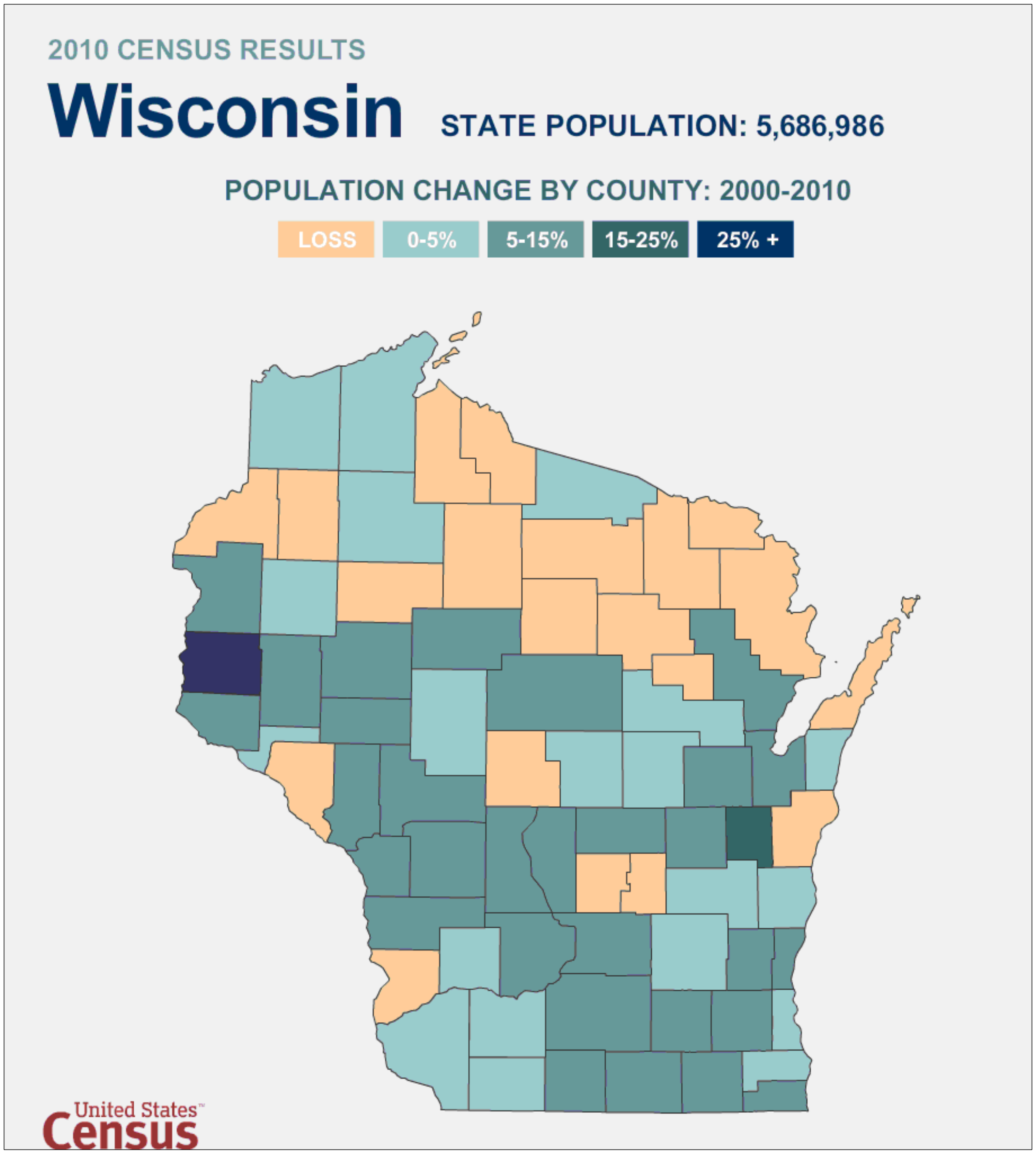

Figure 3.2.1-1 Wisconsin Population Change by County, 2000-2010
Source: US Census Bureau, 2011.

According to population projections calculated by the Demographic Services Center, the state is expected to increase in population to nearly 6.65 million by 2035, which is a growth of 24.1% (http://www.doa.state.wi.us/docview.asp?locid=9&docid=2108). The counties projected to grow fastest over the 35 year study period (2000 to 2035) are Calumet, Dane, Oconto, Kenosha, Pierce, Polk, St. Croix, Sauk, Walworth, and Washington, accounting for 45% of the state's overall increase. Of the 33 counties projected to grow over 24.1% in that time, the largest growth is projected to occur in St. Croix County, increasing its population to 227,000 residents, which is over 150% expected population growth.

Based on the University of Wisconsin's Applied Population Laboratory's analysis of Census 2010 data, Wisconsin's overall population increased 6% between 2000 and 2010 to include 5,686,986 residents. Numerically, this is an increase of 323,271 residents (http://www.apl.wisc.edu/newsletters/Population_Notes_Summer2011.pdf).

TABLE 3.2.1-4 WISCONSIN COUNTIES WITH THE HIGHEST POPULATION CHANGE

County	2000 Census	2010 Census	Numeric Change	% Change
Dane	426,526	488,073	61,547	14.4%
Waukesha	360,767	389,891	29,124	8.1%
Brown	226,658	248,007	21,349	9.4%
Saint Croix	63,155	84,345	21,190	33.6%
Kenosha	149,577	166,426	16,849	11.3%
Outagamie	161,091	176,695	15,604	9.7%
Washington	117,496	131,887	14,391	12.2%
Winnebago	156,763	166,994	10,231	6.5%
Walworth	92,013	102,228	10,215	11.1%
State of Wisconsin	**5,363,715**	**5,686,986**	**323,271**	**6.0%**

Source: US Census Bureau, 2011.

Twenty rural counties, concentrated in northern Wisconsin, lost population between 2000 and 2010. Most of the population growth occurred near the Minneapolis-Saint Paul, Milwaukee, and Chicago metropolitan areas, with the fastest growing counties shown in table 3.2.1-4, above. The counties estimated to gain the largest number of residents were Dane, Brown, Outagamie, and Milwaukee.

Many of Wisconsin's most populous cities, as listed in Table 3.2.1-5 are located near Lake Michigan or along the Mississippi River. As such, these high population centers are particularly vulnerable to coastal hazards, riverine flooding, and flash flooding (as a result of storm water runoff).

Generally population growth and development increase the risk and vulnerability of counties. Since most natural hazards, with the exception of floods, coastal hazards,

TABLE 3.2.1-5 MOST POPULOUS WISCONSIN CITIES

City	Census 2010 Population
Milwaukee	594,833
Madison	233,209
Green Bay	104,057
Kenosha	99,218
Racine	78,860
Appleton	72,623
Waukesha	70,718
Oshkosh	66,083
Eau Claire	65,883
Janesville	63,575
West Allis	60,411
La Crosse	51,320
Sheboygan	49,288
Wauwatosa	46,396
Fond du Lac	43,021

Source: US Census Bureau, 2011.

and dam failure, are so wide-spread, it is difficult to project future risk based solely on population and growth. Increasing residential property value will also increase future risk from tornado damage, in general.

Data included in these projections for the 2011 State Hazard Mitigation Plan utilize Census 2000 and 2010 data, for more accurate growth rate and population projections. The only expected change for the 2014 update is the verification of accuracy in these projections, as no new Census data will be available until 2020.

3.2.2 Terminology

FEMA defines **risk** as "the likelihood that a threat will harm an asset with some severity of consequences" (http://www.fema.gov/pdf/plan/prevent/rms/155/e155_unit_v.pdf). Risk examines not only the **probability**, or likelihood, of event occurrence, but also the consequences of this event's occurrence. Since all hazards do not occur in each locality with the same frequency, it is important to note that probability changes over time. The likelihood of an event occurring is greater as the time horizon increases.

By understanding the probability of occurrence and consequences of an event, the State can better manage the risk with mitigation measures that reduce threats, vulnerabilities, and risks to assets.

Vulnerability speaks to susceptibility of people, property, ecosystems, or resources to a hazard event. Note that vulnerability can be considered any of the following:

- Social (i.e. displacement of people, loss of a critical facility providing services to people)
- Political (i.e. loss of jobs, stability of local government, or political power)
- Environmental (i.e. loss of animal habitat, contamination of a lake)
- Economic (i.e. loss of productivity in a local economy, monetary loss, opportunity cost of re-building)

Understanding the consequences of an event is often dependent upon understanding the **severity** of the event. In other words, by knowing "how bad" a hazard event is, the destructiveness of a natural hazard in Wisconsin can be better understood.

Throughout the Risk Assessment, risk is defined as the dollar value of future expected losses, and is annualized whenever possible. Dollar value is used to express risk simply so different types of losses (i.e. deaths, injuries, loss of property, etc.) can be compared and examined. Methods used for evaluating risk are defined or described in each section devoted a specific hazard.

Furthermore, the investigations of each of Wisconsin's natural hazards are methodically examined on three main criteria:

1. **Nature:** basic information about the natural hazard that distinguishes it from other hazards; used to understand the subsequent vulnerability assessment and loss estimates
   - Information drawn mainly from FEMA, the NWS, and other national agencies
2. **History:** background information about previous occurrences of the natural hazard; focuses on hazard events in Wisconsin and on major occurrences elsewhere in the United States where information for the state is lacking
   - Information drawn mainly from the database of natural historical hazard events in Wisconsin
3. **Probability and Magnitude:** information about the likelihood of occurrence and severity of events in Wisconsin
   - Information drawn from a combination of FEMA and other national sources, Wisconsin expertise, and the Wisconsin natural hazard event database

In the 2008 version of the State Hazard Mitigation Plan, detailed county-level analyses were included for flooding, tornadoes, coastal erosion, and wildfires. In 2011, a county-level analysis was also included for hail, since it leads to millions of dollars of damages each year. Additionally, an assessment of critical State-owned and -operated facilities was performed for floods,[1] tornadoes, and high winds.

3.3 SEVERE THUNDERSTORMS

In the 2011 State Hazard Mitigation Plan, severe thunderstorms are first hazard addressed because of their association with other natural hazards affecting Wisconsin. Severe storms in and of themselves pose great threats to safety in the state; however, the numerous other hazards accompanying severe thunderstorms, such as hail, lightning, tornadoes, high winds, and flooding, pose additional threats to safety affording more in-depth analyses in following sections.

3.3.1 Nature of the Hazard

Thunderstorm events are generated by instability in the atmosphere, sufficient moisture, and rising motion to form clouds and rain. They are characterized by precipitation in the form of rain, lightning, hail, downbursts, and tornadoes. Occasionally, thunderstorms occur in winter during heavy snow events. Typically, Wisconsin thunderstorms are approximately 15 miles across and last for about 30 minutes, but events of longer duration or with high rates of precipitation can lead to flooding (NWS).

The National Weather Service (NWS) classifies a thunderstorm as severe if at least one of the following conditions occurs:

1. Winds reach or exceed 58 mph
2. The storm produces a tornado

1. Coastal and riverine floods were examined for the Risk Assessment.

3. The storm produces hail at least one inch in diameter

In severe thunderstorms, strong downburst winds are created by falling rain and associated sinking air, creating winds that can reach speeds of 60 to 100 mph. Micro-bursts, concentrated versions of downbursts, can have speeds up to 150 mph. Great damages can result from downbursts and micro-bursts.

Throughout this section, the focus is specifically on the wind damages associated with severe thunderstorms, as the lightning and hail accompanying them are evaluated at greater detail in following sections.

3.3.2 Wisconsin Severe Thunderstorm Event History

Thunderstorms and the associated severe weather can occur throughout Wisconsin during any month of the year, but their highest frequency is from May through September. They also occur most often between 12:00 P.M and 10:00 P.M. The peak hour for severe thunderstorms is 6:00 to 7:00 P.M.

Wisconsin averages around 30 thunderstorm days per year over the northeastern counties to around 42 days over the southwestern counties (NWS).

July 4, 1977

On July 4, 1977, a long-lived line of severe thunderstorms produced significant wind damage across a large part of northern Wisconsin. Called a "derecho," a widespread and long-lived, violent, convectively-induced windstorm associated with a fast-moving band of severe thunderstorms developed over west central Minnesota during the morning and moved southeast, increasing in intensity as it approached Wisconsin. A series of intense downburst winds caused major forest blown-downs, widespread severe damage to property, one casualty, and 35 injuries. This band of extreme damage, which was 10 to 20 miles wide and over 160 miles long, extended from eastern Burnett County through Washburn, Sawyer, Price, and Oneida Counties. Approximately 850,000 acres of trees were either destroyed or badly damaged. Damage estimates including buildings and vehicles totaled about $24 million. Wind gusts may have reached 135 mph at times.

May 31, 1998

During the early morning hours of Sunday, May 31, 1998, south-central and southeast Wisconsin experienced another "derecho." Incredibly powerful, hurricane-force high winds, with peak gusts of 100 to 128 mph tore through 12 counties, while another eight counties had peak gusts of 30 to 80 mph. Although all 20 counties in south-central and southeast Wisconsin reported scattered to widespread wind damage, there were five main corridors or swaths of concentrated damage: 1) from central Sauk County through northern Dane County, northern Jefferson County, southern Dodge County, and Waukesha County into Milwaukee County; 2) from east-central Columbia County across northern Dodge County and through southeast Fond du Lac County and southern Sheboygan County; 3) from the West Bend area of central Washington County east to the Port Washington area of Ozaukee County; 4) from southeast Iowa County into northwest Green County; and 5) from the northwest to the central part of Lafayette County.

Utility companies and Emergency Managers stated that the May 31, 1998 event was the most damaging, widespread, straight-line thunderstorm wind event to affect southern Wisconsin in the past 100 years. Estimated monetary damage for all twenty counties was $55.85 million for homes, businesses, utilities' buildings, agriculture buildings, signs, street lights, billboards, campers, and boats. An additional $1.48 million in damages occurred in crop and livestock losses. As a sign of the wind power, many concrete silos had their tops blown off and many barns were flattened. Roofs peeled off homes and other structures. Thousands of large trees were either uprooted or twisted and broken by the winds. Hundreds of power poles were snapped or pushed over by the winds or falling trees and branches. At one time, approximately 60,000 customers in south-central Wisconsin and 170,000 in southeast Wisconsin were without electricity. Some residences and businesses were without power for as long as five or six days due to the deluge of needed utility repairs and a shortage of replacement power poles.

July, 1999

Throughout July 1999, the northwestern portion of Wisconsin received an unusual amount of thunderstorm activity. The cumulative damage from these events led to a Presidential Disaster Declaration for ten counties. Most of the wind damage occurred in the forests of Douglas and Bayfield Counties. The US Forest Service stated that downbursts and wind affected an estimated 92,000-acre area of forest during this month-long period.

Approximately 12,000 acres of trees were nearly 100% down in the affected area and another 30,000 acres were moderately affected with up to 40% of trees destroyed. The downed trees created an immediate debris problem on area roads as well as a severe long-term fire hazard. Other long-term effects include the possible spread of tree diseases, which could affect the value of timber as an economic resource; lost tourism and tourism revenue; increased spending for debris clearance; and increased spending for fire-fighting activities.

May 12, 2000

On May 12, 2000, a major super-cell storm developed in west-central Wisconsin. Chilton and St. Nazianz in Manitowoc County were particularly hard-hit by hail and wet microbursts that produced winds over 100 mph and a brief EF0 to EF1 tornado.

June 11, 2001

On June 11, 2001, a line of thunderstorms with many of the same characteristics as a tropical storm ripped through east-central and west-central Wisconsin. The thunderstorm complex produced hurricane-strength wind gusts and hail, resulting in thousands of downed trees and damage to structures. Nearly $20 million in damage was reported in central and east-central Wisconsin. Much of the wind damage was concentrated in Wood, Portage, Waushara, Waupaca, Winnebago, Outagamie, and Calumet Counties and the cities of Appleton and Oshkosh. Overall, this event affected 30 counties, which were included in Presidential Disaster Declaration 1369.

August 3, 2004

On August 3, 2004, clusters of severe thunderstorms moved southeast through south-central and southeast Wisconsin, resulting in damaging high winds that toppled large trees, very large damaging hail, and heavy rains that led to flash flooding. Columbia County suffered the most damage thanks to hurricane-force thunderstorm winds coupled with hail stones one to three inches in diameter. The wind-driven hail damaged at least 100 homes and several businesses and churches in Fall River (Columbia County). The wind-driven hail also mowed down some corn and soybean fields between Rio and Columbus. Some of the hail stones were still un-melted the next morning. Flash flooding resulted in gravel shoulder washouts and flooded buildings and basements in the Wisconsin Dells to Wyocena area of Columbia County. Rainfall amounts of 2.50 inches were measured in about one to two hours in the Portage area (Columbia County). This storm caused over $3 million in damages.

July 30, 2006

On July 30, 2006, downburst winds hit the Bayfield waterfront where an art fair was in progress at Memorial Park. Most of the ninety fair tents were demolished and art pieces were tossed into Lake Superior. A woman broke her hand and a man received a large gash on his hand. Numerous large trees were blown down in Bayfield. The local Catholic church lost a portion of its roof, resulting in damage estimated at $300,000. There was an unverified report from a private weather system clocking the wind at 99 mph before it became inoperable. At the Apostle Island Marina numerous boats were damaged. Trees were reported down all across northern Douglas County. Damages were over $1.5 million.

August 13, 2007

On August 13, 2007, a large severe thunderstorm produced winds damaging an area from just west of New Richmond to Glenwood City. This damage occurred within an approximately two to four mile swath between these two cities. Some general reports include: 109 homes were damaged or severely damaged; 48 barns were damaged or severely damaged; two barns were destroyed near Emerald; one home was rendered uninhabitable three miles east-southeast of New Richmond; one home at County G and GG was destroyed; barns, homes, and corn fields were flattened near Emerald Dairy along county Highway G; power lines and trees were toppled; and the entire village of Hammond and some outlying areas were without power for approximately 12 hours. Damage was over

$35 million to properties and $10 million to crops.

Figure 3.3.2-1 below shows the average number of thunderstorm days across the United States in 2008 (this study has not been repeated since 2008). The highest concentration of thunderstorm days is found in the Southeast, with an annual average of 60 to 100 thunderstorm days. In Wisconsin, there is an annual average between 30 and 50 thunderstorm days.

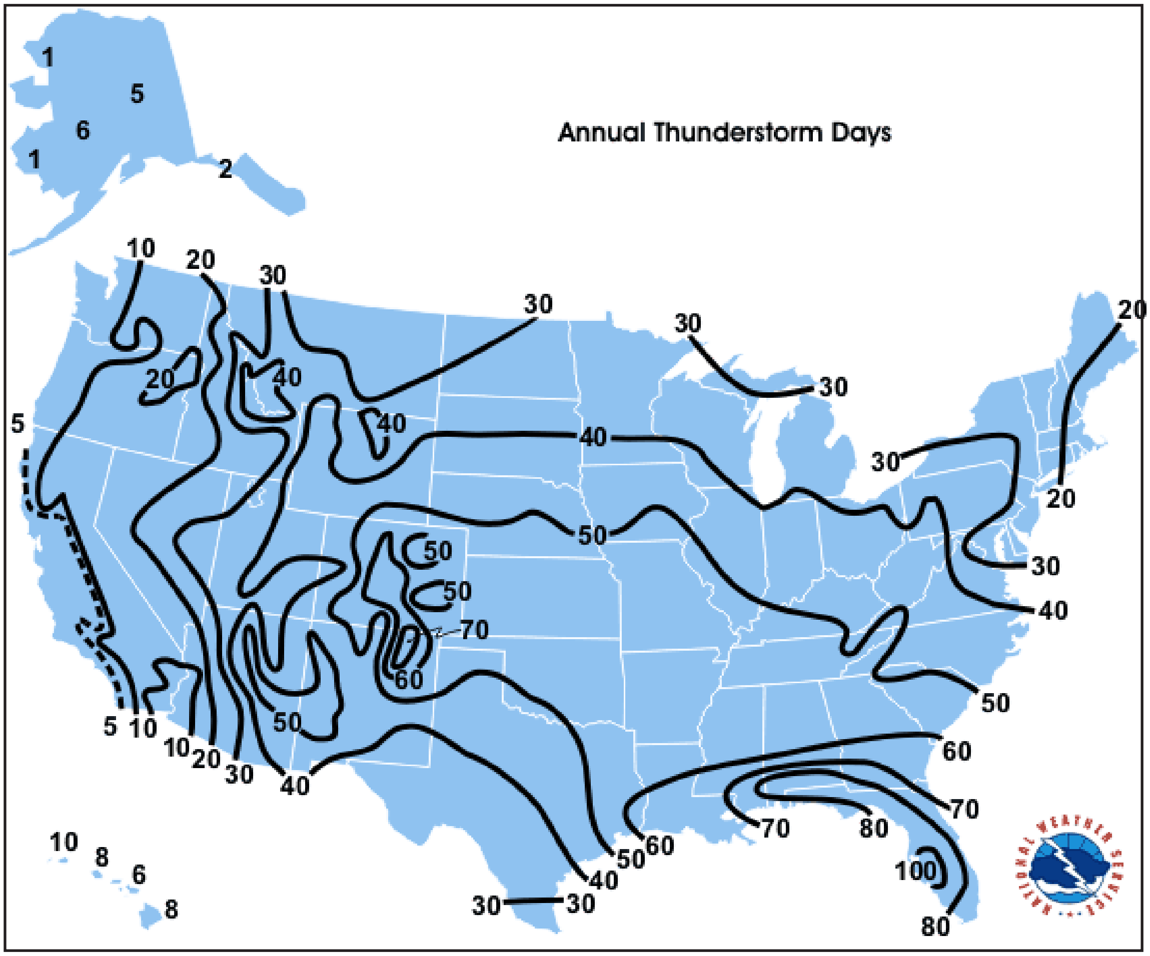

Figure 3.3.2-1 Annual Average Number of Thunderstorm Days in the US
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2008.

3.3.3 Probability of Occurrence

The number of days that severe thunderstorm winds, large hail, or tornadoes occur annually within 25 miles of a given point in Wisconsin ranges from about three days across the northern counties to about seven days across the southwestern counties. Figure 3.3.3-1 below depicts the annual number of days with severe thunderstorm winds that can be expected across the United States. Wisconsin experiences from two to five severe thunderstorm wind events per year, on average.

This is important to note because in some cases, thunderstorm winds can be fatal. 25 fatalities were attributed to wind from severe thunderstorms during the time period from 1982 to 2010 in the US. When a thunderstorm became severe in Wisconsin during the period of 1982 to 2010, short-fuse severe weather was in the form of:

- Damaging high wind 58% of the time,
- Large hail 30% of the time,
- Tornadoes 7% of the time, and
- Flash floods from heavy rain 5% of the time.

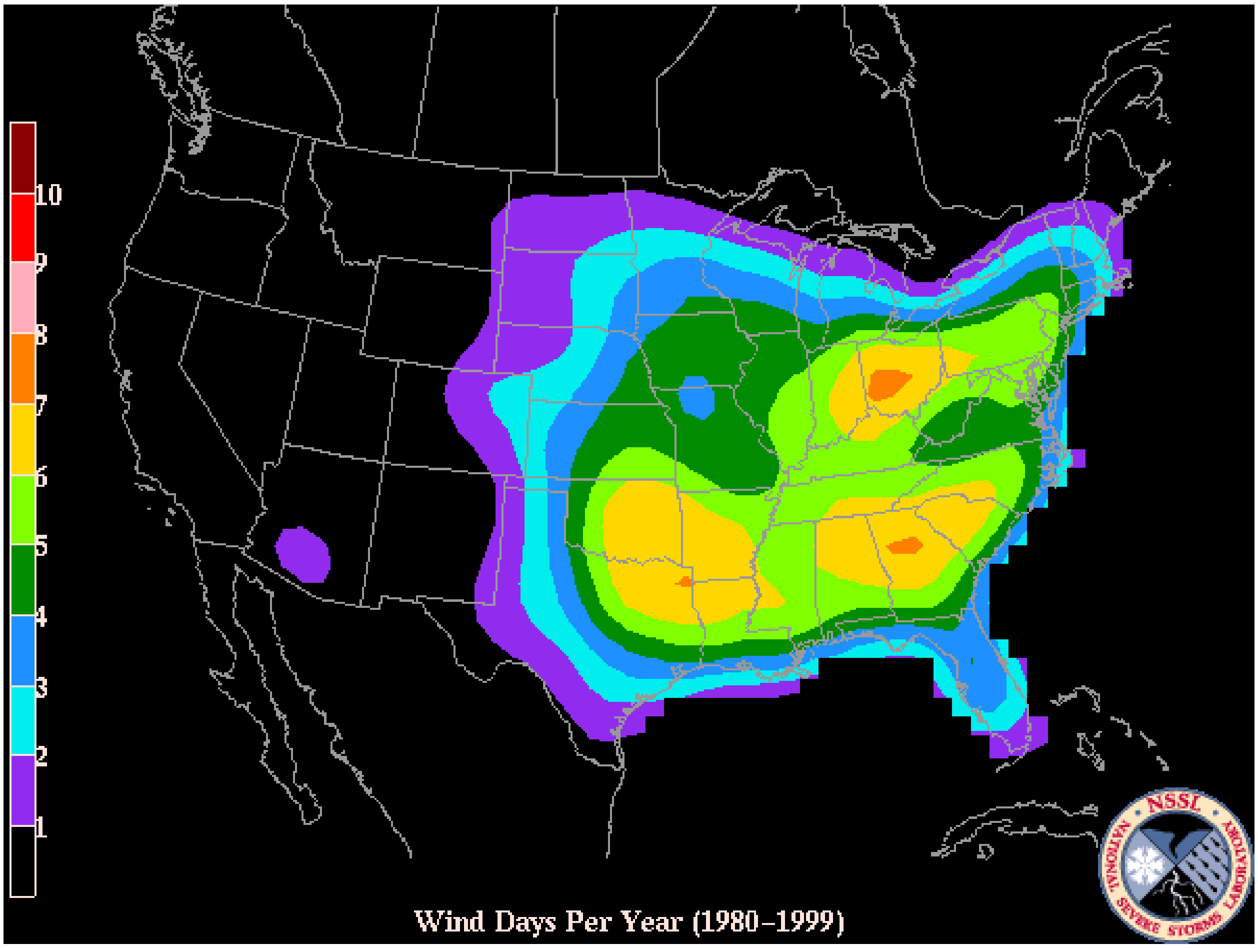

Figure 3.3.3-1 Annual Average Number Days with Severe Thunderstorm Winds in the US
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2008.

Figure 3.3.3-2, below, shows the number of severe thunderstorm wind events, number of directly-related fatalities, and number of directly-related injuries from 1982 to 2010 in each Wisconsin county. Southern Wisconsin has the most of severe thunderstorm wind events. Dane, Rock, Walworth, Waukesha, and Jefferson counties have the most events with 277, 244, 207, 204, and 177 events, respectively. This is particularly alarming due in part to the recent development of land in these counties and the projected population growth. Only seven counties have experienced fewer than 50 severe thunderstorm

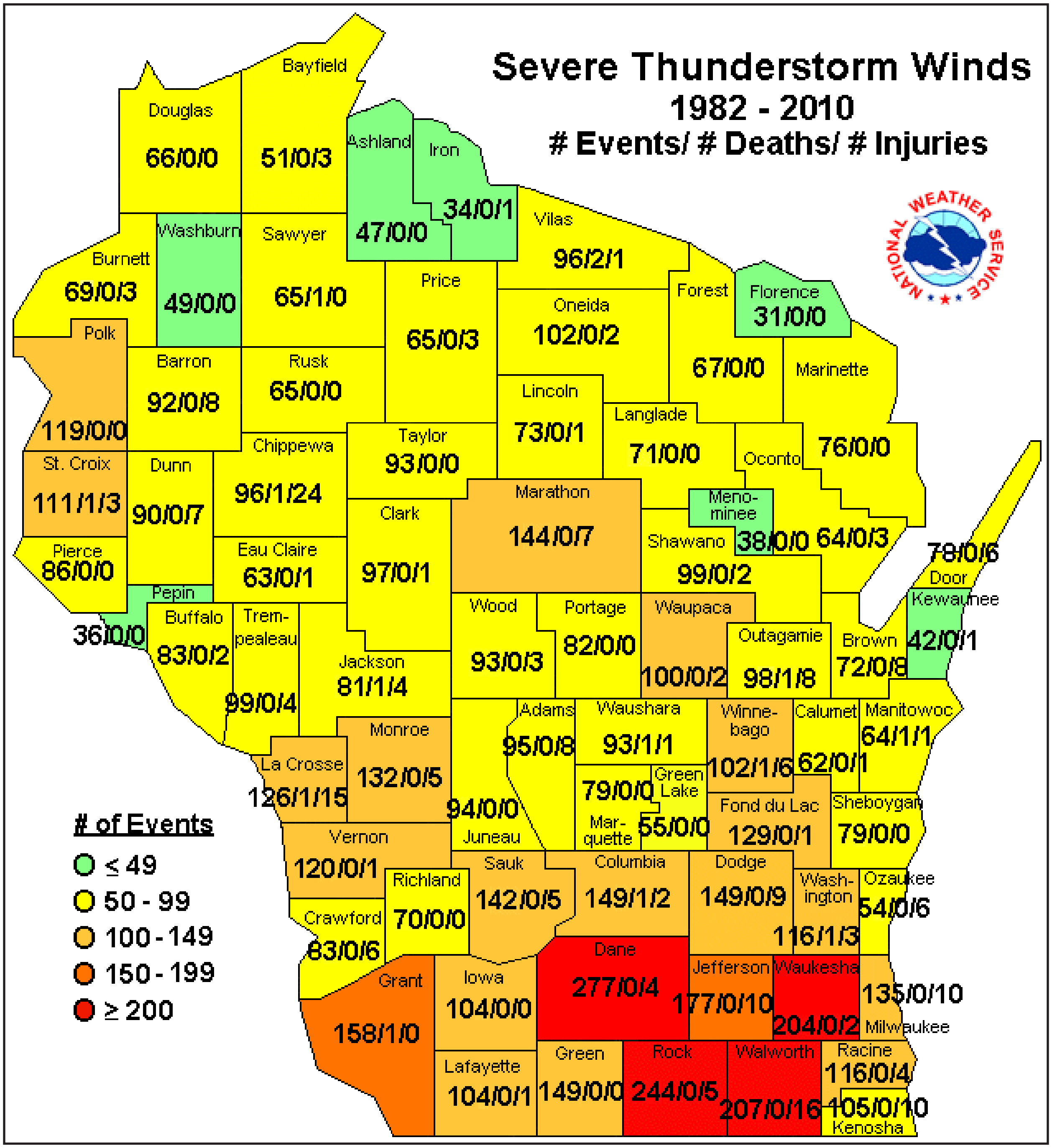

Figure 3.3.3-2 Severe Thunderstorm Wind Events by County, 1982-2010

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

events during the time period. Florence, Iron, and Pepin counties experience many times fewer severe thunderstorm wind events than the highest southern counties.

According to the NWS, in the time period between 1970 and 2010, Wisconsin has experienced 580 hurricane-force wind events (74 mph or higher). In Figure 3.3.3-3, below, the number of severe thunderstorm wind events with hurricane-force wind gusts is shown. Again, note the concentration of events in southeastern Wisconsin. Rock, Dane, and

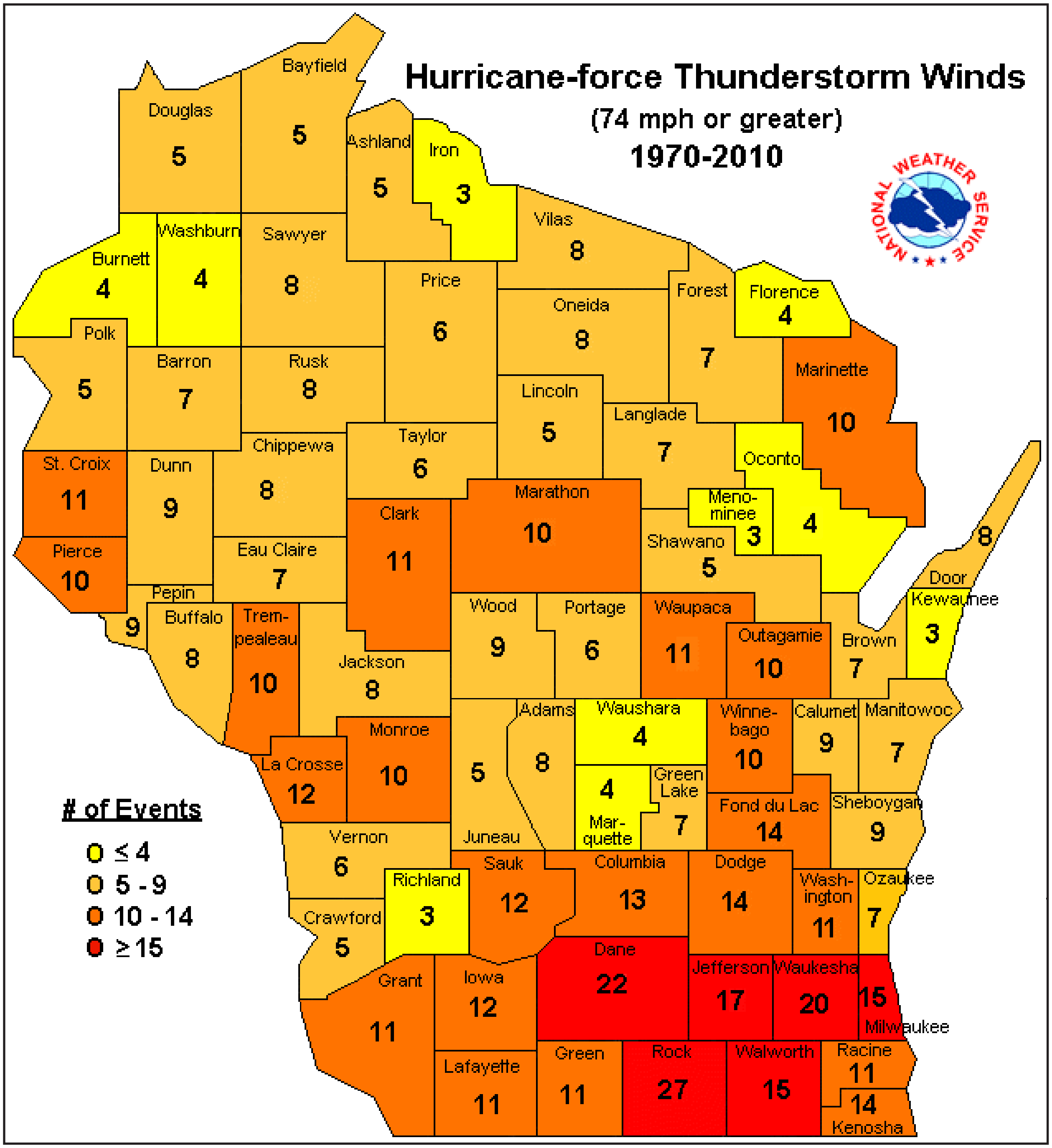

Figure 3.3.3-3 Hurricane-Force Severe Thunderstorm Wind Events by County, 1970-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Waukesha Counties have had 27, 22, and 20 hurricane-force wind gust events since 1970, respectively. This concentration around higher population densities poses the potential for damages where land is most developed.

Within the same time period, winds at or above 100 mph have been documented during 58 events, meaning that winds similar to a Category 2 hurricane are experienced about 1.4 times every year on average in Wisconsin. Figure 3.3.3-4, below, shows the num-

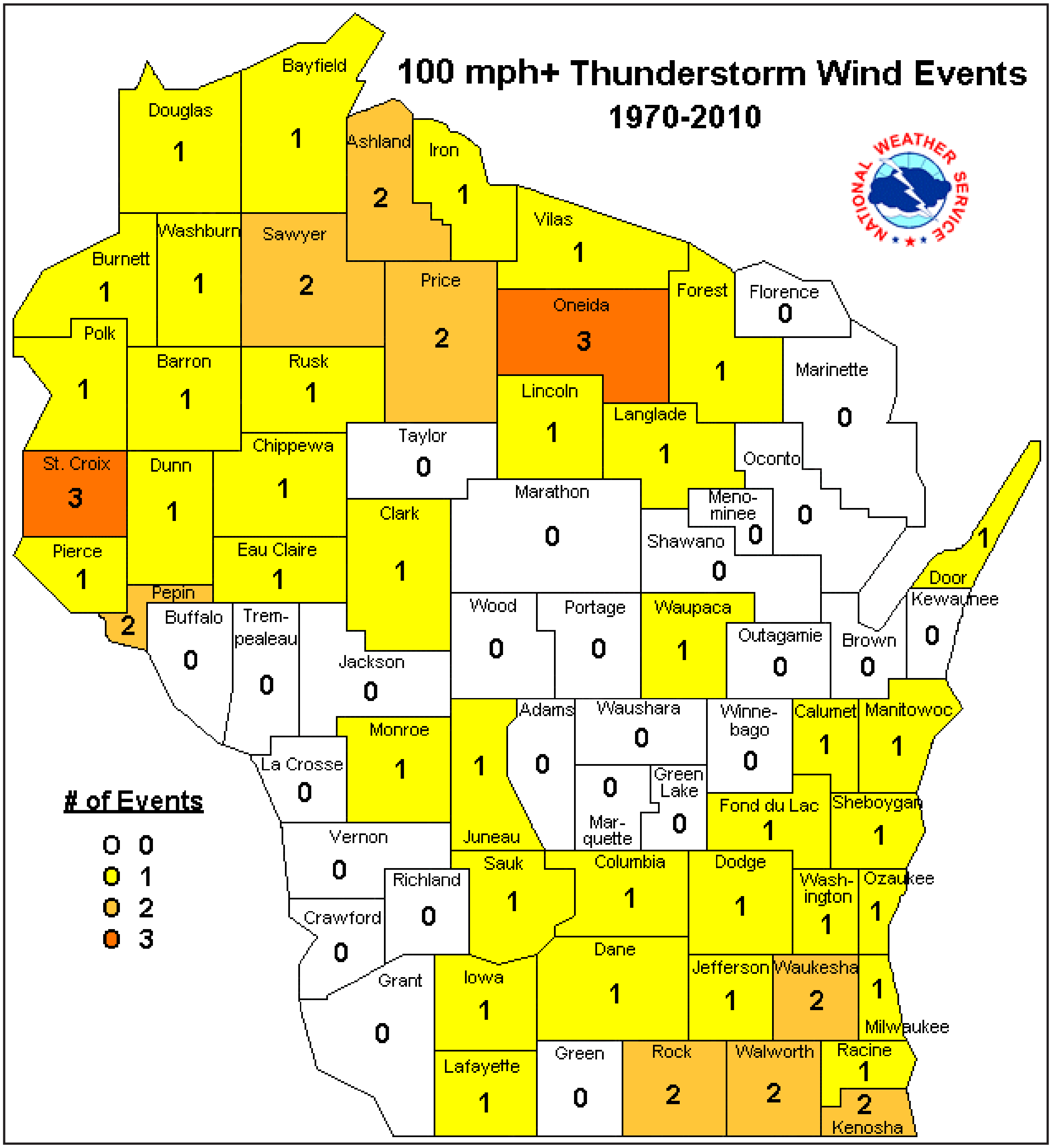

Figure 3.3.3-4 Severe Thunderstorm 100+ mph Wind Events by County, 1970-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

ber of severe thunderstorm wind events with wind gusts of 100 mph or more per county. Since these extreme wind events are not very common, the data shown does not lend itself to meaningful conclusions, though it appears that the northern parts of the state have a slightly higher risk for these extreme wind events, especially Oneida and St. Croix counties. Generally, the central part of the state has experienced very few Category 2 hurricane-force wind gusts as a result of severe thunderstorm events.

Information on large hail, tornadoes, and flood events, which often accompany severe storms, is included in the Sections 3.4, 3.5, and 3.6, which immediately follow.

3.3.4 Hazard Ranking

TABLE 3.3.4-1 HAZARD RANKING FOR SEVERE THUNDERSTORMS		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard has impacted the state numerous times on an annual basis • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Mitigation methods are established • The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard • Some mitigation measures are eligible for federal grants • There is a limited range of effective mitigation measures for the hazard • Mitigation measures are cost-effective only in limited circumstances • Mitigation measures are effective for a reasonable period of time	Medium

3.3.5 Sources for Severe Thunderstorms

TABLE 3.3.5-1 SOURCES FOR SEVERE THUNDERSTORMS	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Part 1: Atmospheric Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
FEMA: Thunderstorms and Lightning	http://www.fema.gov/hazard/thunderstorm/index.shtm
NOAA Severe Weather Information	http://www.noaawatch.gov/themes/severe.php
National Climatic Data Center Storm Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
NWS Storm Prediction Center	http://www.spc.noaa.gov/
Natural Hazards Center, University of Colorado Boulder	http://www.colorado.edu/hazards/
NWS Weather Forecast Office, Milwaukee/Sullivan, WI	http://www.crh.noaa.gov/mkx/
NWS Weather Forecast Office, Green Bay, WI	http://www.crh.noaa.gov/grb/
NWS Weather Forecast Office, La Crosse, WI	http://www.crh.noaa.gov/arx/

3.4 HAIL

3.4.1 Nature of the Hazard

Hail can develop within thunderstorms when strong currents of rising air, known as updrafts, carry water droplets high within the storm, exposing these droplets to cold air and freezing them. As the frozen droplets begin to fall toward the ground, rising currents within the storm lift them again. The hailstones gain an ice layer and grow increasingly larger with each ascent. Eventually the hailstones become too heavy for the updraft to support, and they fall to the ground.

Though hail typically accompanies severe thunderstorms, all strong thunderstorms have the potential to produce hailstones of small diameter (less than 0.75 inches). The size of hailstones varies and is a direct consequence of the severity and size of the thunderstorm; greater instability in the atmosphere causes stronger updrafts. Stronger updrafts can keep hailstones suspended for longer periods of time, resulting in larger hailstones at ground level. Hailstones vary widely in size, as shown in Table 3.4.1-1, below. Trained volunteer storm spotters and the National Weather Service (NWS) officially report severe hail, which are hailstones considered 0.75 inches in diameter or greater.

TABLE 3.4.1-1 ESTIMATING HAIL SIZE

Size Reference of Hailstone	Diameter of Hailstone (Inches)
Pea	0.25
Small Marble	0.50
Penny	0.75
Quarter	1.00
Ping-Pong Ball	1.50
Golf Ball	1.75
Tennis Ball	2.50
Baseball	2.75
Large Apple	3.00
Softball	4.00
Grapefruit	4.50

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.4.2 Wisconsin Hail Event History

Hailstorms are relatively frequent across the US. Since 1986, nearly 3,000 individual hail events have been reported annually across the country (NWS). Although they occur in every state on the mainland US, hailstorms occur most frequently in the midwestern states, particularly in Texas, Oklahoma, Kansas, and Nebraska. Hailstorms can occur throughout the year; however, most hail events occur between April and October. Though hail-related fatalities are rare, great amounts of crop and property damage can be traced to hail damage.

On average, hail causes $1 billion in damage to crops and property each year in the US (NWS). The costliest hailstorms in the US occurred in Dallas/Fort Worth, Texas on May 5, 1995 and in St. Louis, Missouri on April 10, 2001. Both storms had reported damages of over $2 billion (NWS). The largest hailstone ever recorded fell in Vivian, South Dakota on July 23, 2010 with a diameter of eight inches and weighing almost two pounds (NWS). Figure 3.4.2-1, below, depicts the annual number of severe hail reports (0.75 inches in diameter or larger) per 100 square miles in the United States between 2000 and 2009. Note the highest average number of severe hail events occur in the southern Midwest, with Kansas, Oklahoma, Nebraska, and Texas as the leading states. Kansas has the highest concentration of counties experiencing over eight events, while many counties in surrounding states average three to eight events.

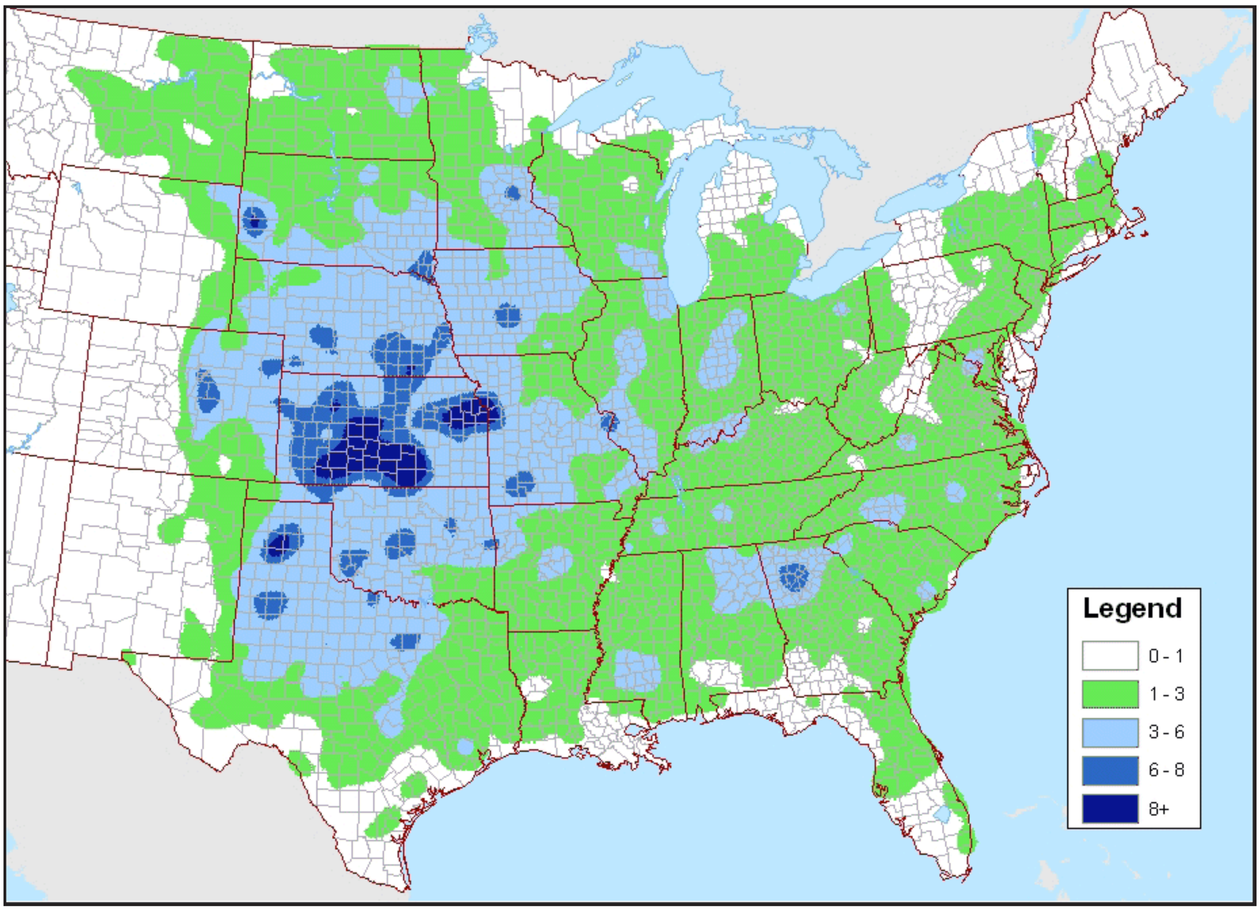

Figure 3.4.2-1 Average Number of Severe Hail Reports per 100 Square Miles, 2000-2009
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Comparing the southern Midwest to Wisconsin during this nine year period, Wisconsin experienced significantly fewer hail events. In fact, most of Wisconsin's counties experienced an average of one to three severe hail events annually from 2000 to 2009, with a higher concentration of up to six events in southeastern Wisconsin.

There is an annual average of 84 hail events producing stones one inch or more in diameter from 1982 to 2010 in Wisconsin (NWS). In this time period, there were 4,657 severe hail events (stones of 0.75 inches in diameter) in the state. Although at least 42 people have reported injuries as a result of large hailstones between 1982 and 2010 in Wisconsin, the actual number of injuries may be higher since some injured people may not seek medical treatment. There have been no reported fatalities due to large hail in Wisconsin, but there have been a few fatalities nationwide.

Wisconsin's largest hailstone with a diameter of 5.7 inches, was reported on the north side of Wausau during the evening of May 22, 1921, even though most hailstones in this hailstorm were four inches in diameter or smaller. Several people were injured by the large hail stones and damage was extensive. The second largest hailstone in Wisconsin weather history fell on June 7, 2007. Hailstones up to 5.5 inches in diameter were measured in Port Edwards (Wood County), shown below in Figure 3.4.2-2. The storm resulted in $45 million in hail damage.

Figure 3.4.2-2 Port Edwards 5.5 Inch Hailstone, June 7, 2007
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

The months of maximum hailstorm frequency are May through September, with approximately 85% of hailstorms occurring during this period. Unfortunately, hailstorms are most frequent during the four months of the growing and harvesting seasons for many of Wisconsin's crops, causing economic losses and damages for the agriculture industry.

Wisconsin's first-ever $100 million dollar hailstorm took place on May 12, 2000 when a single storm moved across the central part of the state from south of La Crosse (La Crosse County) through the Lake Winnebago area to Manitowoc (Manitowoc County) and eventually to Lake Michigan. Ten counties were pounded with hailstones one to three inches in diameter during the morning hours. Damage to property and crops was estimated at $122 million.

On April 13, 2006, three hail-producing severe thunderstorms affected southern Wisconsin. Hail, up to 4.25 inches in diameter, fell across a large swath from Mineral Point (Iowa County) to north of Milwaukee (Milwaukee County). Based on insurance claims information, the April 13, 2006, hailstorms resulted in total damage of about $420 million, making it the most costly hailstorm day in Wisconsin weather history. Over 50,000 vehicle claims, 40,000 residential claims, and about 5,400 business/farm claims were filed with various insurance companies. Additionally, the first of the three hailstorms was the single costliest thunderstorm in Wisconsin weather history, with damage estimated at $300 million.

The paths of the three hailstorms on April 13, 2006 are shown below in Figure 3.4.2-3. The storm shaded in yellow was the strongest of the three, and produced hailstones of two to 4.25 inches in diameter near Lake Mills (Jefferson County).

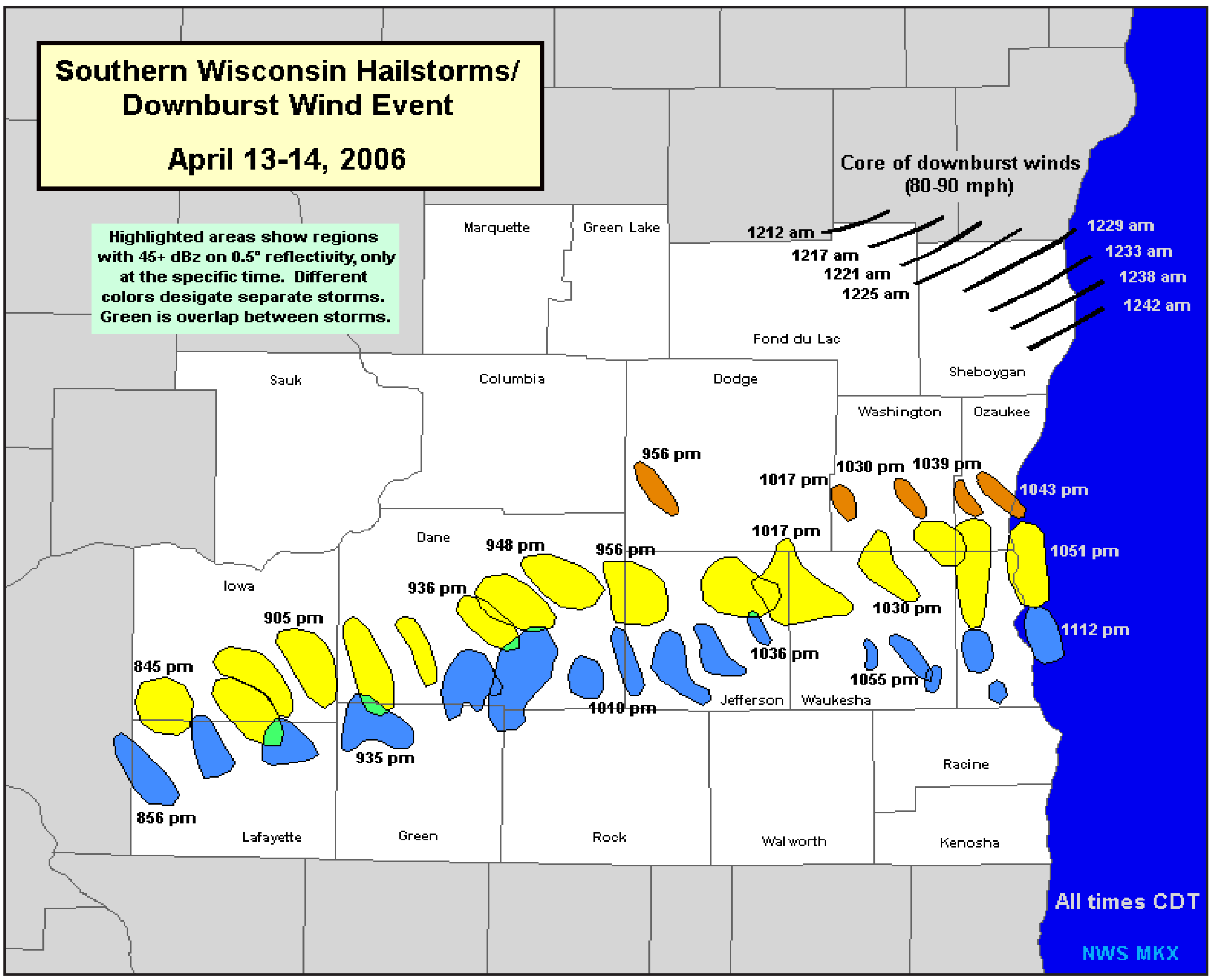

Figure 3.4.2-3 Hailstorm Paths, April 13, 2006
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2008.

On June 25, 2006 a 40- to 45-minute hailstorm moved from about three miles south-southeast of Dekorra (Columbia County) southeast to North Leeds (Columbia County), leaving in its wake a large amount of crop damage from hail the size of quarters. Crop, vegetable, and fruit damage was noted, and in some cases, an entire year's crop was lost. Many homes and vehicles were also damaged. Hail depth on some roads reached eight inches and had to be plowed. A large area of southern Columbia County had considerable flood and hail damage (refer to Section 3.7 for more about the flooding accompanying the hail damage). The slow movement of the thunderstorms amplified the damage. Damage estimates were over $500 million with $1.7 million in crop damage.[1]

On June 12, 2008, a severe storm produced hail stones up to five inches in diameter just west of the City of Waukesha (Waukesha County). This would be the third largest hailstone in Wisconsin's recorded history.

Two years later, scattered severe storms with large hail struck parts of central and southern Wisconsin on April 3, April 10, May 22, and June 8, 2010. There were many reports of hailstones ranging from two inches to 4.25 inches in diameter. On April 3, 2010 alone, at least 575 insurance claims were filed with Madison-based American Family Insurance Company in Dane and Dodge Counties. Collectively, reported and unreported damage for the four days of large hail probably totaled several million dollars.

Figure 3.4.2-4 on the following page highlights the severe hailstorm events (hailstone diameter of 0.75 inch or larger) that occurred in each Wisconsin county from 1982 to 2010, including the number of deaths and injuries attributed to those events. Only three counties have experienced less than twenty hail events during the 28 year period shown. There are ten counties with over 100 severe hail events, and an additional ten counties with between 80 and 99 severe hail events. Many of these counties, such as Dane and Grant, have large amounts of lands used for agriculture. Other counties, such as Milwaukee, Waukesha, Dane, and St. Croix, have a high concentration of development and population. Shockingly, very few injuries have occurred in these more densely populated counties. Manitowoc County has seen the highest number of reported injuries from hail with 30, some of which occurred in the previously mentioned May 12, 2000 event.

3.4.3 Probability of Occurrence

According to local experts at the NOAA National Weather Service in Sullivan, Wisconsin, the average land area affected by an individual hail event is about 225 square miles, or an area equal to half of Green County. In other words, on average, an area with diameter seventeen miles surrounding the center of the storm is affected in a hail event. Hail risk at a single point or over an area is a function of the target at risk (property or crop) and the hail frequency and intensity.[2]

The annual probability of hail occurring somewhere in the state is quite high. However, the site-specific incidence of hail is lower, due to the localized nature of the hazard.

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1. The crop damage estimate is based on a newspaper report which quoted a USDA report. The property damage is purely an estimate based on a variety of reports.
2. The estimate was provided by a meteorologist specializing in storm statistics at the Milwaukee/Sullivan NWS Office, 2011.

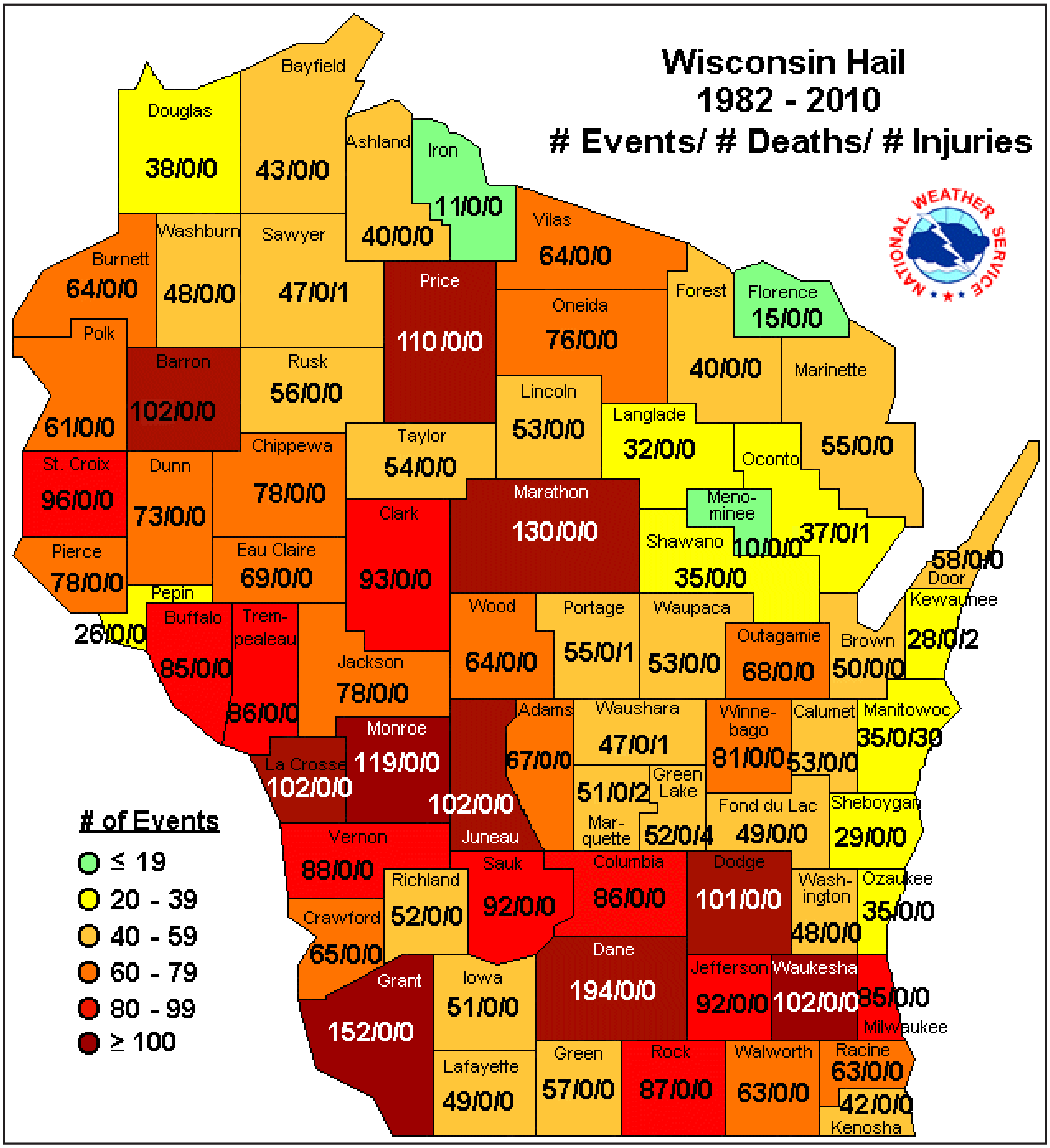


Figure 3.4.2-4 Severe Hail Events by County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.4.4 Estimated Losses

The following five tables (3.4.4-1 through 3.4.4-5) were compiled using historic data from the Milwaukee/Sullivan NWS. Note that not all damages or injuries are reported to the NWS, and the only damages included in these calculations are those reported. Though this data is incomplete, it is the best available.

From January 1, 1994 to December 31, 2010, information on hail events with hailstones greater than 0.75 inches in diameter (penny size hailstones) in each county in the state was used. The NWS does not have complete historic records for severe hail events prior to 1994.

All damages were reported in nominal dollar values, and were adjusted for inflation to reflect 2008 values. 2008 was selected, because it aligns with the most recent version of FEMA Benefit-Cost Analysis software.

Damage calculations included all reported property and crop damages, as well as injuries sustained in a severe hail event. Deaths were not incorporated, since Wisconsin did not experience a death as a result of a hail event during the sixteen year study period.

1. **Injury** was assigned a value based on the May 2009 FEMA Benefit-Cost Analysis Reengineering (BCAR) Methodology Report. Using the “Willingness to Pay” (WTP) or Hedonic Pricing Methodology used by the Federal Aviation Administration (FAA), the rounded value of a minor injury in 2008 was $12,000 and the rounded value of a moderate injury in 2008 was $90,000. These are the most up-to-date values used for calculations in FEMA’s Benefit-Cost Analysis software program.
2. Since the NWS does not differentiate between a major and minor injury in their data, a “**blended injury**” value was calculated by averaging the WTP to avoid a minor and a moderate injury: ($12,000+$90,000)/2 = $51,000.

Using the data provided by NWS, the following calculations were used:

- **Total Reported Injury Damages:** cumulative sum of all damages associated with reported injuries from a severe hail event (1994-2010), as reported to the NWS
- **Total Reported Property Damages:** cumulative sum of all reported property damage as a result of a severe hail event (1994-2010), as reported to the NWS
- **Total Reported Crop Damages:** cumulative sum of all reported crop damages associated with severe hail events (1994-2010), as reported to the NWS
- **Average Reported Property Damage Per Hail Event** = Total Reported Property Damages ($) divided by the Number of Severe Hail Events in a county
- **Average Reported Crop Damage Per Hail Event** = Total Reported Crop Damages ($) divided by the Number of Severe Hail Events in a county
- **Average Damage Per Hail Event** = Total Reported Damages ($) divided by the Number of Severe Hail Events in a county
- **Annual Probability of a Hail Event** = Number of Severe Hail Events divided by the number of years reported (17 years)
- **Estimated Future Annual Loss** = Annual Probability of a Hail Event x Average Damage per Hail Event

Table 3.4.4-1, below, highlights severe hail events in Wisconsin in the 17-year period from 1994 to 2010 by county. The highest value in each category is highlighted in black, while the next four highest values are highlighted in gray. As indicated, there exists a wide range of events and reported damages. Not surprisingly, counties with higher populations tend to have higher reported property damages.

TABLE 3.4.4-1 DAMAGES ASSOCIATED WITH SEVERE HAIL EVENTS IN WISCONSIN, 1994-2010

County Name	Number of Severe Hail Events	Number of Reported Injuries	Total Estimated Losses From Reported Injuries	Total Reported Property Damages	Average Reported Property Damages per Hail Event	Total Reported Crop Damages	Average Crop Damages per Hail Event	Total Reported Damages	Average Total Damage per Hail Event	Annual Probability of a Hail Event	Estimated Average Future Annual Loss
Adams	28	-	-	$503,150	$17,970	$232,710	$8,311	$735,860	$26,281	1.647	$43,286
Ashland	17	-	-	-	-	-	-	-	-	1.000	-
Barron	44	-	-	$33,072,500	$751,648	-	-	$33,072,500	$751,648	2.588	$1,945,441
Bayfield	26	-	-	$11,880	$457	-	-	$11,880	$457	1.529	$699
Brown	26	-	-	-	-	-	-	-	-	1.529	-
Buffalo	43	-	-	$119,480	$2,779	$173,160	$4,027	$292,640	$6,806	2.529	$17,214
Burnett	30	-	-	$352,500	$11,750	-	-	$352,500	$11,750	1.765	$20,735
Calumet	25	-	-	**$46,848,000**	**$1,873,920**	$21,400	$856	**$46,869,400**	**$1,874,776**	1.471	**$2,757,024**
Chippewa	30	-	-	$40,000	$1,333	$45,000	$1,500	$85,000	$2,833	1.765	$5,000
Clark	40	-	-	$225,430	$5,636	$294,540	$7,364	$519,970	$12,999	2.353	$30,586
Columbia	43	-	-	**$541,847,500**	**$12,601,105**	$3,066,000	$71,302	**$544,913,500**	**$12,672,407**	2.529	**$32,053,735**
Crawford	27	-	-	$566,710	$20,989	$1,532,690	$56,766	$2,099,400	$77,756	1.588	$123,494
Dane	**65**	-	-	**$75,686,230**	$1,164,404	$162,490	$2,500	**$75,848,720**	$1,166,903	3.824	**$4,461,689**
Dodge	48	-	-	$3,947,570	$82,241	$2,680	$56	$3,950,250	$82,297	2.824	$232,368
Door	32	-	-	-	-	-	-	-	-	1.882	-
Douglas	22	-	-	$14,100	$641	-	-	$14,100	$641	1.294	$829
Dunn	33	-	-	$122,000	$3,697	-	-	$122,000	$3,697	1.941	$7,176
Eau Claire	30	-	-	-	-	-	-	-	-	1.765	-
Florence	10	-	-	-	-	-	-	-	-	0.588	-
Fond Du Lac	25	-	-	$57,970	$2,319	-	-	$57,970	$2,319	1.471	$3,410
Forest	26	-	-	$110,000	$4,231	-	-	$110,000	$4,231	1.529	$6,471
Grant	**52**	-	-	$3,529,870	$67,882	**$16,111,560**	**$309,838**	$19,641,430	$377,720	3.059	$1,155,378
Green	27	-	-	$12,500	$463			$12,500	$463	1.588	$735

TABLE 3.4.4-1 CONTINUED

County Name	Number of Severe Hail Events	Number of Reported Injuries	Total Estimated Losses From Reported Injuries	Total Reported Property Damages	Average Reported Property Damages per Hail Event	Total Reported Crop Damages	Average Crop Damages per Hail Event	Total Reported Damages	Average Total Damage per Hail Event	Annual Probability of a Hail Event	Estimated Average Future Annual Loss
Green Lake	29	4	$204,000	$1,877,280	$64,734	$393,400	$13,566	$2,474,680	$85,334	1.706	$145,569
Iowa	27	-	-	$24,178,400	$895,496	$398,850	$14,772	$24,577,250	$910,269	1.588	$1,445,721
Iron	6	-	-	-	-	-	-	-	-	0.353	-
Jackson	30	-	-	$2,600,780	$86,693	$1,107,490	$36,916	$3,708,270	$123,609	1.765	$218,134
Jefferson	47	-	-	$14,578,750	$310,186	$125,000	$2,660	$14,703,750	$312,846	2.765	$864,926
Juneau	33	-	-	$673,710	$20,415	$585,450	$17,741	$1,259,160	$38,156	1.941	$74,068
Kenosha	26	-	-	$221,790	$8,530	-	-	$221,790	$8,530	1.529	$13,046
Kewaunee	15	2	$102,000	$1,100	$73	-	-	$103,100	$6,873	0.882	$6,065
La Crosse	25	-	-	$1,767,440	$70,698	$40,910	$1,636	$1,808,350	$72,334	1.471	$106,374
Lafayette	26	-	-	$6,203,030	$238,578	**$12,061,000**	**$463,885**	$18,264,030	$702,463	1.529	$1,074,355
Langlade	23	-	-	$1,370	$60	-	-	$1,370	$60	1.353	$81
Lincoln	28	-	-	$2,680	$96	-	-	$2,680	$96	1.647	$158
Manitowoc	24	**30**	$1,530,000	**$63,922,440**	**$2,663,435**	**$6,268,700**	**$261,196**	**$71,721,140**	**$2,988,381**	1.412	**$4,218,891**
Marathon	**54**	-	-	$12,280	$227	-	-	$12,280	$227	3.176	$722
Marinette	33	-	-	$79,750	$2,417	-	-	$79,750	$2,417	1.941	$4,691
Marquette	29	2	$102,000	$1,252,280	$43,182	-	-	$1,354,280	$46,699	1.706	$79,664
Menominee	8	-	-	-	-	-	-	-	-	0.471	-
Milwaukee	32	-	-	$8,629,000	$269,656	-	-	$8,629,000	$269,656	1.882	$507,588
Monroe	40	-	-	$1,257,790	$31,445	**$4,964,350**	**$124,109**	$6,222,140	$155,554	2.353	$366,008
Oconto	25	1	$51,000	$2,461,000	$98,440	$802,500	$32,100	$3,314,500	$132,580	1.471	$194,971
Oneida	31	-	-	$458,010	$14,775	-	-	$458,010	$14,775	1.824	$26,942
Outagamie	22	-	-	$6,138,000	$279,000	-	-	$6,138,000	$279,000	1.294	$361,059
Ozaukee	19	-	-	$6,810,500	$358,447	$17,550	$924	$6,828,050	$359,371	1.118	$401,650
Pepin	22	-	-	$244,000	$11,091	$1,605,000	$72,955	$1,849,000	$84,045	1.294	$108,765
Pierce	39	-	-	$24,400,000	$625,641	**$5,625,000**	**$144,231**	$30,025,000	$769,872	2.294	$1,766,176
Polk	33	-	-	$160,030	$4,849	-	-	$160,030	$4,849	1.941	$9,414

TABLE 3.4.4-1 CONTINUED

County Name	Number of Severe Hail Events	Number of Reported Injuries	Total Estimated Losses From Reported Injuries	Total Reported Property Damages	Average Reported Property Damages per Hail Event	Total Reported Crop Damages	Average Crop Damages per Hail Event	Total Reported Damages	Average Total Damage per Hail Event	Annual Probability of a Hail Event	Estimated Average Future Annual Loss
Portage	29	1	$51,000	-	-	-	-	$51,000	$1,759	1.706	$3,000
Price	36	-	-	-	-	-	-	-	-	2.118	-
Racine	32	-	-	$192,460	$6,014	$0	$0	$192,460	$6,014	1.882	$11,321
Richland	32	-	-	$61,900	$1,934	$206,980	$6,468	$268,880	$8,403	1.882	$15,816
Rock	46	-	-	$4,766,500	$103,620	$2,904,430	$63,140	$7,670,930	$166,759	2.706	$451,231
Rusk	30	-	-	-	-	-	-	-	-	1.765	-
Sauk	43	-	-	$1,071,940	$24,929	$568,370	$13,218	$1,640,310	$38,147	2.529	$96,489
Sawyer	21	-	-	-	-	-	-	-	-	1.235	-
Shawano	14	-	-	-	-	-	-	-	-	0.824	-
Sheboygan	14	-	-	-	-	$1,200	$86	$1,200	$86	0.824	$71
St. Croix	41	-	-	$3,660,000	$89,268	$39,600	$966	$3,699,600	$90,234	2.412	$217,624
Taylor	23	-	-	$243,990	$10,608	$377,560	$16,416	$621,550	$27,024	1.353	$36,562
Trempealeau	41	-	-	$83,200	$2,029	$124,830	$3,045	$208,030	$5,074	2.412	$12,237
Vernon	33	-	-	$454,070	$13,760	$483,150	$14,641	$937,220	$28,401	1.941	$55,131
Vilas	25	-	-	$895,000	$35,800	-	-	$895,000	$35,800	1.471	$52,647
Walworth	31	-	-	-	-	$2,000	$65	$2,000	$65	1.824	$118
Washburn	24	-	-	$4,230	$176	-	-	$4,230	$176	1.412	$249
Washington	30	-	-	$4,283,870	$142,796	-	-	$4,283,870	$142,796	1.765	$251,992
Waukesha	51	-	-	$25,198,170	$494,082	$29,250	$574	$25,227,420	$494,655	3.000	$1,483,966
Waupaca	28	-	-	$2,140,000	$76,429	-	-	$2,140,000	$76,429	1.647	$125,882
Waushara	24	1	$51,000	$32,500,000	**$1,354,167**	-	-	$32,551,000	**$1,356,292**	1.412	$1,914,765
Winnebago	49	-	-	$22,500,000	$459,184	-	-	$22,500,000	$459,184	2.882	$1,323,529
Wood	33	-	-	**$46,800,000**	**$1,418,182**	-	-	**$46,800,000**	**$1,418,182**	1.941	**$2,752,941**
STATE	**N/A**	**41**	**$2,091,000**	**$1,019,854,130**	**$462,519**	**$60,374,800**	**$27,381**	**$1,082,319,930**	**$490,848**	**N/A**	**$63,665,878**

Source: NOAA National Climatic Data Center Storm Event Database, 2011.

12 counties experienced over $10 million in total reported property damages, as shown in Table 3.4.4-2. Columbia County has had by far the most reported property damages.

TABLE 3.4.4-2 COUNTIES WITH THE HIGHEST TOTAL PROPERTY DAMAGES FROM SEVERE HAIL EVENTS IN WISCONSIN, 1994-2010

County Name	Number of Severe Hail Events	Average Reported Property Damages per Event	Total Reported Property Damages
Columbia	43	$12,601,105	$541,847,500
Dane	65	$1,164,404	$75,686,230
Manitowoc	24	$2,663,435	$63,922,440
Calumet	25	$1,873,920	$46,848,000
Wood	33	$1,418,182	$46,800,000
Barron	44	$751,648	$33,072,500
Waushara	24	$1,354,167	$32,500,000
Waukesha	51	$494,082	$25,198,170
Pierce	39	$625,641	$24,400,000
Iowa	27	$895,496	$24,178,400
Winnebago	49	$459,184	$22,500,000
Jefferson	47	$310,186	$14,578,750
STATE	**N/A**	**$462,519**	**$1,019,854,130**

Source: NOAA National Climatic Data Center Storm Event Database, 2011.

Table 3.4.4-3, below, shows that during the same 17-year period, ten counties experienced over $1 million in total reported crop damages, with two counties over $10 million.

TABLE 3.4.4-3 COUNTIES WITH THE HIGHEST REPORTED CROP DAMAGES FROM SEVERE HAIL EVENTS IN WISCONSIN, 1994-2010

County Name	Number of Severe Hail Events	Average Crop Damages per Hail Event	Total Reported Crop Damages
Grant	52	$309,838	$16,111,560
Lafayette	26	$463,885	$12,061,000
Manitowoc	24	$261,196	$6,268,700
Pierce	39	$144,231	$5,625,000
Monroe	40	$124,109	$4,964,350
Columbia	43	$71,302	$3,066,000
Rock	46	$63,140	$2,904,430
Pepin	22	$72,955	$1,605,000
Crawford	27	$56,766	$1,532,690
Jackson	30	$36,916	$1,107,490
STATE	**N/A**	**$27,381**	**$60,374,800**

Source: NOAA National Climatic Data Center Storm Event Database, 2011.

Only seven counties reported injuries during severe hail events from 1994 to 2010 as seen in Table 3.4.4-4. All of Manitowoc County's injuries were reported in one hail event, profiled in the Wisconsin Hail Event History section.

TABLE 3.4.4-4 INJURIES SUSTAINED AS A RESULT OF SEVERE HAIL EVENTS IN WISCONSIN, 1994-2010

County Name	Number of Severe Hail Events	Number of Reported Injuries	Total Estimated Losses from Reported Injuries
Manitowoc	24	30	$1,530,000
Green Lake	29	4	$204,000
Kewaunee	15	2	$102,000
Marquette	29	2	$102,000
Oconto	25	1	$51,000
Portage	29	1	$51,000
Waushara	24	1	$51,000
STATE	**N/A**	**41**	**$2,091,000**

Source: NOAA National Climatic Data Center Storm Event Database, 2011.

Table 3.4.4-5 lists the 13 Wisconsin counties with estimated average future annual losses over $1 million. Columbia County leads the category, partly due to the 2006 severe hail event which had over $500 million in reported damages. Dane County is second in the rankings, due in part the large concentration of population to report damages. Manitowoc is in third place, partly due to the May 12, 2000 event, in which 30 injuries were reported.

TABLE 3.4.4-5 HIGHEST ESTIMATED AVERAGE FUTURE ANNUAL LOSSES BY COUNTY FOR WISCONSIN HAIL EVENTS

County Name	Number of Severe Hail Events	Total Reported Damages	Average Total Damage per Hail Event	Estimated Average Future Annual Loss
Columbia	43	$544,913,500	$12,672,407	$34,057,094
Dane	65	$75,848,720	$1,166,903	$4,740,545
Manitowoc	24	$71,721,140	$2,988,381	$4,482,571
Calumet	25	$46,869,400	$1,874,776	$2,929,338
Wood	33	$46,800,000	$1,418,182	$2,925,000
Barron	44	$33,072,500	$751,648	$2,067,031
Waushara	24	$32,551,000	$1,356,292	$2,034,438
Pierce	39	$30,025,000	$769,872	$1,876,563
Waukesha	51	$25,227,420	$494,655	$1,576,714
Iowa	27	$24,577,250	$910,269	$1,536,078
Winnebago	49	$22,500,000	$459,184	$1,406,250
Grant	52	$19,641,430	$377,720	$1,227,589
Lafayette	26	$18,264,030	$702,463	$1,141,502

Source: NOAA National Climatic Data Center Storm Event Database, 2011.

3.4.5 Hazard Ranking

TABLE 3.4.5-1 HAZARD RANKING FOR HAIL		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard has impacted the State numerous times on an annual basis • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The State or Counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under Federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor	Low

3.4.6 Sources for Hail

TABLE 3.4.6-1 SOURCES FOR HAIL	
Source Title	Link to Resource
FEMA's Multi-Hazard Identification and Risk Assessment, "Part 1: Atmospheric Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
NOAA Severe Weather Information	http://www.noaawatch.gov/themes/severe.php
National Climatic Data Center Storm Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
NOAA National Severe Storms Laboratory	http://www.nssl.noaa.gov/
NWS Storm Prediction Center	http://www.spc.noaa.gov/
Natural Hazards Center, University of Colorado Boulder	http://www.colorado.edu/hazards/
NWS Weather Forecast Office, Milwaukee/Sullivan, WI	http://www.crh.noaa.gov/mkx/
NWS Weather Forecast Office, Green Bay, WI	http://www.crh.noaa.gov/grb/
NWS Weather Forecast Office, La Crosse, WI	http://www.crh.noaa.gov/arx/

3.5 LIGHTNING

3.5.1 Nature of the Hazard

Lightning typically occurs as a byproduct of a thunderstorm. The action of rising and descending air in a thunderstorm separates positive and negative charges, with lightning the result of the buildup and discharge of energy between positive and negative charge areas. Water and ice particles may also affect the distribution of the electrical charge. In only a few millionths of a second, the air near a lightning strike is heated to 50,000°F, a temperature hotter than the surface of the sun. Thunder is the result of the very rapid heating and cooling of air near the lightning that causes a shock wave.

The hazard posed by lightning is significantly underrated. High winds, rainfall, and a darkening cloud cover are the warning signs for possible cloud-to-ground lightning strikes. While many lightning casualties happen at the beginning of an approaching storm, more than half of lightning deaths occur after a thunderstorm has passed. The lightning threat diminishes after the last sound of thunder, but may persist for more than 30 minutes. When thunderstorms are in the area, but not overhead, the lightning threat can exist when skies are clear. Lightning has been known to strike more than ten miles from the storm in an area with clear sky above.

According to the National Weather Service (NWS), on average, about 25 million cloud-to-ground strikes are detected in the continental United States annually, with about half of all flashes contacting more than one ground point. In addition, there are roughly five to ten times as many cloud-to-cloud flashes as there are to cloud-to-ground flashes (NWS).

In the 69 year period between 1940 and 2009, 9,151 deaths have been reported as a result of lightning in the US (NWS). Over the past 30 years (1980 to 2010) the US has seen an annual average of 56 lightning deaths. In 2010, there were only 45 lightning deaths; however as of July 1 in 2011, there have been 55 lightning deaths nationwide.

In Wisconsin, there have been 290 lightning events between 2000 and 2010. During this ten-year period, five deaths and 56 injuries were reported in the state. These lightning incidents also resulted in about $47 million in reported property damage and $3,000 in crop damages.

These numbers are likely an underestimate of the actual number of casualties because few people report suspected lightning deaths, injuries, and damages. Cloud-to-ground lightning can kill or injure people or damage property through direct or indirect means. As such, to the general public, lightning is often perceived as a minor hazard; however, lightning-caused damage, injuries, and deaths establish lightning as a significant hazard associated with any thunderstorm in any part of the state.

Large outdoor gatherings (sporting events, concerts, campgrounds, etc.) are particularly vulnerable to lightning strikes that could result in injuries and deaths. This vulnerability underscores the importance of developing site-specific emergency procedures for these types of events, with particular emphasis on adequate early warning. Early warning of lightning hazards, combined with prudent protective actions, can greatly reduce the likelihood of lightning-related injuries and deaths.

Researchers identified noticeable patterns in lightning fatality cases. In a 1998 study, the Center for Disease Control (CDC) states that for the period of 1959-1990, “approximately 30% of persons struck by lightning die and 74% of lightning strike survivors have permanent disabilities.” The study also notes that burn victims are at higher risk for death than those struck by lightning. Sixty-three percent of lightning-associated deaths occur within 1 hour of injury, 92% occur between May and September, and 73% occur during the afternoon and early evening. Of persons who died from lightning strikes, 52% were engaged in outdoor recreational activities and 25% were engaged in work activities (CDC, 1998).

3.5.2 Wisconsin Lightning Event History

Wisconsin has a high frequency of property losses due to lightning. During the ten-year period between 2000 and 2010, there was nearly $47 million in property and crop damage reported in Wisconsin (NWS, 2011). One of the most damaging lightning events in this time period occurred during a storm in Kenosha on August 24, 2006. Lightning was responsible for at least $14 million in reported damages.

In Wisconsin from 2000 to 2010 there were five reported fatalities and 56 injuries directly caused by lightning (NWS). Figure 3.5.2-1 on the next page shows the damaging lighting events by county from 1982 to 2010. The number of reported events, deaths, and injuries are also displayed on the map. It is important to consider that these numbers are likely under-estimated, since many incidents go unreported. Note the high concentration of damaging lightning events in the southeastern part of the state. Waukesha County leads Wisconsin in number of lightning events with 75 occurring since 1982. Walworth and Rock Counties have experienced the highest number of reported injuries with 18 and 15, respectively. The high number of lightning-related injuries in southeastern Wisconsin may be related to the higher concentration of population.

3.5.3 Probability of Occurrence

Lightning occurs with most severe thunderstorms, though does not always produce damages. The probability of lightning itself occurring is quite high, due to the high number of severe thunderstorms in the state; however, the site-specific incidence of lightning is considered low because of the localized nature of the hazard.

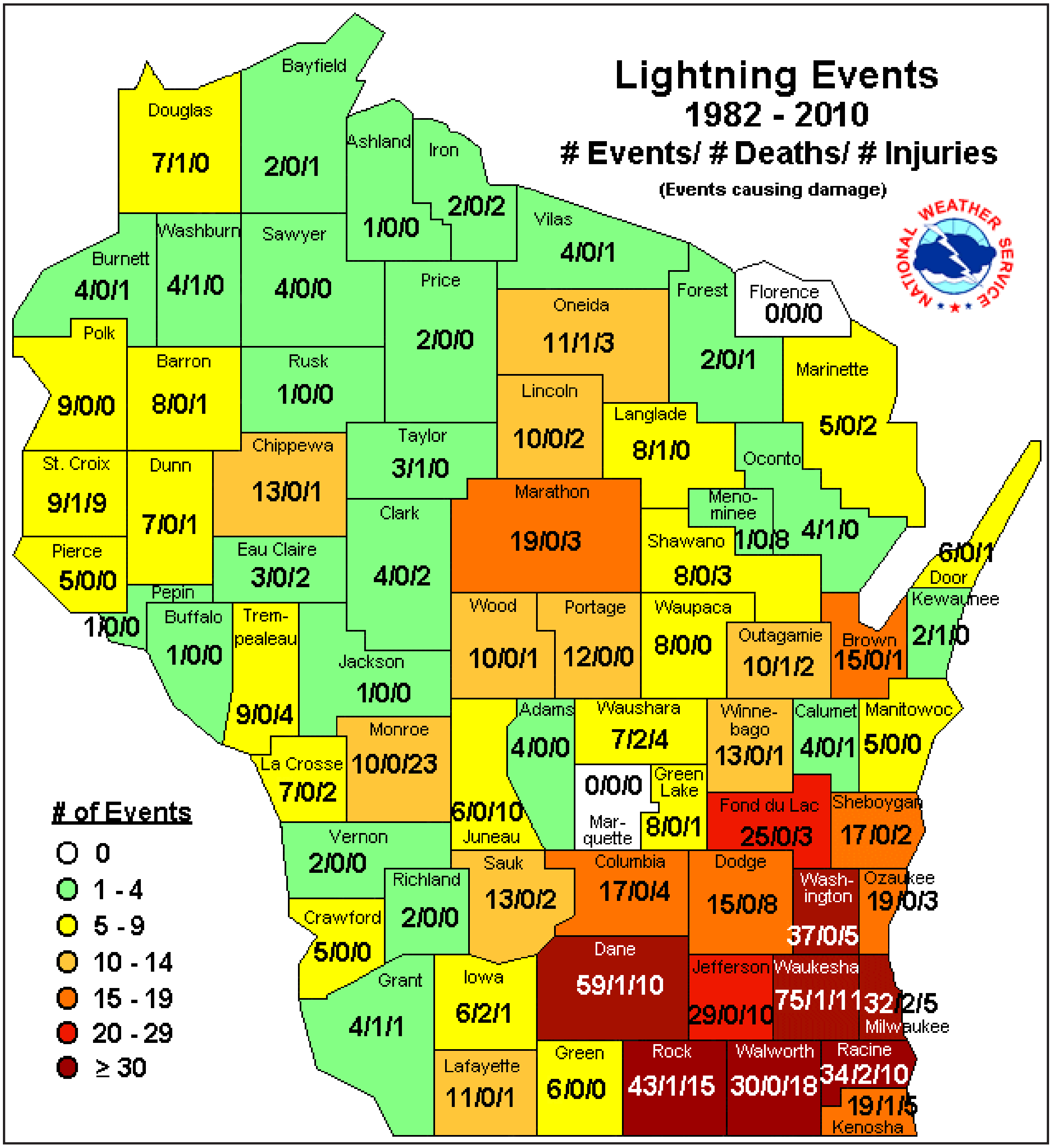


Figure 3.5.2-1 Lightning Events by County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.5.4 Hazard Ranking

TABLE 3.5.4-1 HAZARD RANKING FOR LIGHTNING		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard has impacted the State numerous times on an annual basis • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The State or Counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under Federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor	Low

3.5.5 Sources for Lightning

TABLE 3.5.5-1 SOURCES FOR LIGHTNING	
Source Title	Link to Resource
FEMA's Multi-Hazard Identification and Risk Assessment, "Part 1: Atmospheric Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
NOAA Severe Weather Information	http://www.noaawatch.gov/themes/severe.php
National Climatic Data Center Storm Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
NOAA National Severe Storms Laboratory	http://www.nssl.noaa.gov/
NWS Storm Prediction Center	http://www.spc.noaa.gov/
Natural Hazards Center, University of Colorado Boulder	http://www.colorado.edu/hazards/
NWS Weather Forecast Office, Milwaukee/Sullivan, WI	http://www.crh.noaa.gov/mkx/
NWS Weather Forecast Office, Green Bay, WI	http://www.crh.noaa.gov/grb/
NWS Weather Forecast Office, La Crosse, WI	http://www.crh.noaa.gov/arx/
NWS Office of Climate, Water, and Weather Services Natural Hazard Statistics	http://www.nws.noaa.gov/om/hazstats.shtml
NWS Lightning Safety	http://www.lightningsafety.noaa.gov/

3.6 TORNADOES AND HIGH WINDS

3.6.1 Nature of the Hazard

A tornado is a violently rotating column of air (vortex) extending from the base of a convective cloud (usually cumulonimbus) to the ground. Tornadoes can form within many environments; however, three common environments include intense squall lines, supercell thunderstorms, and the right front quadrant of land-falling hurricanes within the spiral bands of thunderstorms. Though more uncommon, tornadoes may also result from earthquake induced fires, wildfires, or atomic bombs (FEMA, 1997). Additionally, severe weather spotter and research videotapes of tornadoes in the past twenty years have shown that a tornado can be in progress, but a visible "funnel cloud" may be absent at the ground level, while rotating dirt/debris at the ground and cloud-base rotation indicate that a tornado occurred (NWS).

Tornado damage severity is measured by the Enhanced Fujita Tornado Scale (EF-Scale). The EF-Scale keeps the previous numerical values of zero to five from the old Fujita Tornado Scale (F-Scale), but the wind speed values associated with the upper portions of the rating system were lowered in the EF-Scale, based on engineering studies and meteorological research. Table 3.6.1-1, at right, shows the criteria of the EF-Scale. A detailed description of the EF-Scale can be found online at the National Weather Service (NWS) Storm Prediction Center website.

TABLE 3.6.1-1 ENHANCED FUJITA (EF) TORNADO SCALE

Category	F-Scale Wind Speed (mph)	EF-Scale Wind Speed (mph)
EF0 (weak)	40-72 mph	65-85 mph
EF1 (weak)	73-112 mph	86-110 mph
EF2 (strong)	113-157 mph	111-135 mph
EF3 (strong)	158-206 mph	136-165 mph
EF4 (violent)	207-260 mph	166-200 mph
EF5 (violent)	261-318 mph	>200 mph

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.6.2 Wisconsin Tornado Event History

Most tornadoes in the United States last less than 10 minutes, but can exist for more than an hour (NOAA Storm Prediction Center. The path of a tornado can range from a few hundred feet to miles, and tornado widths may range from tens of yards to a mile or two.

Wisconsin lies along the northern edge of the nation's maximum frequency belt for tornadoes, called "tornado alley" by some, which extends northeastward from Oklahoma into Iowa and then across to Illinois and southern Wisconsin. Generally, the southern portion of Wisconsin has a higher frequency of tornadoes, though every county in Wisconsin has had tornadoes and is susceptible to a tornado disaster.

Table 3.6.2-1, on the following page, shows all reported tornado ratings in Wisconsin from 1982 to 2010. This table indicates that about 85.3% of Wisconsin's tornadoes were rated as "weak" (EF0 & EF1), 13.7% were "strong" (EF2 & EF3), and about 0.9% were "violent" (EF4 & EF5).

The “average” Wisconsin tornado for the period of 1982-2007 had a life-span of 7.1 minutes, a path length of 3.7 miles, a path width of 118 yards, and an EF rating of 0.7 (mid-way between an EF0 and EF1) (NWS).

Tornadoes have occurred at all times of the day in Wisconsin. The peak hours of occurrence are between 3:00 and 10:00 p.m., when 75% of the tornadoes occur, with the busiest “spin-up hour” between 6:00 and 7:00 p.m. (NWS).

As seen in Figure 3.6.2-1, on the following page, the only month with no documented tornadoes in Wisconsin is February. June has the highest tornado frequency, followed by July, May, and August. Winter, spring, and fall tornadoes historically are more likely to occur in southern Wisconsin than in the northern parts of the state.

Figure 3.6.2-2, on the following page, is a plot of Wisconsin short- and long-track tornadoes for the period of 1950-2010. This map shows that most long-track tornadoes in the state travel southwest to northeast; however, a number of the tornadoes moved west to east as well as northwest to southeast. Data accompanying the map indicated that northwest to southeast moving tornadoes tended to occur in the later part of the warm season.

Figure 3.6.2-2, on the following page, is a plot of Wisconsin short- and long-track tornadoes for the period of 1950-2010. This map shows that most long-track tornadoes in the state travel southwest to northeast; however, a number of the tornadoes moved west to east as well as northwest to southeast. Data accompanying the map indicated that northwest to southeast moving tornadoes tended to occur in the later part of the warm season.

TABLE 3.6.2-1 WISCONSIN TORNADO RATINGS

Year	EF0	EF1	EF2	EF3	EF4	EF5	Total
1982	1	9	6	0	0	0	16
1983	16	10	3	1	1	0	31
1984	10	8	10	3	2	1	34
1985	3	7	6	0	0	0	16
1986	4	4	5	1	0	0	14
1987	8	8	0	0	0	0	16
1988	8	19	7	1	0	0	35
1989	9	7	1	0	0	0	17
1990	0	6	3	0	0	0	9
1991	5	3	2	0	0	0	10
1992	6	16	2	2	0	0	26
1993	27	9	1	0	0	0	37
1994	8	18	6	2	1	0	35
1995	5	2	0	0	0	0	7
1996	11	7	2	0	0	1	21
1997	6	6	2	0	0	0	14
1998	16	3	3	2	0	0	24
1999	8	2	0	0	0	0	10
2000	11	6	1	0	0	0	18
2001	7	4	0	1	0	0	12
2002	18	5	2	1	0	0	26
2003	10	4	0	0	0	0	14
2004	22	10	2	2	0	0	36
2005	43	16	2	1	0	0	62
2006	10	2	0	0	0	0	12
2007	13	3	1	1	0	0	18
2008	23	13	1	1	0	0	38
2009	11	5	0	0	0	0	16
2010	17	24	5	0	0	0	46
Total	**336**	**236**	**73**	**19**	**4**	**2**	**670**

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

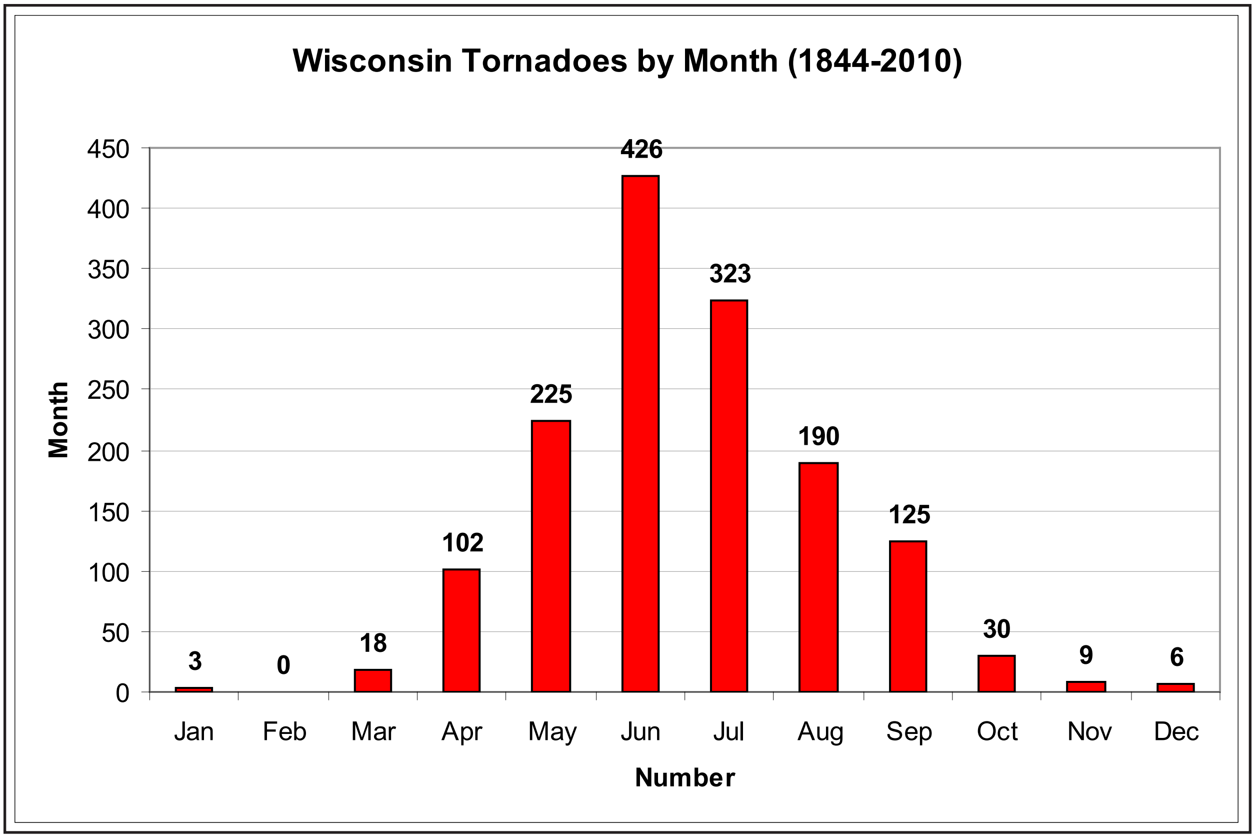


Figure 3.6.2-1 Wisconsin Tornadoes by Month, 1844-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Figure 3.6.2-2, on the following page, is a plot of Wisconsin short- and long-track tornadoes for the period of 1950-2010. This map shows that most long-track tornadoes in the state travel southwest to northeast; however, a number of the tornadoes moved west to east as well as northwest to southeast. Data accompanying the map indicated that northwest to southeast moving tornadoes tended to occur in the later part of the warm season.

The longest-tracked tornado in Wisconsin, 170 miles, was the April 5, 1929, tornado that traveled from southwest of River Falls (Pierce County) to Van Buskirk (Iron County). It resulted in twelve fatalities and 100 injuries. As recently as June 7, 2007, a tornado in northeast Wisconsin traveled for over 40 miles through the counties of Shawano, Menominee, Langlade, and Oconto; the longest-tracked tornado in the entire United States for 2007 (NWS).

Between 1980 and 2010, Wisconsin's tornadoes displayed a strong year-to-year variation, ranging from seven in 1995 to 62 in 2005. For the period of 1971-2000, Wisconsin averaged 20.5 tornadoes and one fatality annually due to tornadoes. That was slightly higher than the average from 1950 to 2009, which was 19.6 tornadoes per year (NWS).

While all Wisconsin counties recorded at least three tornadoes between 1844 and 2010, six counties (Barron, Dane, Dodge, Fond du Lac, Grant, and Marathon) have recorded over 40 tornadoes. Dane, Dodge, Grant, and Marathon Counties have had the most with

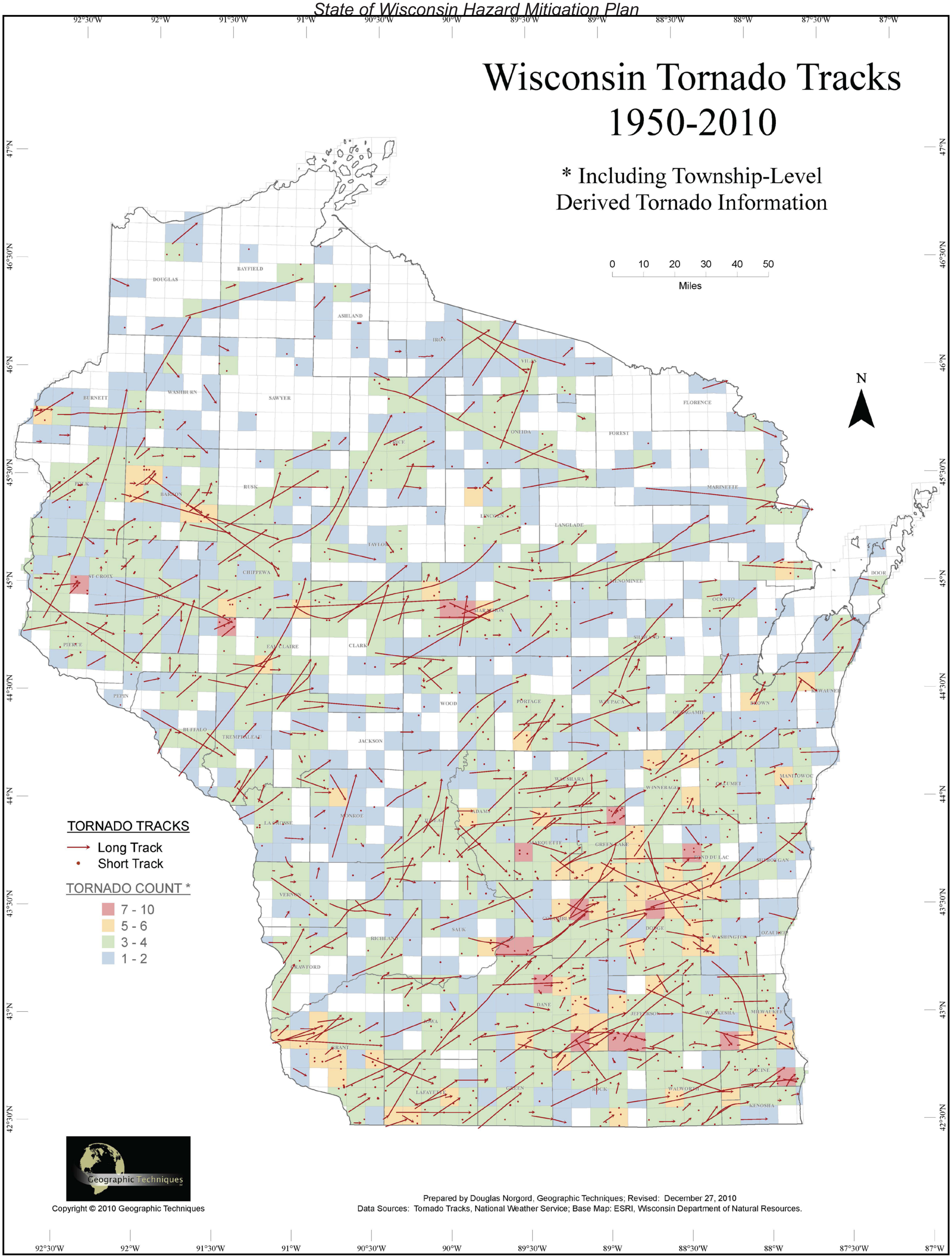


Figure 3.6.2-2 Wisconsin Tornado Tracks, 1950-2010

Source: Geographic Techniques, 2010.

74, 60, 59, and 54, respectively. Figure 3.6.2-3, below, shows the county-by-county distribution of tornadoes between 1844 and 2010. Counties in the southern part of the state have had more recorded tornadoes than the rest of the state, with a concentration of 30 or more tornadoes per county in south-central Wisconsin. Keep in mind that in the 1800s and the early 1900s, tornadoes that did not occur in populated areas during the day were rarely reported or documented.

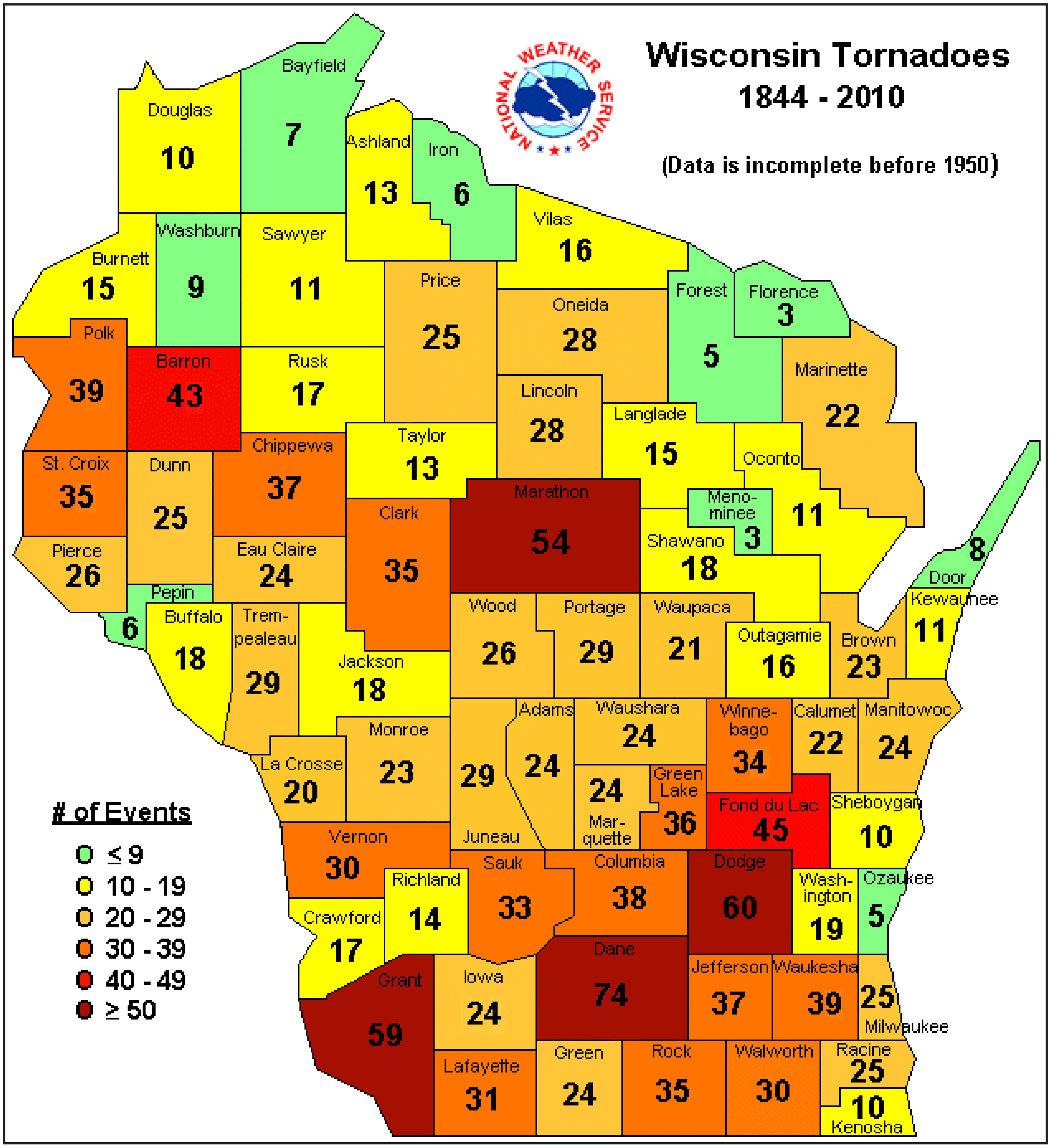


Figure 3.6.2-3 Wisconsin Tornadoes Events by County, 1844-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

June 12, 1899

Figure 3.6.2-4 New Richmond Tornado Damage, June 12, 1899
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2008.

Some of Wisconsin's more noteworthy tornadoes occurred more than 100 years ago. In 1899, half of the City of New Richmond (St. Croix County) was destroyed and 112 people were killed by a powerful tornado. This tornado originated on Lake St. Croix, about five miles south of Hudson. The tornado moved to the northeast, east of Hudson, in the direction of New Richmond, leveling farms near Burkhardt and Boardman. The tornado passed through New Richmond on a day in which about 1,000 people had come from surrounding villages to watch a circus, which ended at about 4:30 p.m. that day. Passing through the very center of town, the tornado leveled buildings and sent debris flying. Over 300 buildings were damaged or destroyed. The damage was estimated at $300,000. The good visibility of the tornado may have prevented an even higher death total. While not a massive tornado, the combination of time and position was unfortunate. Figure 3.6.2-4 shows some of the damage caused by the 1899 tornado.

April 3, 1956

A tornado struck the southeast sector of the City of Berlin (Green Lake County), after damaging three or more farms south and west of the city. It came within a few yards of the high school where 400 students were in class; however, the tornado changed its path, barely missing the school. Witnesses saw cars and buildings lifted and carried through the air. The tornado killed seven people and injured 50. Damage was estimated at over $1 million.

June 4, 1958

20 people died, 110 were injured, and 60 buildings were destroyed in the City of Colfax (Dunn County) by a tornado estimated to be F4 intensity. The same storm system spawned three other tornadoes in Chippewa and Clark Counties that day.

April 21, 1974

A tornado, estimated to be F4 intensity, hit the City of Oshkosh (Winnebago County). Despite a lack of advance warning no one was killed, although seventeen people were reported injured. Eleven commercial structures were damaged and property damage reached $4 million. About the time the tornado began ripping through Oshkosh, a series of tornadoes spun up in the Lomira/Brownsville area (Dodge County). The tornadoes left a trail of broken homes and barns in their wake and destroyed a large lumberyard. Two deaths and numerous injuries were attributed to the storms.

1980

Tornadoes and downbursts occurred in Chippewa, Dunn, Eau Claire, and Pierce Counties and caused more than $150 million in property damage.

June 8, 1984

A powerful F5 tornado struck the Village of Barneveld (Iowa County) and proceeded to move northeast through Dane County. It killed nine people and injured 200 with damage pegged at $40 million along its 36 mile path between 12:41 a.m. and 1:40 a.m.

July 18, 1996

In the late afternoon, a line of thunderstorms caused the NWS to issue a tornado watch for the eastern two-thirds of Wisconsin. As the line moved east, the storms became more severe in Marathon and Portage Counties. The storms were very dangerous by the time they reached Fond du Lac County. Warning sirens sounded in the Village of Oakfield (Fond du Lac County) at approximately 7:08 p.m. At 7:13 p.m., a tornado intensifying from F3 to F4 tore through the community. This violent tornado intensified to an F5 just east of Oakfield. The path of destruction was about 13.3 miles long and up to 0.25 mile wide. Only twelve people were injured, but over 150 homes and businesses were damaged or destroyed.

March 8, 2000

A tornado classified as an F1 by the NWS spun up at General Mitchell International Airport in Milwaukee (Milwaukee County). Tornadoes of this category were considered weak, with 73-112 mph winds (on the old Fujita Scale). However, in just a few minutes, the tornado caused $381,000 worth of damage to about 75 homes and $3.8 million in damage to commercial real estate.

June 18, 2001

A strong F3 tornado hit Burnett and Washburn Counties. This tornado touched down near Grantsburg and continued traveling east for over 25 miles to an area just outside

Spooner. Witnesses said the tornado split into three tornadoes in some areas. There was extensive damage and destruction along the tornado's path. Damage was most concentrated in a six-block wide area of the Village of Siren (Burnett County), where numerous homes and businesses were completely leveled, three people were killed, and sixteen were injured.

September 2, 2002

On Labor Day, the Village of Ladysmith (Rusk County) was hit by an F3 tornado, with estimated winds of 158 to 206 mph. The damage the tornado caused to a 16-by-4-block area, which included most of the downtown business district, was estimated at $20 million. The tornado damaged more than 130 structures in this community of 3,900. There were 24 injuries, none of them serious, primarily because the downtown business district was unusually empty due to the Labor Day holiday.

September 30, 2002

Tornadoes and large hail-producing thunderstorms struck north-central and northeast Wisconsin in the evening. Two tornadoes spun up within twenty minutes of each other. One hit several miles west of Tomahawk (Lincoln County), destroying a trailer home and several out-buildings on the property, throwing a pick-up truck up into a nearby tree, and pushing a 28-foot camper trailer 300 feet. Thousands of trees were knocked over in a nearby wooded area. The F2 twister spun and dissipated just west of the Tomahawk Regional Airport (Lincoln County).

June 8, 2003

During the afternoon, scattered showers and thunderstorms developed across central and east-central Wisconsin as a strong upper-level low pressure system moved across the State. At least five tornadoes developed, four of them in the NWS Green Bay forecast area. The tornado south of Marshfield (Wood County) did several thousand dollars in damage to a garage and play house. Two 50-pound metal barrels were thrown over 200 yards. None of the other tornadoes did any damage.

August 18, 2005

It was a memorable day with 27 tornadoes spinning up in Wisconsin; a new single-day state record. Figure 3.6.2-5, on the following page, shows a plot of the 27 tornadoes. The strongest tornado, which raked the Stoughton area (Dane County), was rated at the top of the EF3 category, traveled for twenty miles, and resulted in one fatality, 23 injuries, and $35 million in reported damages.

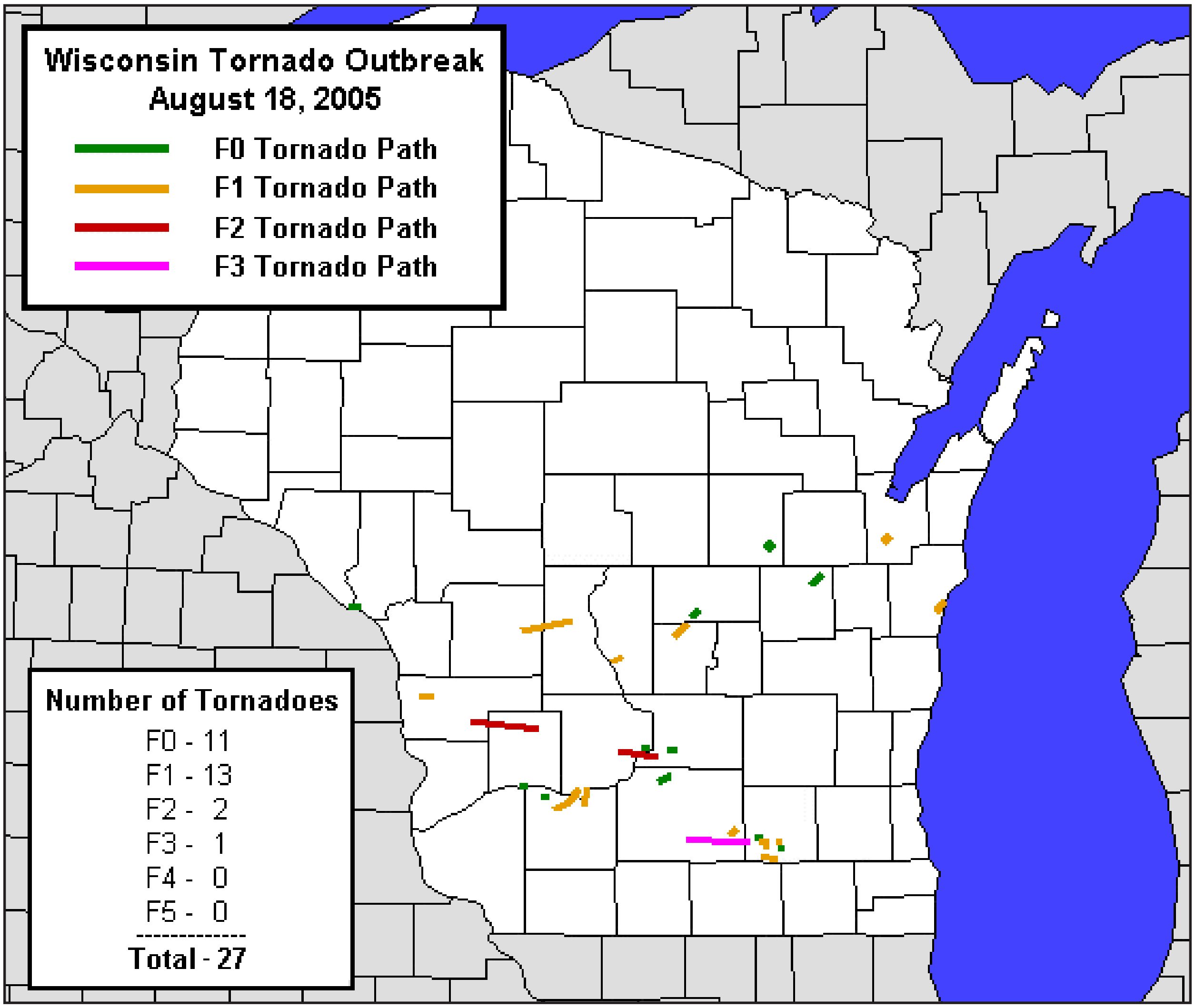


Figure 3.6.2-5 Wisconsin Single-Day State Record Tornado Outbreak, August 18, 2005
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2008.

January 7, 2008

A rare January weather event occurred in southeastern Wisconsin. With temperatures in the lower 60s, thunderstorms formed ahead of a stationary front and produced hail, damaging winds, and a few tornadoes. The first tornado spun up in southeast Walworth County and then tracked through the Wheatland and Brighton areas (Kenosha County). The second tornado occurred in the Town of Somers (Kenosha County) and on the north side of the City of Kenosha (Kenosha County).

In Walworth County, five structures sustained damage - three had minor damage and two had moderate damage. In Kenosha County, with both tornadoes combined, 105 homes sustained damage: 46 homes had minor damage, 32 had major damage, and 27 were destroyed. Thanks to early warnings issued by the NWS, this tornado resulted in only fifteen minor injuries and about $13.8 million in damage. This was the first EF3 tornado in Kenosha County since the rating system began in 1982, and was the first tornado in

Wisconsin in January since the January 24, 1967 tornado in Green and Rock Counties. Figure 3.6.2-6, below, shows the tornadoes' paths.

a

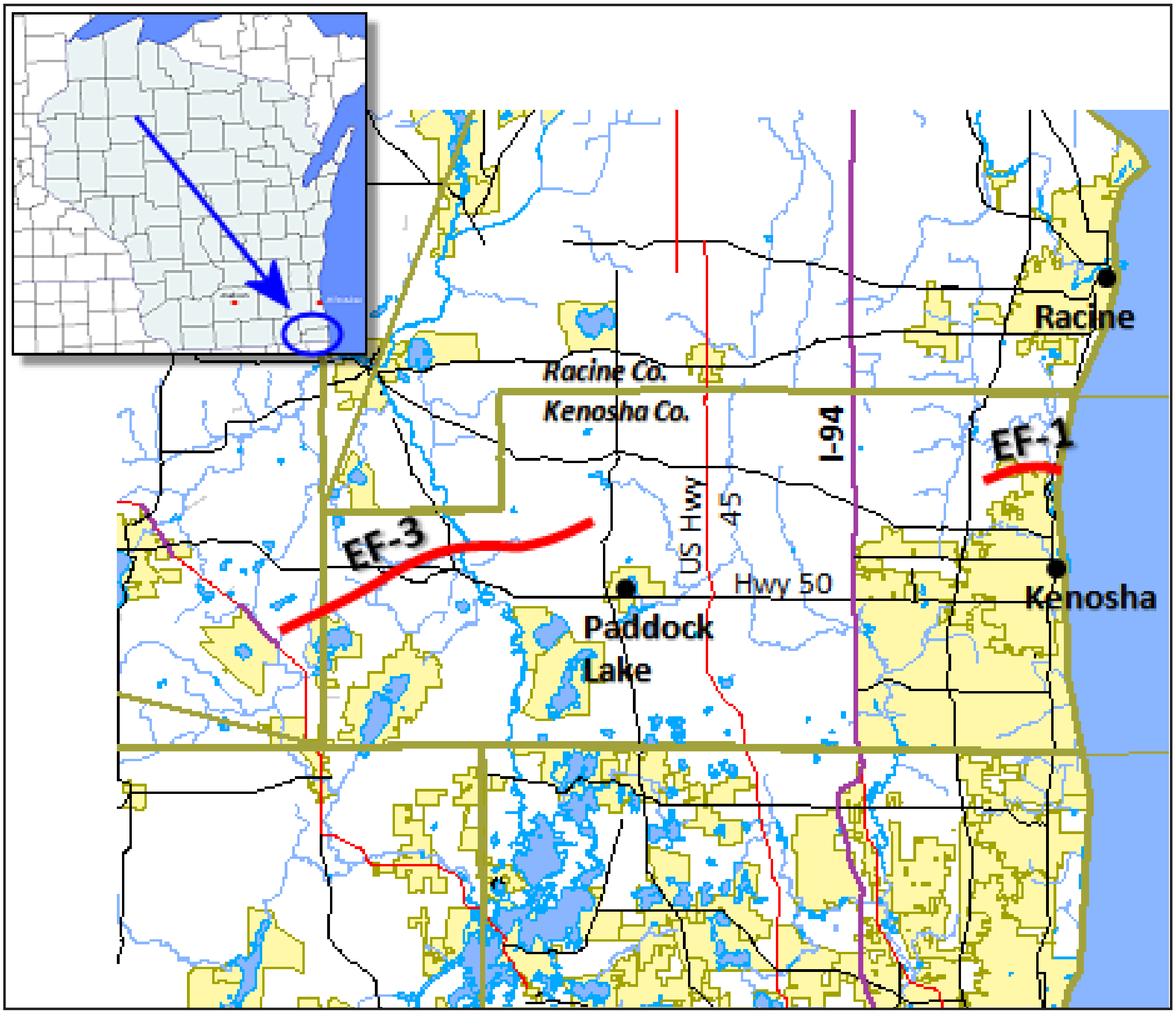


Figure 3.6.2-6 Southeastern Wisconsin Winter Tornadoes, January 7, 2008
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2008.

Table 3.6.2-2, on the following page, lists significant tornadoes in Wisconsin's history and the damage they caused.

TABLE 3.6.2-2 SIGNIFICANT TORNADO EVENTS IN WISCONSIN, 1865-2010				
Date	**EF Rating**	**Location (County or Counties)**	**Reported Damage**	**Fatalities**
6/29/1865		Vernon	Not Available	24
5/23/1878	EF4 (est.)	Dane, Iowa, Jefferson, Milwaukee, Waukesha (may have been 3 separate tornadoes)	Not Available	19
5/18/1898	EF5 (est.)	Clark, Eau Claire, Langlade, Lincoln, Marathon	Not Available	17
6/12/1899		St. Croix	Not Available	117
9/21/1924		Eau Claire to Oneida	Not Available	26
9/21/1924		Barron to Ashland	Not Available	10
4/5/1929	EF4 (est.)	Barron, Pierce, St. Croix	$4,000,000	7
4/3/1956	EF4 (est.)	Green Lake, Waushara, Winnebago	$1,000,000	7
6/4/1958		Chippewa, Clark, Dunn (3 tornadoes)	$27,750,000	27
4/11/1965	EF2 (est.)	Dodge, Jefferson	Not Available	3
4/21/1974	EF4 (est.)	Winnebago	$4,000,000	0
4/21/1974	EF3 (est.)	Dodge, Fond du Lac	$5,000,000	2
7/15/1980		Chippewa, Dunn, Eau Claire (9 tornadoes)	$150,000,000	0
4/27/1984	EF3	Oneida, Vilas	$52,500,000	1
4/27/1984	EF3	Menominee, Shawno, Waupaca	$2,624,000	0
4/27/1984	EF4	Outagamie, Winnebago	$3,600,000	1
4/27/1984	EF4	Waukesha	$1,300,000	1
6/8/1984	EF5	Columbia, Dane, Iowa	$40,000,000	9
8/29/1992	EF3	Waushara	$10,100,000	1
7/5/1994	EF4	Manitowoc	$2,100,000	0
8/27/1994	EF3	Adams	$4,600,000	2
7/18/1996	EF5	Fond du Lac	$40,400,000	0
8/23/1998	EF3	Door	$7,000,000	0
3/8/2000	EF1	Milwaukee	$4,181,000	0
6/18/2001	EF3	Burnett, Washburn	$10,000,000	3
9/2/2002	EF3	Rusk	$25,000,000	0
6/23/2004	EF3	Dodge, Fond du Lac, Green (2 tornadoes merged)	$20,000,000	1
8/18/2005	EF3	Dane, Jefferson	$35,052,000	1
8/18/2005	EF2	Richland, Vernon	$3,570,000	0
6/7/2006	EF3	Langlade, Menominee, Oconto, Shawno	$15,400,000	0
1/7/2008	EF3	Kenosha, Walworth	$13,810,000	0
6/21/2010	EF2	Waukesha	$206,000,000	0

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.6.3 Probability of Occurrence

Wisconsin averages 22 documented tornadoes annually, based on data from 1950 through May 31, 2011 (NWS). This number has increased recently from an average of 18.7 per year for the 45-year period of 1950 through 1994, due to more highly-trained severe weather spotters and more accurate documentation by the NWS. Table 3.6.3-1, below, shows how Wisconsin ranked with other states in terms of number of tornadoes, fatalities, injuries, and nominal reported damages (i.e. not adjusted for inflation). The number of tornadoes per year varies due to fluctuations in the jet stream pattern which influences thunderstorm movement. Wisconsin ranked 4th nationally in 1980 when 43 tornadoes spun up, which was more than the normal leading state, Texas, had that year. However, during 1999, there were only eleven confirmed tornadoes in Wisconsin, a small number compared to an average year. In 2005, Wisconsin had 62 tornadoes, which was the seventh highest state total for the year.

TABLE 3.6.3-1 NATIONAL TORNADO RANKINGS BY NUMBER OF TORNADOES, FATALITIES, INJURIES, AND DAMAGES, 1950-2010

Rank	State	Tornadoes	State	Fatalities	State	Injuries	State	Damages (Millions)
1	TX	7,904	TX	537	TX	8,200	TX	$11,755.64
2	KS	3,667	MS	418	MS	6,072	OK	$7,794.64
3	OK	3,290	AL	376	AL	5,815	FL	$7,325.97
4	FL	3,052	AR	367	AR	5,014	IA	$6,063.41
5	NE	2,542	TN	304	OH	4,441	KS	$5,481.56
6	IA	2,212	OK	282	OK	4,404	MS	$5,202.19
7	IL	2,102	IN	252	IN	4,230	MO	$4,890.01
8	MO	1,942	MI	243	IL	4,124	GA	$4,559.70
9	CO	1,890	KS	232	TN	3,884	NE	$4,452.33
10	MS	1,791	MO	230	GA	3,735	AL	$4,203.08
11	AL	1,695	IL	203	MI	3,364	IL	$4,119.25
12	LA	1,689	OH	191	FL	3,292	LA	$4,013.20
13	SD	1,658	GA	178	MO	3,147	AR	$3,893.04
14	AR	1,587	FL	161	KY	2,792	IN	$3,471.40
15	MN	1,580	LA	155	KS	2,679	**WI**	**$3,326.62**
16	GA	1,380	KY	125	LA	2,650	OH	$3,268.95
17	ND	1,356	MA	102	NC	2,208	TN	$3,164.56
18	IN	1,236	NC	100	IA	2,190	MN	$2,782.75
19	**WI**	**1,224**	**WI**	**99**	MN	1,932	MI	$2,759.80
20	NC	1,116	MN	98	**WI**	**1,634**	NC	$2,550.29

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

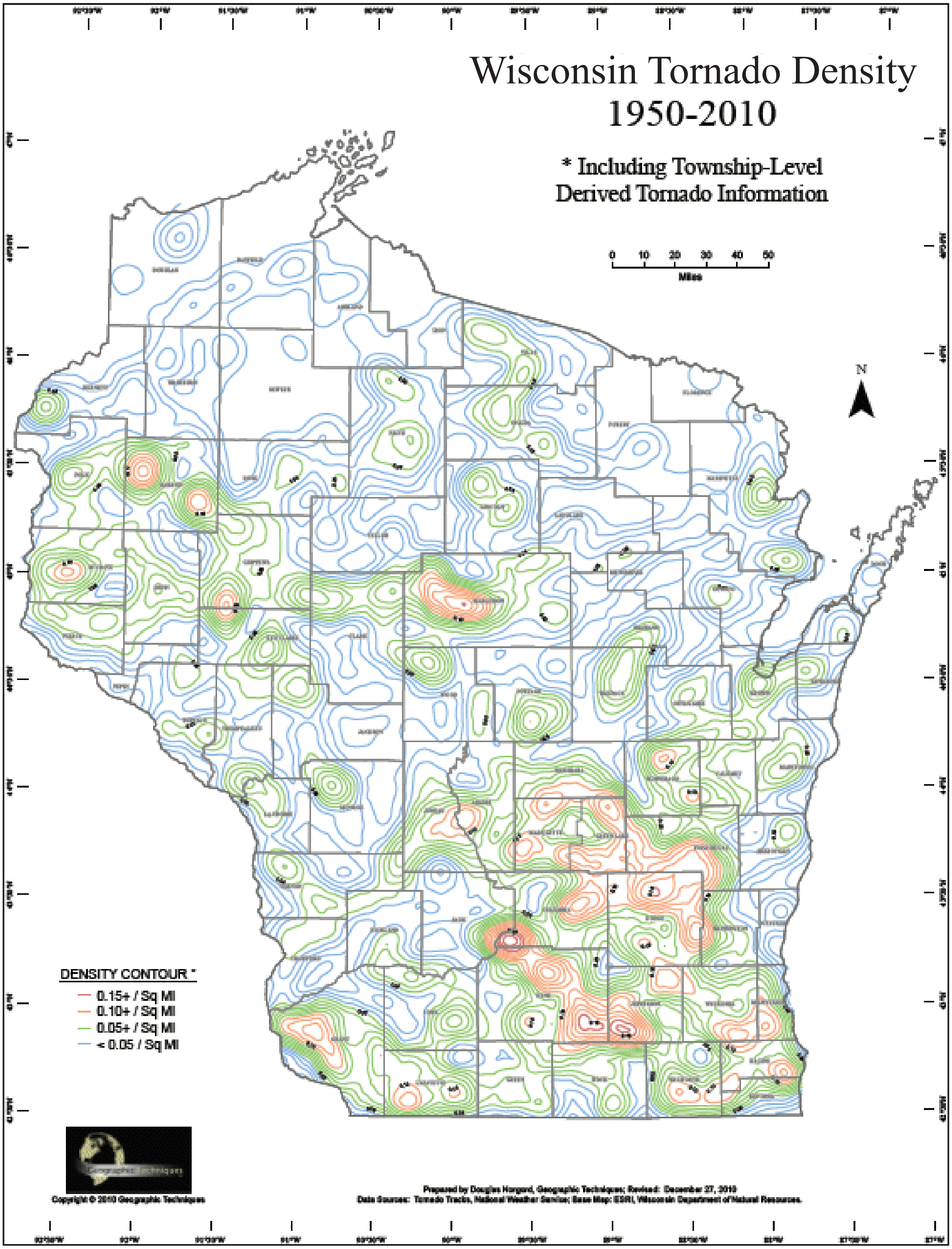


Figure 3.6.3-1 Wisconsin Tornado Density , 1950-2010
Source: Geographic Techniques, 2011.

Figure 3.6.3-1, on the previous page, shows a density plot of Wisconsin tornadoes. The number of tornadoes per township in each county was determined in order to find the number of tornadoes per square mile. This data was then projected onto 100-meter square grids. This technique allows for tornado count data to be applied on a regional level, showing trends of tornado occurrence (FEMA, 2009). Using this technique allows the untrained eye to clearly identify the local "hot spots" across the state at the township level for the 61 years of data provided. Speculation suggests that the concentration of tornadoes between Madison and Lake Winnebago may be related to the fact that the terrain in that area is flatter, as compared to the southwestern counties. Additionally, an interaction between a lake breeze front generated by Lake Winnebago and outflow boundaries (gust fronts) generated by individual thunderstorms may enhance the spin-up of the tornado circulation below the cloud base.

3.6.4 Estimated Losses

The four tables (3.6.4-1 through 3.6.4-4) that follow, were compiled using historic data from the Milwaukee/Sullivan NWS. All NWS reported property damage (including reported crop damages) was used in damage calculations.

From January 1, 1950 to December 31, 2010, information on tornadoes from each county in the state was entered into a spreadsheet that included the following information: average damage amounts per tornado, annual probability, and estimated future annual losses. The following are definitions of the terms/figures used in Tables 3.6.4-1 through 3.6.4-4:

- **Total Damages:** Cumulative sum of all reported total damages associated with all tornadoes occurring during in the 61 year period from January 1, 1950 to December 31, 2010 (reported damages provided by National Weather Service)[1]
- **Average Damage/Tornado** = Total damages (in dollars) divided by the number of tornadoes
- **Annual Probability of a Tornado** = Number of tornadoes divided by the number of years (61)
- **Estimated Future Annual Losses** = Annual probability x average damage/tornado

Damage calculations include all reported property and crop damage, as well as injuries and deaths sustained as a result of the tornado event. These figures were incorporated as follows:

1. **Injury** was assigned a value based on the May 2009 FEMA Benefit-Cost Analysis Reengineering (BCAR) Tornado Methodology Report. Using the "Willingness to Pay" (WTP) or Hedonic Pricing Methodology used by the Federal Aviation Administration (FAA), the rounded value of a minor injury in 2008 was $12,000 and the

1. Damages included in the calculations include all property and crop damages recorded by the NWS; if damages were not reported, they were not included in these calculations. For multi-county tornadoes, each county's respective damage total was provided by the NWS.

rounded value of a moderate injury in 2008 was $90,000. These are the most up-to-date values used for calculations in FEMA's Benefit-Cost Analysis software program.

2. Since the NWS does not differentiate between a major and minor injury in their data, a "**blended injury**" value was calculated by averaging the WTP to avoid a minor and a moderate injury: ($12,000+$90,000)/2 = $51,000.
3. The FAA assigned **death** a rounded WTP value of $5,800,000 in 2008, based on the BCAR Tornado Methodology Report.

Note that all reported damages were recorded in nominal values by the NWS. All values were adjusted for inflation, and reported in 2008 dollars, since FEMA's Benefit-Cost Analysis uses 2008 data, which is the best available. Using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator, the prices for 2009 and 2010 were adjusted using multipliers of 1 and 0.99, respectively.

For instance, Marathon County had 47 tornadoes over the 61 year time period (1950-2010). This translates to:

- Average damage:
  $16,464,000 (total damage) / 47 tornadoes = $350,298 per tornado
- Annual probability of tornado:
  47 tornadoes / 61 years = 0.77049 annual probability
- Estimated future annual losses:
  $367,813 per tornado x 0.77049 = $283,396 in average annual damages

These calculations were done for each county to arrive at the future annual probability of a tornado and estimated annual losses from tornado events. Table 3.6.4-1, below, lists the counties in alphabetical order, and highlights the top five counties in each category, with the top county represented in black, and the next four in gray.

TABLE 3.6.4-1 TORNADO PROPERTY LOSS ESTIMATE BY COUNTY, 1950-2010

County Name	Number of Tornadoes (1950-2010)	Total Damages (1950 to 2010) (2008 Dollars)	Average Damage per Tornado (2008 Dollars)	Annual Probability of Tornado	Estimated Future Annual Loss (2008 Dollars)
Adams	15	$3,258,000	$217,333	0.24590	$53,443
Ashland	9	$300,000	$33,333	0.14754	$4,918
Barron	35	$8,603,000	$252,871	0.57377	$145,090
Bayfield	5	$775,000	$155,000	0.08197	$12,705
Brown	21	$4,043,000	$197,238	0.34426	$67,902
Buffalo	14	$8,598,000	$614,709	0.22951	$141,081
Burnett	13	$12,550,000	$966,146	0.21311	$205,900
Calumet	19	$3,850,000	$202,632	0.31148	$63,115

TABLE 3.6.4-1 CONTINUED					
County Name	**Number of Tornadoes (1950-2010)**	**Total Damages (1950 to 2010) (2008 Dollars)**	**Average Damage per Tornado (2008 Dollars)**	**Annual Probability of Tornado**	**Estimated Future Annual Loss (2008 Dollars)**
Chippewa	27	$36,893,000	$1,366,407	0.44262	$604,803
Clark	22	$7,783,000	$354,223	0.36066	$127,752
Columbia	35	$9,154,000	$359,428	0.57377	$206,229
Crawford	11	$553,000	$57,086	0.18033	$10,294
Dane	**56**	**$69,129,000**	$1,244,849	**0.91803**	**$1,142,812**
Dodge	**57**	$28,058,000	$497,860	**0.93443**	$465,213
Door	8	$8,018,000	$1,002,250	0.13115	$131,443
Douglas	8	$856,000	$107,000	0.13115	$14,033
Dunn	16	**$58,297,000**	**$3,643,563**	0.26230	**$955,689**
Eau Claire	14	$15,805,000	$1,128,929	0.22951	$259,098
Florence	2	$75,000	$37,500	0.03279	$1,230
Fond Du Lac	**41**	**$60,218,000**	$1,468,732	**0.67213**	**$987,180**
Forest	4	$5,300,000	$1,325,000	0.06557	$86,885
Grant	**44**	$5,298,000	$120,745	**0.72131**	$87,095
Green	18	$3,558,000	$197,667	0.29508	$58,328
Green Lake	26	$12,493,000	$492,758	0.42623	$210,028
Iowa	23	$2,198,000	$95,565	0.37705	$36,033
Iron	4	$253,000	$140,718	0.06557	$9,227
Jackson	13	$3,905,000	$300,385	0.21311	$64,016
Jefferson	33	$10,128,000	$325,815	0.54098	$176,261
Juneau	21	$4,967,000	$236,524	0.34426	$81,426
Kenosha	9	$21,925,000	**$2,447,331**	0.14754	$361,082
Kewaunee	7	$550,000	$78,571	0.11475	$9,016
La Crosse	14	$3,130,000	$230,929	0.22951	$53,000
Lafayette	26	$7,400,000	$291,725	0.42623	$124,342
Langlade	6	$4,955,000	$825,833	0.09836	$81,230
Lincoln	21	$1,825,000	$86,905	0.34426	$29,918
Manitowoc	19	$8,450,000	$444,737	0.31148	$138,525
Marathon	**47**	$16,464,000	$350,298	**0.77049**	$269,902
Marinette	18	$3,925,000	$218,056	0.29508	$64,344
Marquette	18	$1,428,000	$99,889	0.29508	$29,475
Menominee	2	$5,200,000	**$2,600,000**	0.03279	$85,246
Milwaukee	17	$7,753,000	$456,059	0.27869	$127,098
Monroe	18	$3,916,000	$217,556	0.29508	$64,197
Oconto	10	$11,354,000	$1,135,400	0.16393	$186,131

TABLE 3.6.4-1 CONTINUED					
County Name	**Number of Tornadoes (1950-2010)**	**Total Damages (1950 to 2010) (2008 Dollars)**	**Average Damage per Tornado (2008 Dollars)**	**Annual Probability of Tornado**	**Estimated Future Annual Loss (2008 Dollars)**
Oneida	20	**$51,181,000**	**$2,559,050**	0.32787	**$839,033**
Outagamie	14	$15,176,000	$1,084,000	0.22951	$248,787
Ozaukee	3	$2,800,000	$933,333	0.04918	$45,902
Pepin	5	$600,000	$120,000	0.08197	$9,836
Pierce	19	$3,808,000	$200,421	0.31148	$62,426
Polk	24	$8,628,000	$365,729	0.39344	$143,893
Portage	21	$2,088,000	$99,429	0.34426	$34,230
Price	18	$26,383,000	$1,465,722	0.29508	$432,508
Racine	20	$3,166,000	$468,336	0.32787	$153,553
Richland	11	$3,455,000	$314,091	0.18033	$56,639
Rock	23	$7,733,000	$336,608	0.37705	$126,918
Rusk	13	$25,850,000	$1,988,462	0.21311	$423,770
Sauk	23	$6,544,000	$284,522	0.37705	$107,279
Sawyer	8	$278,000	$34,750	0.13115	$4,557
Shawano	12	$5,856,000	$488,000	0.19672	$96,000
Sheboygan	8	$3,278,000	$454,244	0.13115	$59,573
St. Croix	31	**$37,230,000**	$1,221,129	0.50820	**$620,574**
Taylor	8	$4,206,000	$525,750	0.13115	$68,951
Trempealeau	16	$5,879,000	$367,438	0.26230	$96,377
Vernon	19	$4,658,000	$246,474	0.31148	$76,770
Vilas	13	$26,450,000	**$2,034,615**	0.21311	$433,607
Walworth	23	$4,530,000	$240,000	0.37705	$90,492
Washburn	8	$2,780,000	$347,500	0.13115	$45,574
Washington	17	$30,280,000	$1,781,176	0.27869	$496,393
Waukesha	28	$14,508,000	$1,291,510	0.45902	$592,824
Waupaca	14	$4,266,000	$304,714	0.22951	$69,934
Waushara	16	$28,830,000	$1,801,875	0.26230	$472,623
Winnebago	24	$8,279,000	$349,527	0.39344	$137,519
Wood	17	$26,510,000	$1,559,412	0.27869	$434,590
STATE		**$848,421,000**			**$14,513,866**

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

There are 14 counties in Wisconsin (out of 72) that have experienced over $20 million in tornado damages, as reported to the NWS. They are listed in Table 3.6.4-2, on the following page. Dane County has had the second highest number of events (56) since 1950, and also has a high concentration of population, which helps explain the high amount of reported damages.

TABLE 3.6.4-2 COUNTIES WITH OVER $20 MILLION IN TOTAL REPORTED TORNADO DAMAGES, 1950-2010

County Name	Number of Events	Total Damages (2008 Dollars)
Dane	56	$69,129,000
Fond Du Lac	41	$60,218,000
Dunn	16	$58,297,000
Oneida	20	$51,181,000
St. Croix	31	$37,230,000
Chippewa	27	$36,893,000
Washington	17	$30,280,000
Waushara	16	$28,830,000
Dodge	57	$28,058,000
Wood	17	$26,510,000
Vilas	13	$26,450,000
Price	18	$26,383,000
Rusk	13	$25,850,000
Kenosha	9	$21,925,000

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

TABLE 3.6.4-3 COUNTIES WITH THE HIGHEST AVERAGE REPORTED TORNADO DAMAGES, 1950-2010

County Name	Number of Events	Average Damages (2008 Dollars)
Dunn	16	$3,643,563
Menominee	2	$2,600,000
Oneida	20	$2,559,050
Kenosha	9	$2,447,331
Vilas	13	$2,034,615
Rusk	13	$1,988,462
Waushara	16	$1,801,875
Washington	17	$1,781,176
Wood	17	$1,559,412
Fond Du Lac	41	$1,468,732
Price	18	$1,465,722
Chippewa	27	$1,366,407
Forest	4	$1,325,000
Waukesha	28	$1,291,510
Dane	56	$1,244,849
St. Croix	31	$1,221,129
Oconto	10	$1,135,400
Eau Claire	14	$1,128,929
Outagamie	14	$1,084,000
Door	8	$1,002,250

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

There exists a large disparity between the numbers of tornado events occurring throughout the state. Table 3.6.4-3, at right, lists the counties in Wisconsin that experience the most costly tornado events. 20 counties experience average reported damages over $1 million per tornado, some of which also have a higher number of tornado events. Though Menominee and Forest Counties have had only two and four tornadoes since 1950, respectively, these counties have experienced serious damages. The other counties with costly average damages per event have had between 13 and 41 tornado events in the 61 year period.

This data was used to project the annual probability of death and injury at the county level. Both injury and death were based on an annual probability of .01639 (1/61 = 0.01639). Table 3.6.4-4 lists the counties in alphabetical order, with supplemental tables showing the most at-risk counties for death and injury, as well as estimated annual losses.

For an example of how these losses were estimated: Take Marathon County which had 19 injuries since 1950, which equates to an annual probability of an injury 0.3115 (19 injuries/61 years) x $51,000 (FAA "rounded value of a blended injury") = $15,885. Zero deaths occurred in this county. The NWS provided data for reported crop and property damages, and they were annualized and added to the annual death and injury damages. Therefore, the expected annual total damages for Marathon County equals $285,787.

Note: in order to demonstrate loss estimates when a death occurs in a county, Burnett County will be used as an example. Burnett County had 3 deaths which equates to an annual probability of a death as .0492 (3 deaths/61 years) x $5,800,000 (FAA "rounded value of death") = $285,246. This amount would then be added to the totals for injuries and property losses.

TABLE 3.6.4-4 ESTIMATED FUTURE ANNUAL TORNADO LOSSES BY COUNTY IN WISCONSIN [1]

County Name	Deaths, 1950-2010	Annual Probability of Death	Annual Loss Due to Death, 1950-2010	Injuries, 1950-2010	Annual Probability of Injury	Annual Loss Due to Injury, 1950-2010	Annual Property Loss, 1950-2010 (From Table 3.6.4-1)	Total Estimated Future Annual Tornado Losses
Adams	0	0.00000	-	18	0.2951	$15,049	$53,443	**$68,492**
Ashland	0	0.00000	-	0	0.0000	-	$4,918	**$4,918**
Barron	0	0.00000	-	16	0.2623	$13,377	$145,090	**$158,467**
Bayfield	0	0.00000	-	4	0.0656	$3,344	$12,705	**$16,049**
Brown	0	0.00000	-	7	0.1148	$5,852	$67,902	**$73,754**
Buffalo	0	0.00000	-	7	0.1148	$5,852	$141,081	**$146,933**
Burnett	3	0.04918	$285,246	25	0.4098	$20,902	$205,900	**$512,048**
Calumet	1	0.01639	$95,082	7	0.1148	$5,852	$63,115	**$164,049**
Chippewa	5	0.08197	$475,410	90	1.4754	$75,246	$604,803	**$1,155,459**
Clark	1	0.01639	$95,082	7	0.1148	$5,852	$127,752	**$228,687**
Columbia	1	0.01639	$95,082	55	0.9016	$45,984	$206,229	**$347,295**
Crawford	0	0.00000	-	9	0.1475	$7,525	$10,294	**$17,819**
Dane	4	0.06557	$380,328	66	1.0820	$55,180	$1,142,812	**$1,578,320**
Dodge	0	0.00000	-	36	0.5902	$30,098	$465,213	**$495,311**
Door	0	0.00000	-	4	0.0656	$3,344	$131,443	**$134,787**
Douglas	0	0.00000	-	0	0.0000	-	$14,033	**$14,033**
Dunn	21	0.34426	$1,996,721	77	1.2623	$64,377	$955,689	**$3,016,787**
Eau Claire	6	0.09836	$570,492	20	0.3279	$16,721	$259,098	**$846,311**
Florence	0	0.00000	-	0	0.0000	-	$1,230	**$1,230**
Fond Du Lac	2	0.03279	$190,164	24	0.3934	$20,066	$987,180	**$1,197,410**

1. All monetary values in this table were adjusted for inflation and reported in 2008 dollars as explained earlier in this section.

TABLE 3.6.4-4 CONTINUED								
County Name	Deaths, 1950-2010	Annual Probability of Death	Annual Loss Due to Death, 1950-2010	Injuries, 1950-2010	Annual Probability of Injury	Annual Loss Due to Injury, 1950-2010	Annual Property Loss, 1950-2010 (From Table 3.6.4-1)	Total Estimated Future Annual Tornado Losses
Forest	0	0.00000	-	3	0.0492	$2,508	$86,885	**$89,393**
Grant	0	0.00000	-	7	0.1148	$5,852	$87,095	**$92,948**
Green	0	0.00000	-	45	0.7377	$37,623	$58,328	**$95,951**
Green Lake	8	0.13115	$760,656	54	0.8852	$45,148	$210,028	**$1,015,831**
Iowa	9	0.14754	$855,738	206	3.3770	$172,230	$36,033	**$1,064,000**
Iron	0	0.00000	-	3	0.0492	$2,508	$9,227	**$11,736**
Jackson	0	0.00000	-	5	0.0820	$4,180	$64,016	**$68,197**
Jefferson	3	0.04918	$285,246	36	0.5902	$30,098	$176,261	**$491,605**
Juneau	3	0.04918	$285,246	38	0.6230	$31,770	$81,426	**$398,443**
Kenosha	0	0.00000	-	15	0.2459	$12,541	$361,082	**$373,623**
Kewaunee	0	0.00000	-	1	0.0164	$836	$9,016	**$9,852**
La Crosse	0	0.00000	-	3	0.0492	$2,508	$53,000	**$55,508**
Lafayette	0	0.00000	-	12	0.1967	$10,033	$124,342	**$134,375**
Langlade	0	0.00000	-	3	0.0492	$2,508	$81,230	**$83,738**
Lincoln	0	0.00000	-	2	0.0328	$1,672	$29,918	**$31,590**
Manitowoc	0	0.00000	-	2	0.0328	$1,672	$138,525	**$140,197**
Marathon	0	0.00000	-	19	0.3115	$15,885	$269,902	**$285,787**
Marinette	2	0.03279	$190,164	8	0.1311	$6,689	$64,344	**$261,197**
Marquette	0	0.00000	-	0	0.0000	-	$29,475	**$29,475**
Menominee	0	0.00000	-	0	0.0000	-	$85,246	**$85,246**
Milwaukee	0	0.00000	-	176	2.8852	$147,148	$127,098	**$274,246**
Monroe	0	0.00000	-	4	0.0656	$3,344	$64,197	**$67,541**
Oconto	0	0.00000	-	6	0.0984	$5,016	$186,131	**$191,148**
Oneida	5	0.08197	$475,410	36	0.5902	$30,098	$839,033	**$1,344,541**
Outagamie	0	0.00000	-	10	0.1639	$8,361	$248,787	**$257,148**
Ozaukee	0	0.00000	-	30	0.4918	$25,082	$45,902	**$70,984**
Pepin	0	0.00000	-	6	0.0984	$5,016	$9,836	**$14,852**
Pierce	0	0.00000	-	6	0.0984	$5,016	$62,426	**$67,443**
Polk	4	0.06557	$380,328	18	0.2951	$15,049	$143,893	**$539,270**
Portage	2	0.03279	$190,164	4	0.0656	$3,344	$34,230	**$227,738**
Price	0	0.00000	-	26	0.4262	$21,738	$432,508	**$454,246**
Racine	0	0.00000	-	10	0.1639	$8,361	$153,553	**$161,913**

TABLE 3.6.4-4 CONTINUED								
County Name	Deaths, 1950-2010	Annual Probability of Death	Annual Loss Due to Death, 1950-2010	Injuries, 1950-2010	Annual Probability of Injury	Annual Loss Due to Injury, 1950-2010	Annual Property Loss, 1950-2010 (From Table 3.6.4-1)	Total Estimated Future Annual Tornado Losses
Richland	0	0.00000	-	9	0.1475	$7,525	$56,639	**$64,164**
Rock	0	0.00000	-	2	0.0328	$1,672	$126,918	**$128,590**
Rusk	0	0.00000	-	34	0.5574	$28,426	$423,770	**$452,197**
Sauk	0	0.00000	-	13	0.2131	$10,869	$107,279	**$118,148**
Sawyer	0	0.00000	-	0	0.0000	-	$4,557	**$4,557**
Shawano	0	0.00000	-	1	0.0164	$836	$96,000	**$96,836**
Sheboygan	1	0.01639	$95,082	8	0.1311	$6,689	$59,573	**$161,343**
St. Croix	2	0.03279	$190,164	35	0.5738	$29,262	$620,574	**$840,000**
Taylor	0	0.00000	-	3	0.0492	$2,508	$68,951	**$71,459**
Trempealeau	0	0.00000	-	3	0.0492	$2,508	$96,377	**$98,885**
Vernon	0	0.00000	-	2	0.0328	$1,672	$76,770	**$78,443**
Vilas	0	0.00000	-	4	0.0656	$3,344	$433,607	**$436,951**
Walworth	0	0.00000	-	3	0.0492	$2,508	$90,492	**$93,000**
Washburn	0	0.00000	-	0	0.0000	-	$45,574	**$45,574**
Washington	3	0.04918	$285,246	57	0.9344	$47,656	$496,393	**$829,295**
Waukesha	1	0.01639	$95,082	32	0.5246	$26,754	$592,824	**$714,660**
Waupaca	6	0.09836	$570,492	8	0.1311	$6,689	$69,934	**$647,115**
Waushara	1	0.01639	$95,082	34	0.5574	$28,426	$472,623	**$596,131**
Winnebago	1	0.01639	$95,082	52	0.8525	$43,475	$137,519	**$276,076**
Wood	0	0.00000	-	30	0.4918	$25,082	$434,590	**$459,672**
STATE	**95**	**N/A**	**$9,032,787**	**1596**	**N/A**	**$1,334,361**	**$14,513,866**	**$24,881,014**

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.6.5 Hazard Ranking

TABLE 3.6.5-1 HAZARD RANKING FOR TORNADO		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard has impacted the State numerous times on an annual basis • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Methods for reducing risk from the hazard are technically reliable • The State or Counties have experience in implementing mitigation measures • Mitigation measures are eligible under Federal grant programs • There are multiple possible mitigation measures for the hazard • The mitigation measure(s) are known to be cost-effective	High

3.6.6 Sources for Tornadoes and High Winds

TABLE 3.6.6-1 SOURCES FOR TORNADOES AND HIGH WINDS	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Part 1: Atmospheric Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
FEMA, "Understanding Your Risks: Identifying Hazards and Estimating Losses," 2001	http://www.fema.gov/library/viewRecord.do?id=1880
NOAA Severe Weather Information	http://www.noaawatch.gov/themes/severe.php
National Climatic Data Center Storm Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
NOAA National Severe Storms Laboratory	http://www.nssl.noaa.gov/
NWS Storm Prediction Center	http://www.spc.noaa.gov/
Natural Hazards Center, University of Colorado Boulder	http://www.colorado.edu/hazards/
NWS Weather Forecast Office, Milwaukee/Sullivan, WI	http://www.crh.noaa.gov/mkx/
NWS Weather Forecast Office, Green Bay, WI	http://www.crh.noaa.gov/grb/
NWS Weather Forecast Office, La Crosse, WI	http://www.crh.noaa.gov/arx/
NWS Office of Climate, Water, and Weather Services Natural Hazard Statistics	http://www.nws.noaa.gov/om/hazstats.shtml
NWS, "Annual U.S. Killer Tornado Statistics"	http://www.spc.noaa.gov/climo/torn/fataltorn.html
NWS, "The Enhanced Fujita (EF) Scale"	http://www.spc.noaa.gov/efscale/
Norgood, Douglas G., Geographic Techniques, Mt. Horeb, WI, 2003.	http://geotechmap.com/default.aspx

3.7 FLOODING

3.7.1 Nature of the Hazard

Flooding, as defined by the National Flood Insurance Program (NFIP), is "a general and temporary condition where two or more acres of normally dry land or two or more properties are inundated by water or mudflow" (NFIP, 2011). Floods specifically affect floodplains, or lowlands adjacent to water bodies. Floods are natural events that are considered hazards only when people and/or property are affected. Nationwide, hundreds of flood hazard events occur each year, making it one of the most common hazards in all 50 states and U.S. territories (FEMA, 2011).

There are a number of categories of floods in the U.S; however, the most common type of flooding event is riverine flooding, also known as overbank flooding. In Wisconsin, riverine floodplains range from narrow, confined channels in the steep valleys of hilly regions, to wide, flat areas in plains and coastal regions. The amount of water in the floodplain is a function of the size and topography of the contributing watershed, the regional and local climate, geological characteristics, and land use attributes.

The cause of flooding in large rivers is typically prolonged periods of rainfall from weather systems covering large areas. These systems may saturate the ground and overload the rivers and/or reservoirs in numerous smaller basins that drain into larger rivers. Localized weather systems, such as thunderstorms, may cause intense rainfall over smaller areas, leading to flooding in smaller rivers and streams. These events may also lead to flooding in larger waterways, as smaller rivers and streams feed into these larger systems. Annual spring floods, due to the melting of snowpack, may affect both large and small rivers and areas.

As such, Wisconsin is prone to experiencing flash floods, ice jam floods, local drainage floods, and high groundwater floods. In Wisconsin, the most notable are flash floods, as they occur quickest, with little or no warning, and tend to be accompanied by other problems. Flash floods are floods that occur within six hours of a causative event such as heavy rains, ice jams, or dam failures. They usually involve a rapid rise in water level, high velocity, and large amounts of debris, which can lead to significant damage including the tearing out of trees, undermining of buildings and bridges, scouring of new channels, and creation of sink holes. The intensity of flash flooding is a function of the intensity and duration of rainfall, steepness of the watershed, stream gradients, watershed vegetation, natural and artificial flood storage areas, and configuration of the streambed and floodplain. Urban areas are increasingly subject to flash flooding due to the removal of vegetation, installation of impermeable surfaces, and construction of drainage systems.

Much of Wisconsin's flooding on larger rivers occurs more than six hours after a causative event such as heavy rain, or rain combined with snowmelt. This kind of flooding can ultimately affect not only larger rivers, but also small streams and low areas outside of the flood plains of larger rivers. It is not uncommon in Wisconsin to have flash flooding on the larger rivers transition to general river flooding that persists for days.[1]

Many urban areas that have historically been flood prone have been removed from the floodplain through the application of two construction types: 1) flood control dams, which reduce peak discharges; and, 2) levees, which redirect floods away from areas that would otherwise be inundated. It is noteworthy that as Wisconsin develops, urbanization decreases the abilities of natural systems to absorb rainfall because of the increased amount of impervious surfaces and runoff.

The aforementioned types of "natural" flooding occur nationally. FEMA and the Wisconsin Department of Natural Resources (DNR) Division of Water through the NFIP usually map flood plains and flood occurrences. Regulation of new construction in mapped flood hazard areas is a responsibility of local government.

Flooding resulting from inadequate man-made infrastructure is a type of flooding that must be addressed, but has not typically been mapped by the NFIP, since the NFIP only requires local governments to impose land use regulations in a mapped floodplain. The NFIP standard flood insurance policy, however, often pays claims for flood losses in these areas with inadequate infrastructure.

3.7.2 Wisconsin Flood Event History

The counties that border the Mississippi and Wisconsin Rivers, the largest rivers in Wisconsin, are prone to flooding in low-lying areas, including along the tributaries. Smaller rivers have periodically flooded in other places, such as the Chippewa River, Menomonee River, Kickapoo River, Pecatonica River and its tributaries, Bad River, Wolf River, and Milwaukee River.

Flooding has been a principle cause of damage in 29 of 43 Presidential Disaster Declarations and one of six Presidential Emergency Declarations in Wisconsin from 1971 through April 2011. Flood damages tend to be the most widespread of Wisconsin's disasters. For instance, during the state's second worst flooding event in the summer of 1993, extremely heavy rainfall resulted in a major Presidential Disaster Declaration for 47 counties with total associated damage exceeding $740 million. 40 of the counties were declared for both Public and Individual Assistance, while the other seven were declared for Individual Assistance only. Though Wisconsin was not affected as severely as other states in the Midwest, the 1993 floods were one of the state's most significant disasters in terms of both damages and funds received through disaster relief programs. The total amount of disaster relief funds received from all declarations prior to this was $352 million. Approximately $300 million in disaster relief was received for the 1993 Presidential Disaster Declaration alone.

1. Losses associated with local drainage are most significant when they occur with other hazards described in this document, such as widespread flooding and thunderstorms; therefore, they are not analyzed as a distinct hazard.

Understanding the risk involved with flooding in Wisconsin is important, especially as many counties develop lands that once were set aside for agricultural or preservation purposes. Throughout recent years, flooding in Wisconsin has changed in scale and scope; this is due largely to the increasing demand for housing along Wisconsin's waterfronts.

Using Table 3.7.2-1, below, to compare the major flood events in Wisconsin from 1973 onward, it can be understood that flood events in recent years have increased in magnitude and severity, based on the large number of counties affected and the monetary value of damages.

TABLE 3.7.2-1 MAJOR FLOOD EVENTS IN WISCONSIN, 1973-2010

Date	Disaster Number	Area Affected (Counties Unless Otherwise Specified)	Damages ($1,000)	Deaths
1973	376	Adams, Brown, Buffalo, Chippewa, Clark, Crawford, Door, Dunn, Eau Claire, Green Lake, Jefferson, Kenosha, Kewaunee, La Crosse, Langlade, Lincoln, Manitowoc, Marathon, Marinette, Marquette, Milwaukee, Oconto, Outagamie, Ozaukee, Pepin, Portage, Racine, Rock, Rusk, Sheboygan, Walworth, Waukesha, Waupaca, Waushara, Wood	$24,000	0
1975	482	Buffalo, Pepin, Pierce, Trempealeau	$5,200	0
1978	559	16 counties in southern and southwestern Wisconsin; the Kickapoo River Valley was the most severely affected area	$51,000	0
June, Sept. 1980	626	6 northwestern and west-central counties including Chippewa, Dunn, Eau Claire, and Pierce	$6,000	0
July 1984	3091	Vernon	$1,000	0
Sept. 1985		Ashland, Bayfield, Douglas	$3,000	0
Aug. 1986	770	Milwaukee Waukesha	$20,000	2
Sept. 1986	775	Dodge, Fond du Lac, Kenosha, Milwaukee, Ozaukee, Sheboygan, Washington, Waukesha	$6,000	0
June 1990	874	East-central and southwestern counties, including Brown (including City of Green Bay), Kewaunee, Calumet, Manitowoc, Outagamie, Winnebago, Dane, Green, Rock, Grant, Iowa, Lafayette (including City of Darlington), Crawford, Richland, Sauk, Juneau, and Vernon	$21,000	0
Aug. 1990	877	City of Tomah and surrounding areas of Monroe County	$6,200	2
Sept. 1992	964	Brown, Calumet, Crawford, Dane, Grant, Green, Iowa, Juneau, Kewaunee, Lafayette, Manitowoc, Monroe, Outagamie, Richland, Rock, Sauk, Vernon, Winnebago	$17,000	0

TABLE 3.7.2-1 CONTINUED				
Date	Disaster Number	Area Affected (Counties Unless Otherwise Specified)	Damages ($1,000)	Deaths
June-Aug. 1993	994	Adams, Brown, Buffalo, Calumet, Chippewa, Clark, Columbia, Crawford, Dane, Dodge, Dunn, Eau Claire, Fond du Lac, Grant, Greene, Green Lake, Iowa, Jackson, Jefferson, Juneau, Kenosha, La Crosse, Lafayette, Lincoln, Marathon, Marquette, Menominee, Milwaukee, Monroe, Outagamie, Pepin, Pierce, Portage, Price, Racine, Richland, Rock, Rusk, Sauk, Shawano, St. Croix, Trempealeau, Vernon, Waupaca, Waushara, Winnebago, Wood	$740,000	2
July 1996	1131	Fond du Lac, Green (including City of Monroe and the Village of Monticello)	$6,000	2
June 1997	1180	Milwaukee, Ozaukee, Washington, Waukesha	$87,700	0
Aug. 1998	1238	Milwaukee, Waukesha, Sheboygan, Racine, Rock	$55,000	2
July 1999	1284	Ashland, Bayfield, Douglas, Florence, Iron, Oneida, Price, Rusk, Sawyer, Vilas	$31,000	0
May–July 2000	1332	Columbia, Crawford, Dane, Grant, Iowa, Juneau, Kenosha, Lafayette, Milwaukee, Richland, Sauk, Vernon, Walworth, Adams, Ashland, Barron, Burnett, Forest, Green, Iron, Jackson, Monroe, Oneida, Polk, Rusk, Sawyer, Washburn, Dodge, Racine, Waukesha	$74,000	0
April 2001	1369	Adams, Ashland, Barron, Bayfield, Buffalo, Burnett, Calumet, Chippewa, Clark, Crawford, Douglas, Dunn, Grant, Iron, Jackson, Juneau, La Crosse, Outagamie, Pepin, Pierce, Polk, Portage, Rusk, St. Croix, Taylor, Trempealeau, Vernon, Washburn, Waupaca, Waushara, Winnebago, Wood	$84,200	0
June 2002	1429	Adams, Clark, Dunn, Marathon, Marinette, Portage, Waushara, Wood	$14,300	0
Sept. 2002	1432	Polk	$3,000	0
May-June, 2004	1526	Southern and central counties - widespread (most counties south of a line from Eau Claire to Wausau to Green Bay)	$268,425	1
July 2006		Waukesha County and City of Madison	$13,000	0
Aug. 2007	1719	Columbia, Crawford, Dane, Grant, Green, Iowa, Jefferson, Kenosha, La Crosse, Racine, Richland, Rock, Sauk, Vernon	$116,400	1
June 2008	1768	Adams, Calumet, Crawford, Columbia, Dane, Dodge, Fond du Lac, Grant, Green, Green Lake, Iowa, Jefferson, Juneau, Kenosha, La Crosse, Lafayette, Marquette, Manitowoc, Milwaukee, Monroe, Ozaukee, Racine, Richland, Rock,, Sauk, Sheboygan, Vernon, Walworth, Washington, Waukesha, Winnebago	$ 763,619	1

TABLE 3.7.2-1 CONTINUED				
Date	Disaster Number	Area Affected (Counties Unless Otherwise Specified)	Damages ($1,000)	Deaths
July 2010	1933	Calumet, Grant, Milwaukee	$45,000	0
Oct. 2010	1944	Buffalo, Clark, Jackson, Juneau, Marathon, Portage, Taylor, Trempealeau, Wood	Ongoing	0

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

<u>1997</u>

Since 1993, several flooding events have been especially noteworthy; the first of which occurred on June 20 and 21, 1997. During this event, a rainstorm dumped more than seven inches of rain in a 30-hour period in Milwaukee and surrounding counties. The intense rainfall overwhelmed creeks and rivers, as well as storm and sanitary sewers. Hundreds of local roads and highways were filled with water, as deep as 23 feet in some areas. Thousands of homes were damaged, many of which had six to seven feet of water in their basement. The flood also damaged hundreds of businesses, many of which were forced to close temporarily or permanently. Some of the damaged businesses that provide critical services included Bayshore Clinical Labs, St. Michael's Hospital Health Center, St. Luke's South Shore Hospital, and the dialysis center in the City of Brown Deer.

Total, the initial damage losses from the 1997 floods amounted to almost $55 million for the public and private sectors, with most of the $44 million in private sector losses being uninsured. The severity of the storm and significance of the uninsured losses prompted a request for a Presidential Disaster Declaration for four Wisconsin counties. The declaration was granted for both Public and Individual Assistance. A fifth county was added later for Public Assistance only.

<u>2001</u>

In 2001, flooding was the principal reason Wisconsin initially received Presidential Disaster Declaration, DR-1369, although tornadoes and severe storms were also major factors as the disaster progressed. Heavy winter snowfall combined with spring rain led to spring flooding. In mid-April, rain and rapid snowmelt caused the Mississippi River and many of its tributaries to flood. Floodwaters along the Mississippi River from Alma (Buffalo County) to Prairie du Chien (Crawford County) rose to their highest levels since 1965. In addition, severe storms also struck northern Wisconsin in late April. Heavy rains mixed with freezing rain, snow, and strong winds caused widespread flooding and wind damage. The initial flooding affected 17 counties; eventually, 32 counties were declared for DR-1369 for a variety of storm-related damage, including tornadoes.

2002

Late in June 2002, a series of severe thunderstorms swept across central and northeastern Wisconsin. The storms produced up to 15 inches of rain in 24 hours in some locations with flooding on the Peshtigo, Wisconsin, and Yellow Rivers; flash flooding on smaller streams; and extensive ponding throughout many of the affected areas. There were reports of one to two feet of water in the streets of Marinette (Marinette County), and reports of one foot of water in the streets Wautoma (Waushara County). The high-velocity floodwaters destroyed or caused extensive damage to bridges, bridge approaches, culverts and road surfaces, leaving impassable gaps on county and township roads throughout the disaster area. Erosion and scouring around culverts and bridges reached depths of up to eight feet. Areas particularly hard hit were Marathon, Adams, Portage, and Marinette Counties. Nearly $4 million in damage was identified in these four counties, primarily to roads, bridges, drainage ditches, culverts, and sewer lines.

2004

In the months of May and June, 2004, a series of weather systems periodically moved east across the central and southern parts of Wisconsin and generated thunderstorms that dumped heavy rains. This resulted in widespread river, urban, and agricultural flood damage that totaled a staggering $268,425,000, with one flood-related death. Rainfall amounts in May 2004, ranged from seven inches to a maximum of 14.72 inches at Lynxville (Crawford County), or two to three times the monthly average. In May alone, the water level in Lake Michigan rose eleven inches due to rain and runoff. In June 2004, rainfall totals ranged from five to 12.72 inches at Readstown (Vernon County). Some of the larger rivers rose two to four feet above flood stage which constituted moderate to major flooding.

2007

In August, 2007, a series of thunderstorm clusters moved east-southeast through the southern third of Wisconsin, dumping record-setting rains. Many locations set new all-time daily and monthly August rainfall records. Much of the rain fell during August 19-20, 2007, when six to 12 inches were measured (150% to 300% of the August monthly average). Only one person perished in a flash flood event in southern Richland County. Alongside unofficial reports of 22 to 25 inches of water, Viroqua (Vernon County) picked up 21.74 inches of rain for the month, a new all-time monthly record for Wisconsin. Total flood damages were about $116.4 million. A record flood crest was reported at the Root River Canal near Raymond (Racine County), and major flood levels were observed at New Munster on the Fox River (Kenosha County) and at Newville on the Rock River (Rock County). Some locations along the Kickapoo River came within one to two inches of establishing a new all-time record crest.

2008

In June 2008, yet another widespread, severe flooding/flash flooding event, consisting of two rounds of heavy rains, ravaged an already saturated part of the state south of a line from La Crosse (La Crosse County) to Manitowoc (Manitowoc County). The first round of heavy rains occurred June 5 through 8, 2008 and the second round during the overnight hours of June 12 through 13, 2008. Collectively, amounts ranged from six to over 15 inches. In many locations, 24-hour and monthly rainfall records were established. Milwaukee would eventually measure 12.27 inches, which was a new record monthly rainfall. At least 38 river gauge sites set new all-time record-high crests; in some cases exceeding flood stage by six to over 11 feet. The Baraboo River in Baraboo (Sauk County) crested at 27.48 feet, where normal flood stage is 16.0 feet.

Thousands of homes, businesses, and farms were damaged or destroyed by the flood waters. In some cases, rivers remained in flood stage into late July 2008, and some low spots in farm fields still had standing water into September 2008 due to a high water table. Most of the flooding was of the "100-year" magnitude, and some was probably of the "200- or 300-year" type. Numerous roads were closed, damaged, or washed-out in river valleys and other low spots, and some bridges were significantly damaged. The worst river flooding occurred on the Baraboo, Kickapoo, Rock, Northern and Southeastern Fox, and Crawfish Rivers. A number of farm fields were never replanted by the time they dried out in late July or early August 2008. In some areas, the June 2008 flooding in Wisconsin was worse than the 1993 flooding. On June 14th, President Bush declared Disaster Declaration 1768 in the state. Eventually the declaration included 31 counties with estimated damages totaling roughly $763 million (FEMA, 2011).

Changes in precipitation patterns indicate that rainfall totals have increased in the past few years during individual rain events. For instance, heavy rain events in both 2007 and 2008 precipitated 20 to 25 inches (50-75% of the yearly average) or more in some river basins. This is important to note, since in many cases these heavy rain events occur after soils have already become saturated, leading to record-setting floods, resulting in hundreds of millions in damages. Figure 3.7.2-1, on the following page, illustrates this phenomenon as witnessed in June 2008.

The rains combined with the already saturated soils worsened the flooding conditions necessitating rescues, evacuations, road closures, and sandbagging. Thousands of homes sustained damages and many people were left homeless. Hundreds of small businesses were damaged and temporarily closed. Damage to public facilities is estimated to be in the tens of millions of dollars. Both the agriculture and tourism industries, representing the heart of state and local economies, suffered significantly. Many of the communities were still recovering from flooding that occurred ten months earlier which also resulted in a federal disaster declaration.

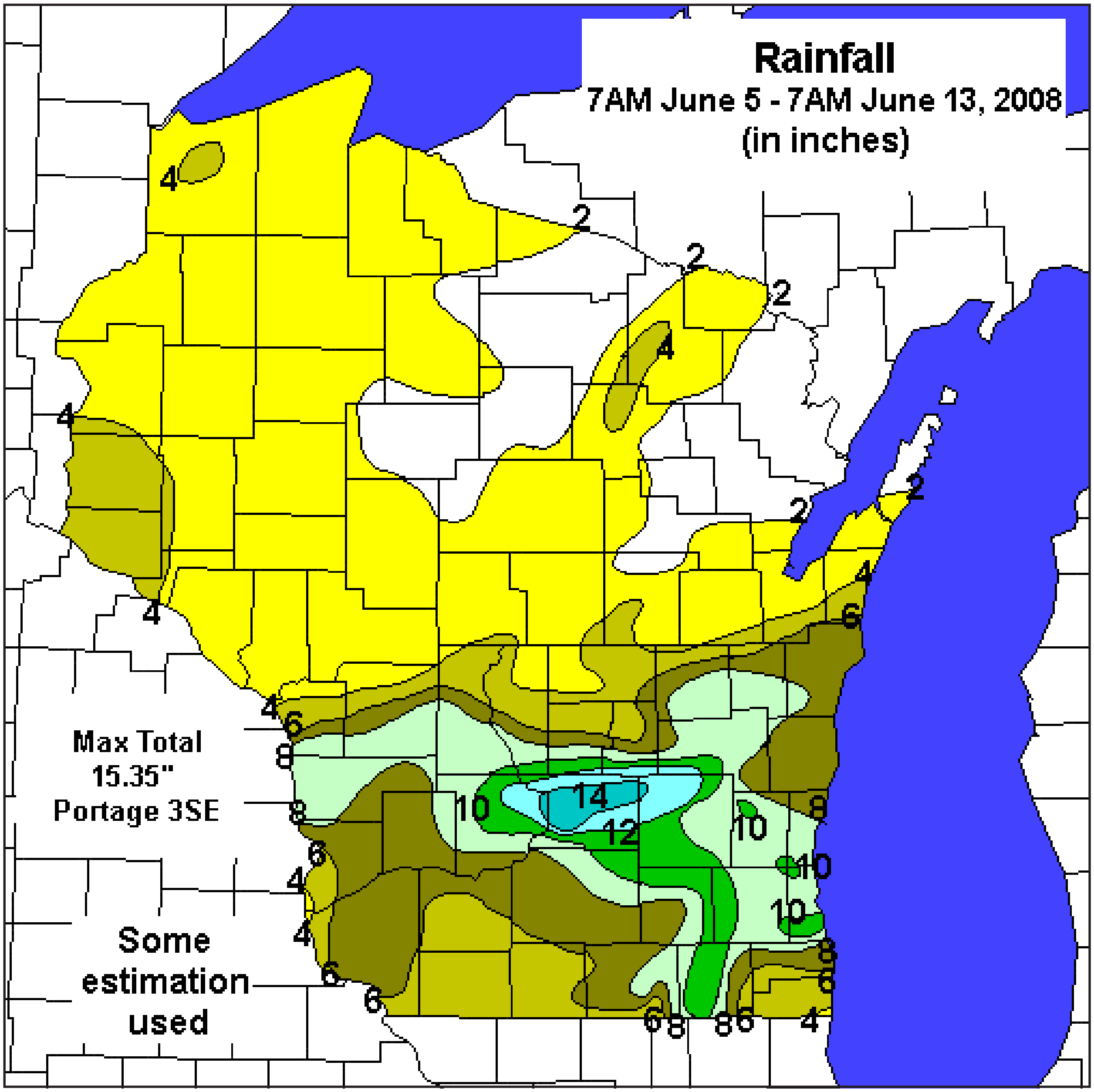


Figure 3.7.2-1 Rainfall Totals, 7 a.m. June 5 - 7 a.m June 13, 2008
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

<u>July 2010</u>

Parts of south-central and southeast Wisconsin experienced several rounds of record-setting torrential heavy rains during the afternoon and evening hours of July 22, 2010 that led to flash flooding. During the afternoon, a persistent band of strong to severe thunderstorms developed and moved very slowly over the region throughout the evening hours. The individual storms were moving quite fast, at about 40 to 50 mph, but the slow southward movement of the boundary of these storms resulted in storms repeatedly moving over the same area. Widespread three to four inch rainfall amounts were reported along and on either side of the I-94 corridor, with locally higher amounts of five to eight inches.

The greatest rain amounts fell in Milwaukee County, where the most damage occurred. Mitchell Field recorded 5.61 inches for the day, breaking a record for the date. The previous record was 1.26 set in 1948.

Massive flooding shut down streets and the freeway system in parts of Milwaukee County at rush hour with up to four feet of rushing water. There was one fatality in Milwaukee. The Milwaukee Fire Department logged 50 rescues from homes and streets. The Milwaukee Metropolitan Sewerage District reported that the storm resulted in a combined sewer overflow of around two billion gallons. All Lake Michigan beaches in Milwaukee were closed through the following weekend of July 24 and 25, 2010, due to sewer contamination. The City of Milwaukee received at least 2,000 calls for sewer backups into basements of homes, with the northern half of the City hit hardest. Flooding rains created a massive 20 foot deep sink hole in the City of Milwaukee, swallowing a sport utility vehicle and a street light. The driver of the SUV was injured and treated at a hospital. Electrical power cables and other cable lines were also damaged.

General Mitchell International Airport (Milwaukee County) was closed late Thursday night, July 22, through 2 p.m. Friday, July 23, 2010 due to flooded runways. Over 4,400 homes reported water-filled basements in the City of Milwaukee alone. 11,764 homes received some sort of impact from the flooding, with six homes destroyed; 57 homes receiving major damage; 1,859 home receiving minor damage; and 9,842 homes minimally affected by the flood waters. 68 businesses were affected, with nine having major damage and 59 having minor damage. About 32,000 WE Energy utility customers lost electricity throughout southeast Wisconsin due to the flooding and lightning.

<u>September 2010</u>

An excessive rainfall event, with amounts of three to six inches, occurred across parts of central and northeast Wisconsin starting on the evening of September 22 and lasting through the morning hours of September 23, 2010. The heaviest rain fell over the central part of the state where many locations received more than five inches. This led to flash flooding, as well as moderate to record river flooding across parts of central Wisconsin. A new record stage of 18.41 feet was established on the Yellow River at Babcock (Wood County). This is 6.41 feet above flood stage. The Wisconsin River at Portage (Columbia County) set a new record crest of 20.66 feet on September 28, 2010, or 3.66 feet over flood stage.

Figure 3.7.2-2, on the following page, shows the county-by-county distribution of flood events across Wisconsin for the period of 1982-2010. The map shows the number of flood events, the number of directly-related fatalities, and the number of directly-related injuries. Notice that the southern part of the state has most of the flood events. Hilly terrain in the southwestern counties and the built-up urban areas in the southeast are factors that increase the chances of flooding. Noteworthy is the fact that Dane and Vernon Counties have the most flooding events during the time period, with 77 and 71, respectively. Very few injuries and deaths are recorded during the 28 year period, with the highest number of injuries sustained in any one county equal to three (Rock and Jackson counties).

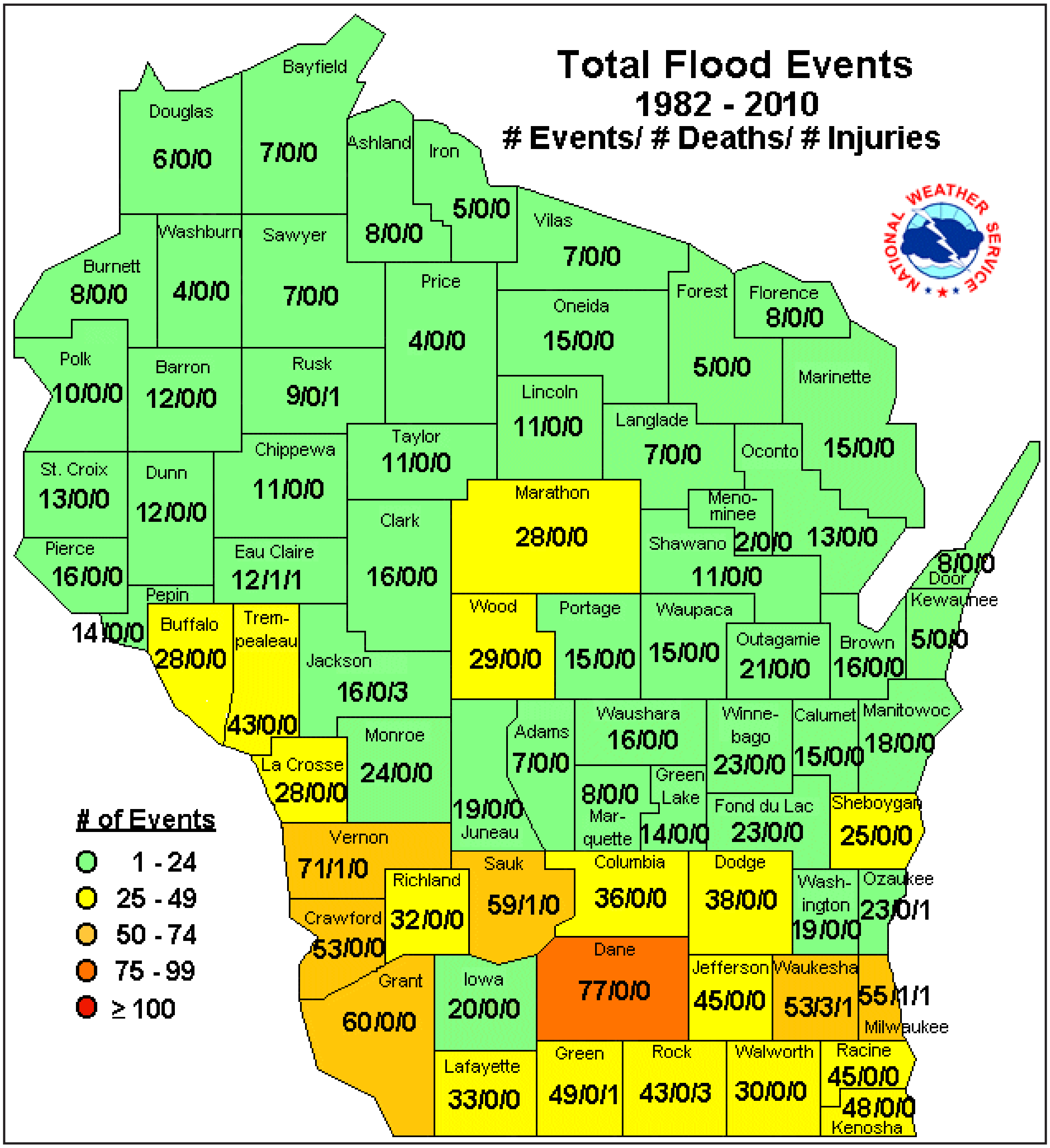


Figure 3.7.2-2 Flood Events by County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.7.3 Probability of Occurrence

Floods are described in terms of their extent and the related probability of occurrence. Flood studies use historical records to determine the probability of occurrence for different extents of flooding. From these records, a probability of occurrence is determined and expressed in a percentage. The percentage describes the chance that the level of flood water exceeds a certain height, on average in any given year. The most widely adopted design and regulatory standard for floods in the US is the one-percent annual chance flood (base flood), which has been formally adopted by FEMA. The base flood, or "100-year flood," has a one-percent chance of occurring in any particular year. This measure is a simple and general way to express the statistical likelihood of a flood; actual recurrence periods vary from place to place.

Smaller floods occur more often than larger, deeper and more widespread floods. Thus, a "10-year" flood has a greater likelihood of occurring than a "100-year" flood. Table 3.7.3-1, to the right, shows a range of flood recurrence intervals and their probabilities of occurrence.

TABLE 3.7.3-1 FLOOD PROBABILITY TERMS

Flood Recurrence Intervals	Annual Percent Chance of Occurrence
10-year	10.0%
50-year	2.0%
100-year	1.0%
500-year	0.2%

Source: FEMA, 2001.

It is important to note that risk of a flood event occurring changes over time. Since natural hazards, like floods, do not affect a particular location every single year, the focus is on the overall probability of the event occurring over a selected time horizon. Assuming that most hazard events are independent outcomes, the probability of a 100-year flood occurring at any given time is 1/100 or 0.01. However, the probability of a 100-year flood occurring at least once over the next 100 years is 1-(0.99)^100=0.634.

This plan considers hazards over the entire State of Wisconsin; however, flood probability and magnitude are highly location-specific, so it is not possible to characterize these generally across the state in a meaningful way. The State Plan includes flood risk assessments that implicitly include probability and magnitude determinations on a state and county basis. However, truly accurate determinations of flood probability and magnitude require site-specific engineering studies and data-gathering that is beyond the scope of this hazard profile.

3.7.4 HAZUS Flood Risk Assessment

Hazard USA (HAZUS) is a software tool used to estimate damages from wind, floods, and earthquakes, among other natural disasters. This software was developed by FEMA under contract with the National Institute of Building Sciences (NIBS). Loss estimates produced by HAZUS are based on current scientific and engineering knowledge of the effects of hurricane winds, floods, and earthquakes. Estimating losses is essential to decision-making at all levels of government, providing a basis for developing mitigation plans and policies, emergency preparedness, and response and recovery planning. HAZUS provides estimates of hazard-related damage before a disaster occurs and takes into account various impacts of a hazard event. The impacts include the following:

- Physical damage to residential and commercial buildings, schools, critical facilities, and infrastructure
- Economic loss, including lost jobs, business interruptions, and repair and reconstruction costs
- Social impacts and impacts to people, including requirements for shelters and medical aid

HAZUS uses Geographic Information System (GIS) software to map and display hazard data and the results of damage and economic loss estimates for buildings and infrastructure. It also allows users to estimate the impacts of hurricane winds, floods, and earthquakes on populations. HAZUS provides for three levels of analysis:

- Level 1 Analysis: rough estimate based on the nationwide database; a way to begin the risk assessment process and prioritize high-risk communities
- Level 2 Analysis: requires the input of additional or refined data; hazard maps that will produce more accurate risk and loss estimates[1]
- Level 3 Analysis: yields the most accurate estimate of loss and typically requires the involvement of technical experts (i.e. structural and geotechnical engineers); allows users to supply their own techniques to study special conditions

Wisconsin is currently running a level 1+ analysis, incorporating Digital Flood Information Rate Maps where available. In addition to the HAZUS supplied data, WEM provided updated essential facilities data. The site specific inventory (specifically schools, hospitals, fire stations, Emergency Operation Centers, and police stations) was updated using the best available statewide information.

FEMA HAZUS data were used to estimate the number of structures located within the one-percent chance, or 100-year, floodplain based upon Flood Insurance Rate Maps (FIRMs) published by FEMA. This data was supplemented by US Census housing data to estimate dates of construction.[2]

The statewide flood risk assessment is an initial step in identifying and quantifying flood risks throughout Wisconsin. The risk assessment uses existing available information, including GIS data with HAZUS.

1. Assistance from local emergency management personnel, city planners, GIS professionals, and others may be necessary for this level of analysis.
2. Under National Flood Insurance Program (NFIP) floodplain management regulations, which must be adopted by communities in order to benefit from Federal flood insurance, structures built after the date a FIRM becomes effective must be elevated at or above the base flood elevation (BFE). Thus, structures completed after the FIRM effective date are significantly less vulnerable to flood damage than pre-FIRM construction. In determining the vulnerability of housing stock, the FIRM effective date can be applied as a benchmark to separate the most vulnerable structures from the total building stock.

The initial assessment uses existing State-level information. The information is compiled in digital formats that enable the future update and enhancement of the assessment to use more detailed local data. As individual community hazard mitigation plans are updated, the statewide flood hazard mitigation risk assessment can be enhanced in future State Hazard Mitigation Plan updates.

The hazard identification and data inventory tasks, completed in 2008, were conducted by WEM with assistance from the Land Information and Computer Graphics Facility (LICGF) at the University of Wisconsin-Madison and the Polis Center at Indiana University-Purdue University Indianapolis. The LICGF and Polis teams assisted WEM in developing the flood risk assessment using HAZUS as a risk assessment tool.

Identify Hazards

The initial task involved reviewing flood information from the Wisconsin Department of Natural Resources (DNR). The DNR maintains a file of each county's and community's hydrologic/hydraulic assessments. The file includes FEMA Flood Insurance Study (FIS) reports, geo-referenced images of scanned FIRM maps, DFIRM vector maps, and Q3 vector maps. LICGF visited DNR and obtained copies of the available files.

Flood Risk Assessment Reports from local hazard mitigation plans were used to identify the local historical hazards. Approved Flood Risk Assessment Reports were provided by WEM for 46 counties and cities in Wisconsin. Eleven preliminary county reports were also made available.

Profile Hazard Events

Following the hazard identification task, staff performed HAZUS 100-year flood return interval analysis for each county using DFIRM or Q3 flood boundaries (DFIRM being preferable) whenever they were available. Prototyping prior to the commencement of the project indicated that the Enhanced Quick Look method available in HAZUS 2.0 provided loss estimates consistent with traditional methods.

For counties without DFIRM or Q3 boundaries, HAZUS was used to generate new 100-year flood boundaries and flood depth grids. Hydrologic and hydraulic analyses were performed at square mile intervals on all reaches generated from USGS 30 meter digital elevation models (DEMs).

TABLE 3.7.4-1 FLOOD RISK DATA SOURCES

Sources	Counties	Ratio
DFIRM	46	64%
Q3	3	4%
H&H + FIS Discharge Values	23	32%
Total	**72**	**100%**

Source: WEM, 2011.

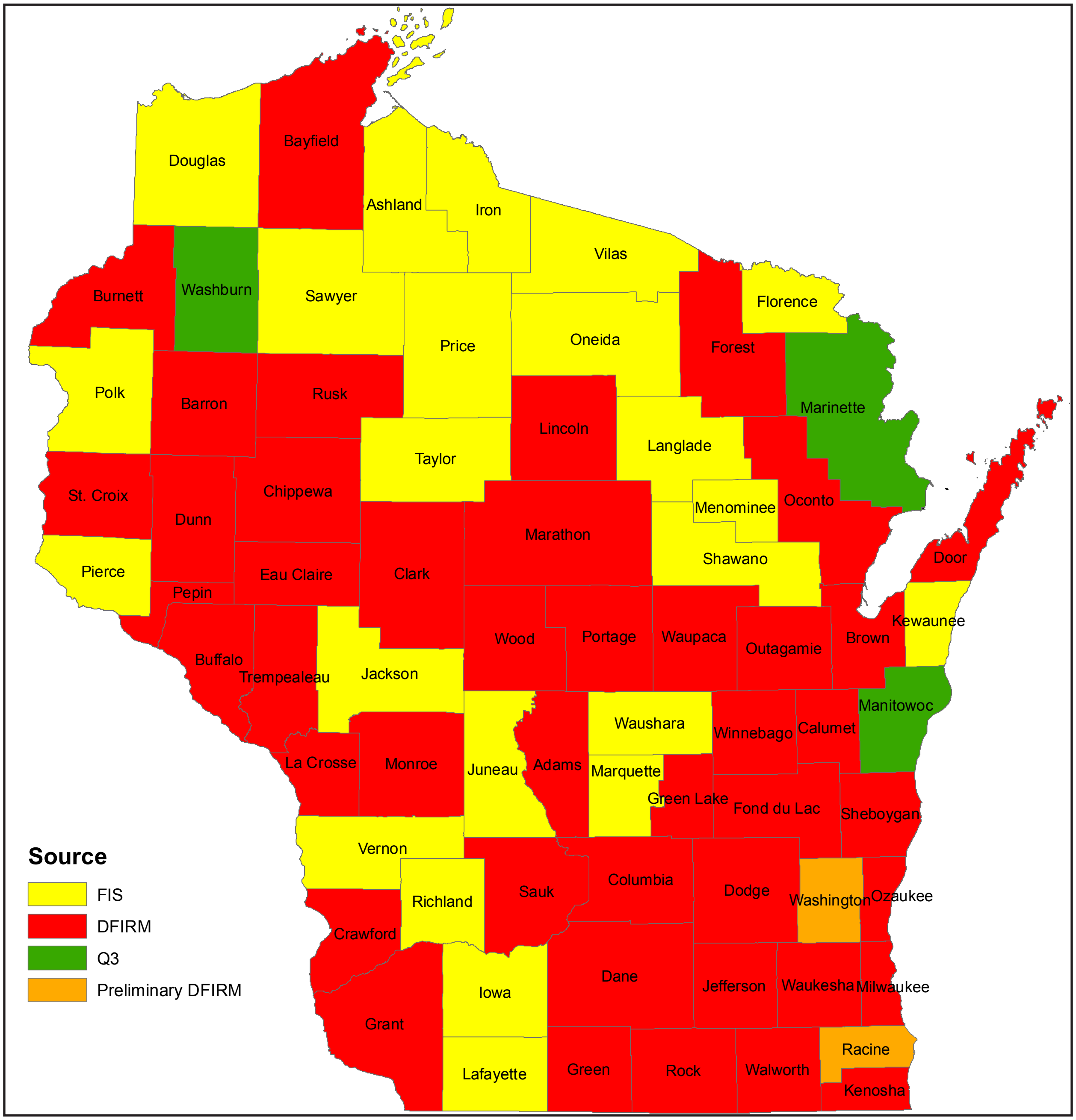


Figure 3.7.4-1 Flood Risk Data Sources by County
Source: WEM, 2011.

Figure 3.7.4-1, above, shows which data sources were used for each county. WEM has been gathering the new DFIRMs as they have become available and has been completing HAZUS runs using the new DFIRMs. Since 2009, WEM has completed 18 HAZUS runs using the new DFIRMs.

<u>*Inventory Assets*</u>

The HAZUS analysis was performed using default inventory data contained within the software. HAZUS default inventory data includes the following:

- General building stock
- Essential facilities
- Demographic information
- Transportation lifeline systems
- Utility lifeline systems
- High potential loss facilities
- Hazardous materials facilities

In addition to the HAZUS supplied data, WEM provided updated essential facilities data. The site-specific inventory (specifically schools, hospitals, fire stations, Emergency Operation Centers, and police stations) was updated using the best available statewide information.

Table 3.7.4-2 shows the differences between the default HAZUS data sets for Wisconsin and the updated data that were used for the 2008 flood assessment.

TABLE 3.7.4-2 STATEWIDE DATABASE UPDATES

Feature Class	Default Counts	Updated Counts	Default Exposure	Updated Exposure
Schools	3,093	3,299	$ 1,654,615	$ 2,046,405
Care Facilities	143	574	$ 1,258,320	$ 5,399,059
Police Stations	541	985	$ 810,418	$ 1,410,625
Fire Stations	617	900	$ 396,114	$ 727,000
EOCs	16	55	$ 17,120	$ 71,500
Communications	362	920	$ 38,734	$ 123,280
Dams*	629	3713	-	$ 1,418,000

*Dam losses are not reported in HAZUS flood models.
Source: University of Wisconsin and The Polis Center, 2008, "Wisconsin Statewide Flood Risk Assessment Report."

The State of Wisconsin has created a GIS layer for all DNR-managed properties. The risk assessment process overlaid the flood boundaries with the DNR-managed properties to identify any properties at risk.

Estimate Losses

The loss estimation was performed using HAZUS. This process reflects a Level 1+ approach to flood modeling. The Level 1+ approach uses default data while referencing additional data. As indicated above, the loss estimation process used supplementary essential facility information for the purpose of improving the accuracy of the model predictions.

HAZUS flood modeling was performed one county at a time. A stream network was delineated for every square mile within the county. The HAZUS flood model performs an area weighted assessment of flood damage. The number of grid cells at a given depth is counted and then divided by total number of cells within a census block. The result is used to "weight" damage at that flood depth for each occupancy class. Essential facilities are evaluated by their specific location by default. Buildings are considered a total loss once they reach the 50% damage threshold.

HAZUS analysis was performed within a study region created for each county. Separate case studies within each study region were frequently required:

- Coastal flood analysis was performed separately from the riverine analysis except when DFIRM or Q3 boundaries were used for the analysis.
- Streams for which FIS discharge values were available were segregated into a separate case study.
- Riverine flood analysis was performed in a separate case study whenever the number of reaches exceeded around 100. This threshold number varied depending on the problems encountered for each case study or study region.

The analysis included:

General Building Stock
- Building losses
- By occupancy and by building type
- By full replacement value and depreciated replacement value
- Shelter requirements
- Building, content, and inventory losses

Essential Facilities

Building and content losses
Restoration time to 100% functionality
Lifeline losses (for selected components)
Losses to structures and equipment

Table 3.7.4-3 provides a summary of building loss and economic loss for each county. The table also includes short term shelter requirements and population.

TABLE 3.7.4-3 FLOOD RISK ASSESSMENT RESULTS BY COUNTY							
County	Population	Estimated Total Buildings	Total Damaged Buildings	Total Building Exposure ($1,000)	Total Economic Loss ($1,000)	Building Loss ($1,000)	Short Term Shelter
Adams	18,643	13,532	156	$1,714,102	$53,424	$30,367	230
Ashland	16,866	7,767	33	$1,424,733	$18,051	$7,976	139
Barron	44,963	18,699	155	$3,790,003	$114,253	$46,428	544
Bayfield	15,013	11,111	63	$1,637,752	$54,931	$27,326	19
Brown	226,778	69,571	385	$19,961,716	$448,922	$183,041	10,818
Buffalo	13,804	5,462	45	$1,027,996	$46,272	$21,206	599
Burnett	15,674	12,110	162	$1,853,439	$65,233	$36,945	135
Calumet	40,631	13,711	54	$3,188,818	$68,200	$24,978	606
Chippewa	55,195	19,897	77	$4,096,770	$136,198	$60,010	951
Clark	33,557	12,496	26	$2,228,193	$43,852	$19,365	144
Columbia	52,468	19,485	474	$4,419,256	$242,423	$130,669	1,903
Crawford	17,243	7,696	84	$1,184,381	$47,946	$22,504	586
Dane	426,526	120,062	588	$37,942,411	$460,477	$180,345	8,107
Dodge	85,897	27,873	136	$6,819,041	$108,225	$47,375	1,699
Door	27,961	17,670	305	$3,544,600	$58,146	$30,818	354
Douglas	426,526	17,059	37	$3,567,617	$33,129	$15,281	8,107
Dunn	39,858	12,786	17	$2,765,823	$48,097	$21,633	824
Eau Claire	93,142	29,742	344	$7,849,911	$300,969	$94,818	9,855
Florence	5,088	4,065	6	$530,974	$3,736	$2,107	38
Fond du Lac	97,296	32,524	106	$7,842,669	$170,858	$65,109	5,916
Forest	10,024	7,898	9	$1,087,102	$15,365	$7,701	46
Grant	49,597	17,179	17	$3,344,675	$43,584	$20,006	309
Green	33,647	12,042	70	$2,915,843	$82,537	$33,036	899
Green Lake	19,105	10,071	28	$1,655,646	$32,742	$12,451	574
Iowa	23,000	8,595	14	$1,816,053	$23,216	$10,320	230
Iron	6,861	5,212	10	$727,042	$10,292	$4,316	26
Jackson	19,100	7,230	32	$1,298,474	$28,897	$11,141	251
Jefferson	74,021	24,973	129	$6,476,456	$150,487	$57,626	2,528
Juneau	24,316	11,351	55	$1,790,806	$50,421	$17,339	640
Kenosha	149,577	47,404	374	$12,467,944	$250,736	$93,902	3,740
Kewaunee	20,187	7,393	147	$1,517,568	$57,109	$22,520	587
La Crosse	107,120	33,301	495	$8,866,469	$294,438	$112,867	8,088
Lafayette	16,137	6,109	7	$1,214,511	$27,613	$12,736	28
Langlade	20,740	10,166	19	$1,741,110	$31,342	$10,518	402

TABLE 3.7.4-3 CONTINUED							
County	**Population**	**Estimated Total Buildings**	**Total Damaged Buildings**	**Total Building Exposure ($1,000)**	**Total Economic Loss ($1,000)**	**Building Loss ($1,000)**	**Short Term Shelter**
Lincoln	29,641	13,180	14	$2,413,646	$28,109	$11,752	334
Manitowoc	82,887	29,082	105	$7,463,475	$87,338	$39,738	980
Marathon	125,834	43,255	232	$10,019,212	$240,673	$101,922	3,733
Marinette	43,384	24,343	175	$3,770,304	$125,246	$59,390	1,031
Marquette	15,832	8,278	76	$1,187,213	$25,244	$9,532	223
Menominee	4,562	2,005	0	$253,325	$4,282	$1,449	33
Milwaukee	940,164	256,229	1,059	$78,904,721	$732,195	$286,370	13,038
Monroe	40,899	14,618	124	$2,808,608	$91,692	$37,601	1,869
Oconto	35,634	18,667	45	$3,024,420	$47,883	$23,102	824
Oneida	36,776	24,793	26	$4,242,933	$51,173	$16,840	274
Outagamie	160,971	51,491	72	$13,930,487	$152,435	$61,684	589
Ozaukee	82,317	26,361	396	$8,424,827	$257,259	$106,533	4,061
Pepin	7,213	2,705	28	$543,852	$27,441	$12,140	249
Pierce	36,804	11,320	38	$2,745,224	$69,889	$27,163	494
Polk	41,319	19,110	154	$3,854,074	$91,323	$39,262	1,124
Portage	67,182	22,213	59	$4,802,272	$67,398	$27,617	2,615
Price	15,822	8,898	3	$1,534,217	$13,589	$6,048	77
Racine	188,831	59,300	501	$15,693,961	$238,307	$106,819	5,924
Richland	17,924	7,221	49	$1,329,972	$47,598	$19,157	335
Rock	152,307	52,424	485	$12,746,145	$316,841	$123,674	3,831
Rusk	15,347	7,111	24	$1,068,768	$29,397	$13,356	143
Saint Croix	63,155	20,525	352	$5,369,002	$249,531	$138,451	1,386
Sauk	55,225	20,828	163	$4,709,308	$134,539	$53,249	1,696
Sawyer	16,196	13,194	31	$1,990,856	$31,915	$15,397	113
Shawano	40,664	16,584	13	$3,054,433	$21,462	$9,660	164
Sheboygan	112,646	37,082	209	$10,241,080	$187,311	$82,217	1,993
Taylor	19,680	7,857	35	$1,458,249	$92,146	$23,299	157
Trempealeau	27,010	10,011	104	$2,118,192	$85,197	$34,963	1,192
Vernon	28,056	11,406	94	$1,677,827	$46,199	$20,440	290
Vilas	21,033	21,564	11	$3,116,310	$13,696	$6,127	22
Walworth	93,759	35,741	285	$9,304,295	$232,517	$120,010	1,053
Washburn	16,036	10,233	174	$1,554,736	$78,854	$44,926	165
Washington	117,493	37,309	377	$10,613,383	$351,573	$134,719	4,692
Waukesha	360,767	114,352	1,154	$35,955,764	$739,778	$291,616	13,042

TABLE 3.7.4-3 CONTINUED							
County	**Population**	**Estimated Total Buildings**	**Total Damaged Buildings**	**Total Building Exposure ($1,000)**	**Total Economic Loss ($1,000)**	**Building Loss ($1,000)**	**Short Term Shelter**
Waupaca	51,731	19,655	72	$4,154,334	$134,620	$49,495	2,140
Waushara	23,154	13,102	0	$1,921,060	$10,094	$3,508	507
Winnebago	156,763	51,009	213	$12,530,045	$220,746	$73,710	7,099
Wood	75,555	27,481	73	$6,328,340	$95,649	$38,988	1,155
Totals	5,747,134	1,852,779	11,684	$461,168,774	$9,093,260	$3,766,704	148,569

Source: WEM, 2011.

County summaries of site specific losses relative to essential facilities are compiled in Table 3.7.4-4. Counts of the moderately damaged essential facility buildings for each county are provided.

TABLE 3.7.4-4 MODERATELY DAMAGED ESSENTIAL FACILITY BUILDINGS BY COUNTY					
County	**Care**	**EOC**	**Fire**	**Police**	**School**
Adams	0	0	0	1	1
Ashland	0	0	0	0	0
Barron	0	0	0	0	0
Bayfield	0	0	0	0	0
Brown	0	0	0	0	4
Buffalo	0	0	0	1	0
Burnett	0	0	0	0	0
Calumet	0	0	0	0	0
Chippewa	0	0	1	0	1
Clark	0	0	0	0	0
Columbia	1	0	0	0	3
Crawford	0	0	0	0	0
Dane	0	0	1	1	2
Dodge	0	0	1	0	0
Door	0	0	1	0	0
Douglas	0	0	0	0	0
Dunn	0	0	1	0	0
Eau Claire	0	0	0	0	0
Florence	0	0	0	0	0
Fond du Lac	0	0	1	1	2
Forest	0	0	0	0	0

TABLE 3.7.4-4 CONTINUED					
County	Care	EOC	Fire	Police	School
Grant	0	0	0	0	0
Green	0	0	2	2	0
Green Lake	0	0	0	0	2
Iowa	0	0	0	1	1
Iron	0	0	0	0	0
Jackson	0	0	1	1	2
Jefferson	0	0	1	0	0
Juneau	0	0	1	0	2
Kenosha	0	0	0	1	1
Kewaunee	0	0	1	1	0
La Crosse	0	0	0	0	2
Lafayette	0	0	0	0	0
Langlade	0	0	0	0	0
Lincoln	0	0	0	0	0
Manitowoc	0	0	1	1	1
Marathon	0	1	0	0	1
Marinette	1	0	1	0	1
Marquette	0	1	0	4	0
Menominee	0	0	1	0	2
Milwaukee	1	0	0	0	4
Monroe	0	0	1	1	1
Oconto	0	0	0	0	0
Oneida	0	0	0	0	1
Outagamie	0	0	0	0	0
Ozaukee	0	0	2	1	2
Pepin	0	0	0	0	0
Pierce	1	0	0	1	1
Polk	0	0	0	0	0
Portage	0	0	0	0	0
Price	1	0	1	0	2
Racine	0	0	0	0	1
Richland	0	0	0	0	2
Rock	0	0	0	0	0
Rusk	0	0	0	0	0
Saint Croix	0	0	0	0	1
Sauk	0	0	2	1	2
Sawyer	0	0	0	2	1

TABLE 3.7.4-4 CONTINUED					
County	**Care**	**EOC**	**Fire**	**Police**	**School**
Shawano	0	0	0	0	0
Sheboygan	1	0	2	0	1
Taylor	0	0	0	0	0
Trempealeau	1	0	1	1	3
Vernon	0	0	0	2	1
Vilas	0	0	0	0	0
Walworth	0	0	0	0	0
Washburn	0	0	0	0	1
Washington	0	0	1	1	4
Waukesha	4	2	3	6	0
Waupaca	0	0	2	1	4
Waushara	0	0	1	1	0
Winnebago	0	0	0	0	4
Wood	1	0	1	0	2
Totals	**12**	**4**	**32**	**33**	**66**

Source: WEM, 2011.

Figures 3.7.4-2 through 3.7.4-5 can be found on the following pages. Figures 3.7.4-2 and 3.7.4-3 show the estimated building loss per county and the total estimated loss per county calculated in the HAZUS Flood Risk Assessment. Figure 3.7.4-4 shows the ratio of total economic loss to total building exposure per county. Figure 3.7.4-5 illustrates the estimated number of displaced persons per county. HAZUS uses the total number of residential buildings and populations to calculate the estimate. As can be expected, the counties with the highest populations have the highest number of displaced persons.

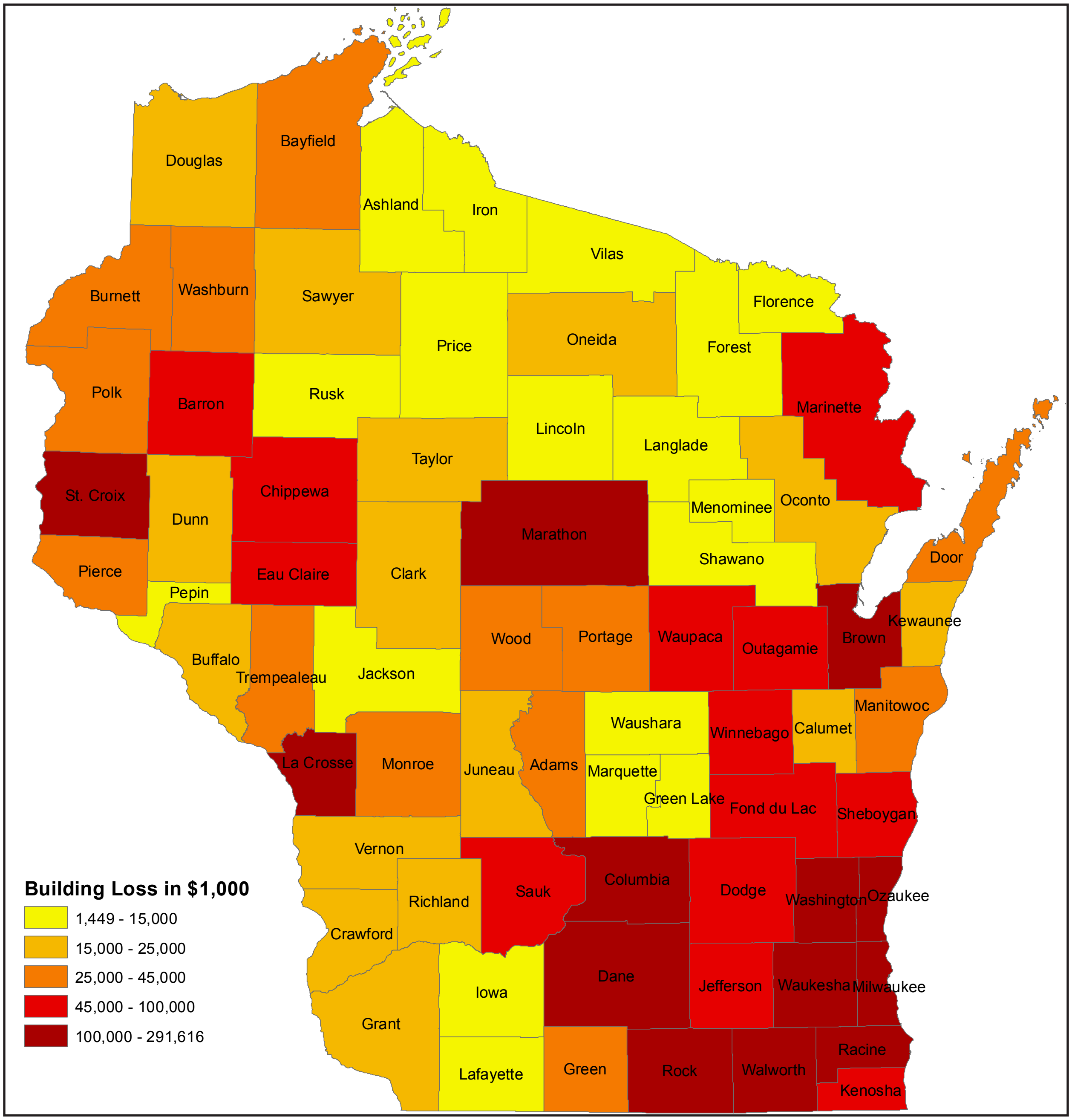


Figure 3.7.4-2 Estimated Building Flood Loss by County
Source: WEM, 2011.

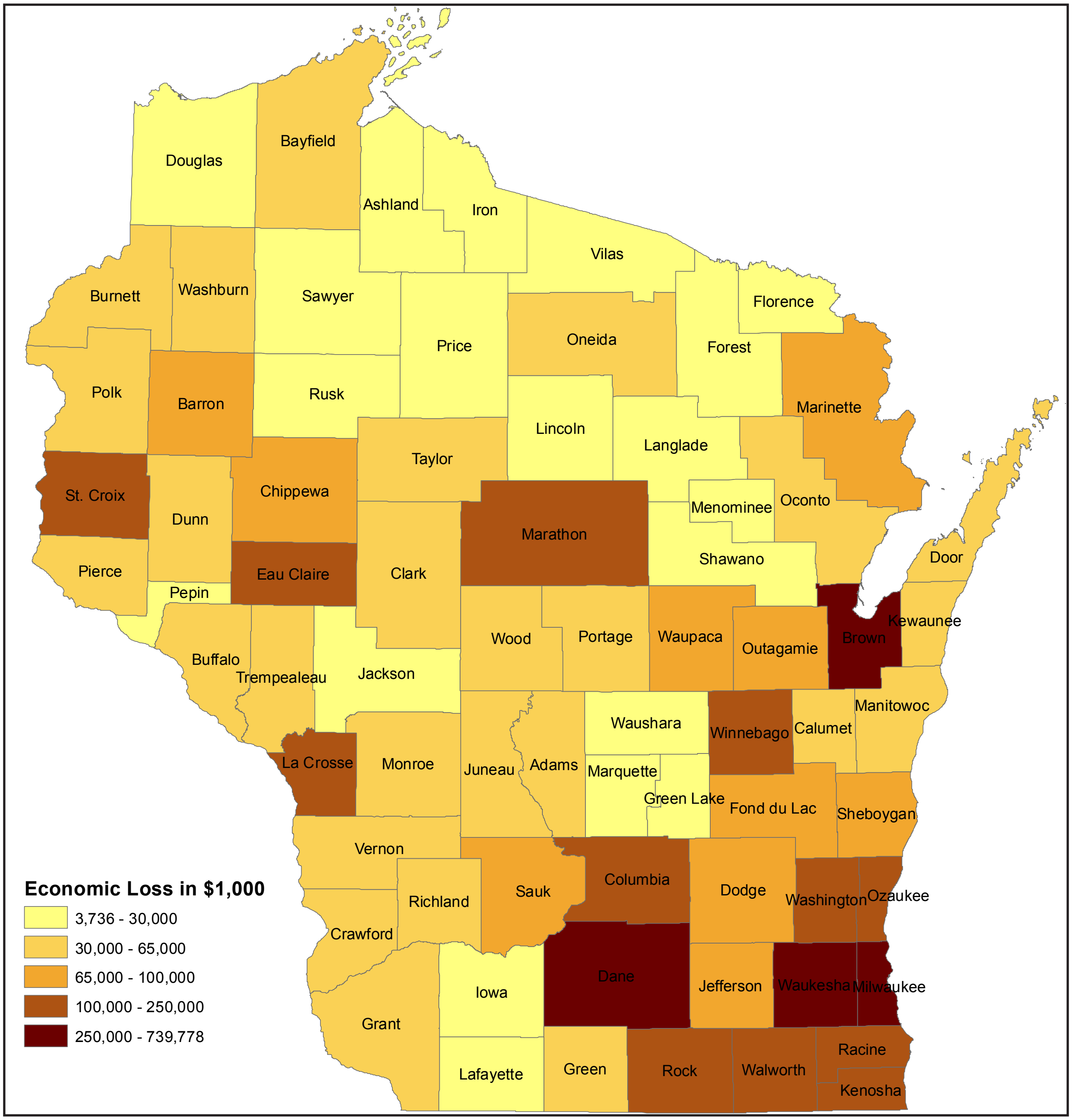


Figure 3.7.4-3 Total Estimated Flood Losses by County
Source: WEM, 2011.

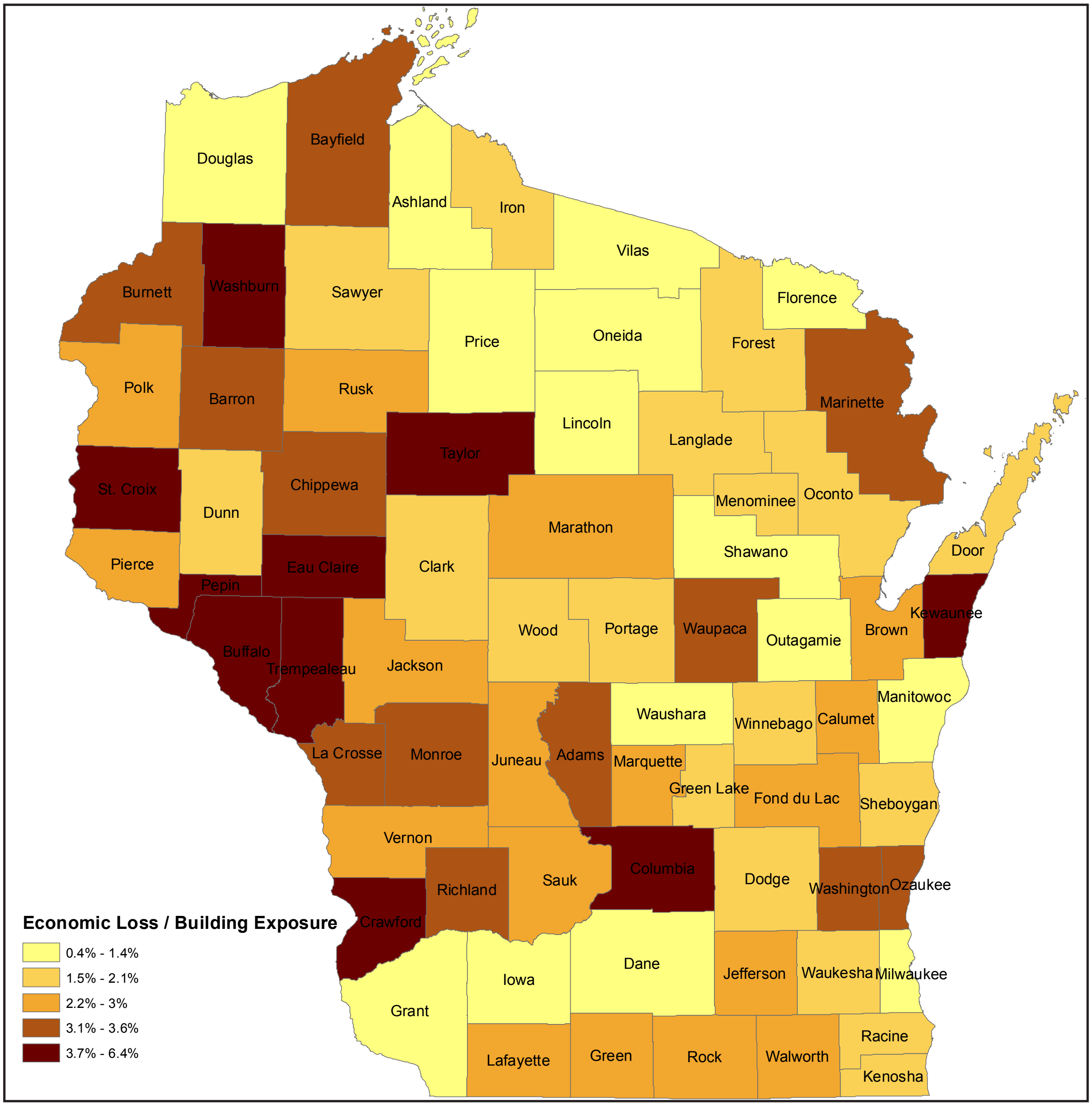


Figure 3.7.4-4 Ratio of Total Estimated Flood Losses to Total Building Exposure by County
Source: WEM, 2011.

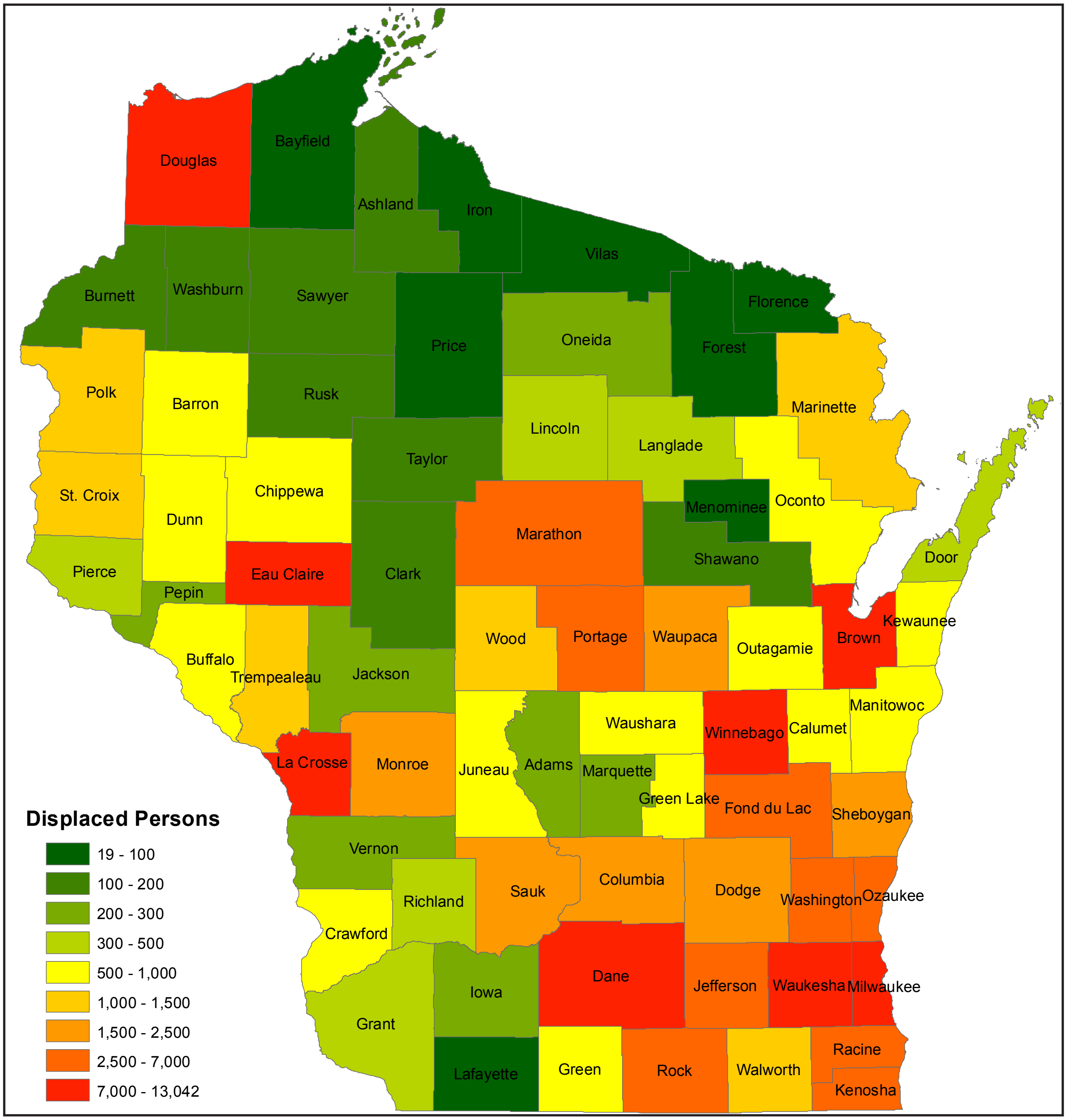


Figure 3.7.4-5 Estimated Persons Displaced by Flood per County
Source: WEM, 2011.

3.7.5 Hazard Ranking

TABLE 3.7.5-1 HAZARD RANKING FOR FLOODING		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard has impacted the state numerous times on an annual basis • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Methods for reducing risk from the hazard are technically reliable • The state or counties have experience in implementing mitigation measures • Mitigation measures are eligible under federal grant programs • There are multiple possible mitigation measures for the hazard • The mitigation measure(s) are known to be cost-effective	High

3.7.6 Sources for Flooding

TABLE 3.7.6-1 SOURCES FOR FLOODING	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Subpart C: Hydrologic Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
NOAA Flooding Information	http://www.noaawatch.gov/themes/flooding.php
National Climatic Data Center Storm Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
NOAA National Severe Storms Laboratory	http://www.nssl.noaa.gov/
NWS Storm Prediction Center	http://www.spc.noaa.gov/
Natural Hazards Center, University of Colorado Boulder	http://www.colorado.edu/hazards/
NWS Weather Forecast Office, Milwaukee/Sullivan, WI	http://www.crh.noaa.gov/mkx/
NWS Weather Forecast Office, Green Bay, WI	http://www.crh.noaa.gov/grb/
NWS Weather Forecast Office, La Crosse, WI	http://www.crh.noaa.gov/arx/
NWS Office of Climate, Water, and Weather Services Natural Hazard Statistics	http://www.nws.noaa.gov/om/hazstats.shtml
National Flood Insurance Program (NFIP)	http://www.floodsmart.gov/floodsmart/
FEMA Flood Hazard Site	http://www.fema.gov/hazard/flood/index.shtm

3.8 WILDFIRE

3.8.1 Nature of the Hazard

Chapter 26.01(2) of the Wisconsin State Statutes defines forest fires as any "uncontrolled, wild, or running fires burning in forest, marsh, field, cutover, or other lands or involving farm, city, or village property and improvements incidental to the uncontrolled, wild, or running fires occurring on forest, marsh, field, cutover, or other lands." They often begin unnoticed, can spread quickly, and are usually signaled by dense smoke that may fill the area for miles around. Wildfires in Wisconsin are primarily human-caused through acts such as burning yard debris, arson, or campfires. They can also be caused by natural events such as lightning.

On average, over 1,500 wildfire events occur annually in Wisconsin, causing thousands of dollars of damage to property, and destroying natural resources (DNR, 2011). In the past five years, 2005 saw the most property burned, with 6,196 acres; over half the acreage burned came from a single wildfire in Adams County. As depicted in Table 3.8.1-1, left, and Figures 3.8.1-1 and 3.8.1-2, on the following page, dozens of structures are damaged and hundreds of structures are destroyed annually by many wildfires throughout the state. Though thousands of acres are burned annually, many structures are saved by sound fire management techniques.

TABLE 3.8.1-1 WISCONSIN WILDFIRES, 2005-2010

Year	Number of Wildfires	Number of Acres Burned	Number of Structures Saved	Number of Structures Burned
2005	1,520	6,196	832	157
2006	1,597	2,124	497	66
2007	1,486	4,713	595	62
2008	821	998	219	31
2009	1,519	3,361	682	85
2010	1,220	2,093	440	41
TOTAL	**8,163**	**19,485**	**3,265**	**442**

Source: Wisconsin Department of Natural Resources, 2011.

Types of Wildfires in Wisconsin

Interface or intermix fires (also known as wildland-urban interface or WUI fires) occur in areas where both vegetation and structures provide fuel.

Firestorms occur during extreme weather (e.g. high temperatures, low humidity, and high winds) with such intensity that fire suppression opportunities are limited. These events typically burn until the weather or fuel conditions change, reducing fire behavior.

Prescribed fires occur with the intentional application of fire to wildland natural fuels, under specific environmental conditions, to accomplish planned land management objectives. They are part of a fuel management strategy and one of the most complicated and complex operations to implement.

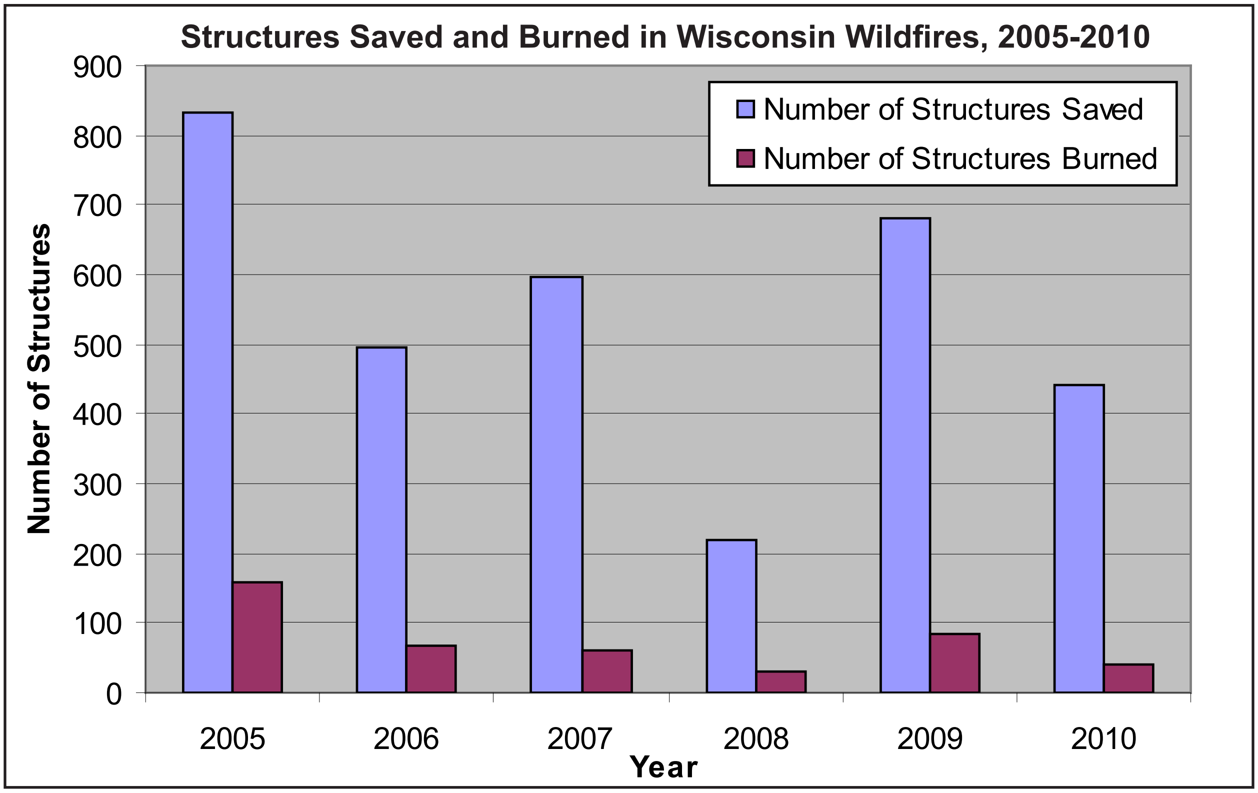


Figure 3.8.1-1 Structures Saved and Burned in Wisconsin Wildfires, 2005-2010
Source: Wisconsin Department of Natural Resources, 2011.

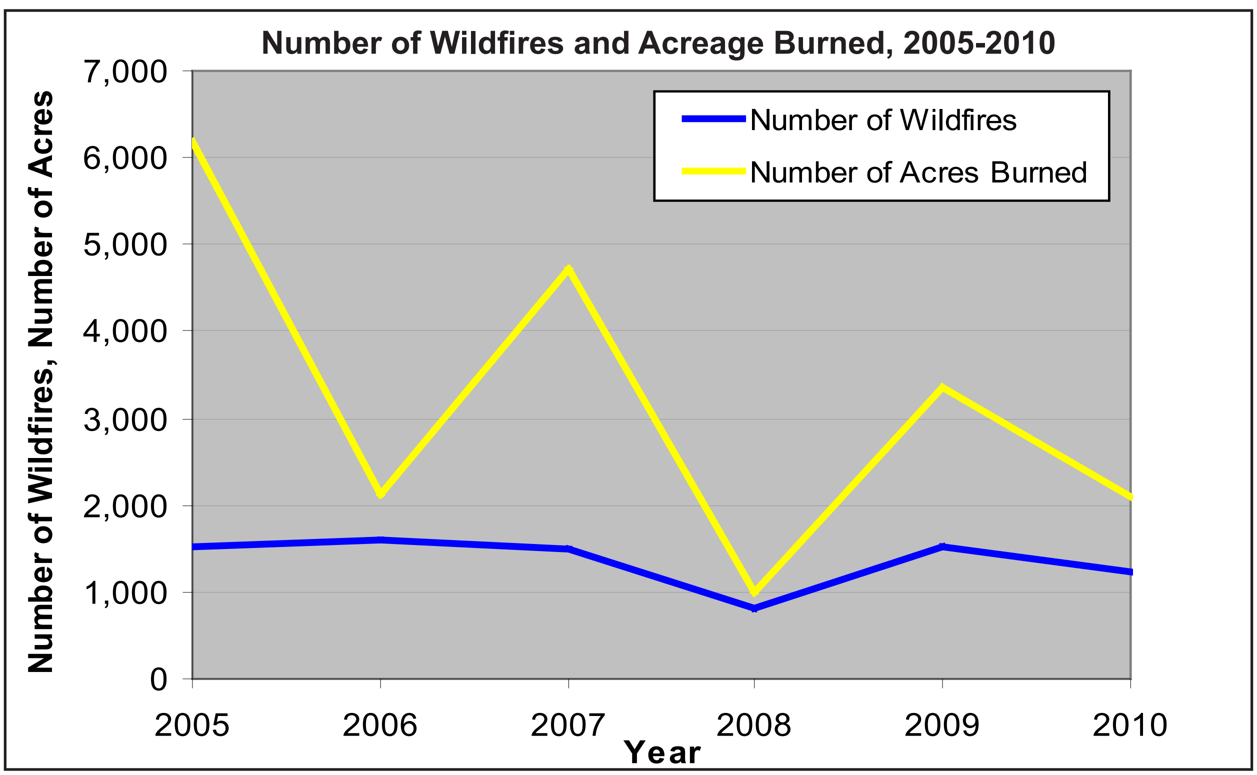


Figure 3.8.1-2 Number of Wildfires and Acreage Burned, 2005-2010
Source: Wisconsin Department of Natural Resources, 2011.

Factors Influencing Fire Behavior

Fuels

Fuel is required for any fire to burn. With regards to wildfire, fuels may consist of any of the following:

- living vegetation (grass, shrubs, and trees)
- dead plant material (dead trees, dried grass, fallen branches, pine needles, and dead leaves)
- "urban fuels" (houses, vehicles, and other man-made objects)

Fuels are arranged horizontally and vertically. Horizontal arrangement refers to the distribution of fuels over the landscape (FEMA). Vertical arrangement consists of the following:

- **Ground fuels** are combustible materials lying beneath the ground, including deep duff, roots, buried logs, and other organic matter.
    - Fires in ground fuels are usually called "peat fires."
- **Surface fuels** are materials lying on or immediately above the ground including pine needles, leaves, grass, downed logs, stumps, tree limbs, and low shrubs.
- **Aerial fuels** are green and dead materials in the upper forest canopy including tree tops and branches, snags, and tall shrubs.
    - "Crown fires" burn these aerial fuels and typically occur in conifer stands; this type of fire tends to be very intense and difficult to control.

Weather

- Temperature: Higher temperatures preheat fuels by driving off moisture, which allows fuels to burn faster.
- Relative humidity: Lower relative humidity and a lack of precipitation lowers fuel moisture; dry fuels burn more easily than fuels with higher moisture content.
- Wind speed: Wind is the most important weather factor since it dries fuel and increases the supply of oxygen. Wind has the greatest influence on the rate and direction of fire spread. In Wisconsin, wind direction almost always changes in a clockwise rotation, and winds tend to be the strongest in mid-afternoon.

Topography

- Slope: Steep slopes spread fire rapidly. Fire travels faster uphill and afternoon winds travel upslope as hot air rises, pushing fire even faster.
- Aspect (direction a slope faces): In Wisconsin, north-facing slopes tend to be more shaded with more moisture and heavier fuels, such as deciduous trees. South-facing slopes tend to be sunnier and drier, with more light fuels such as grasses.

Interaction with Other Hazards

Some natural hazards cause wildfires, others intensify them, and still other hazards are intensified by wildfire events. In Wisconsin, the following hazards often interact with wildfires, altering the conditions in the fire themselves:

- **Severe thunderstorm wind events:** increased wind speed increases the rate at which a wildfire spreads; the rate of spread varies directly with wind velocity (see Section 3.3 for more information about severe thunderstorms)
- **Lightning:** lightning may cause a wildfire as a result of a cloud-to-ground lightning strike (see Section 3.5 for more information about lightning)
- **Flooding:** wildfires remove vegetation from landscape, decreasing the soil's ability to absorb moisture, thus increasing likelihood of flooding in a fire ravaged area (see Section 3.7 for more information about flooding)
- **Landslides:** since wildfires remove vegetation and damage soils, flash runoff erosion may contribute to landslides (see Section 3.14 for more information about landslides)

Most Wisconsin wildfires occur in spring between March and June, with the highest incidence in April, although under the right conditions, they can occur at any time of the year (DNR). The season length and peak months may vary from year to year. Land use, vegetation, amount of combustible materials present, and weather conditions such as high wind, low humidity, and lack of precipitation are the chief factors in determining the number of fires and acreage burned. Generally, fires are more likely when vegetation is dry from a winter with little snow and/or a spring and summer with sparse rainfall.

Wildfire management involves the control, containment and suppression of a wild or uncontrolled fire. If not promptly controlled, a wildfire may grow into an emergency or disaster. Even small fires can threaten lives, resources, and improved property. The indirect effects of wildfires can also be detrimental. In addition to charring vegetation and destroying forest resources, large, intense fires can harm the soil, waterways, and the land itself.

Wildfires are capable of causing significant injury, death, and damage to property. A recent inventory showed that 16 million acres, or 46 percent of the State, is covered with forests. The potential for property damage from wildfires increases each year as additional properties are developed in woodland areas and higher numbers of people use these areas recreationally. Fires can extensively impact the economy of an affected area, especially the logging, recreation, and tourism industries. Major direct costs associated with forest fires or wildfires are the expenses of suppression, property loss, salvage, removal of downed timber and debris, and restoration of the burned area.

3.8.2 Wisconsin Wildfire Event History

While most of the wildfires starts in Wisconsin are quickly contained and kept to less than ten acres in size, Wisconsin has experienced catastrophic fires throughout its history.

The DNR highlights the events described below as noteworthy wildfires in the state's history.

1871: The most disastrous fire in Wisconsin's history is the Peshtigo Fire, when more than 1.5 million acres of forest burned in northeastern Wisconsin, mainly in Oconto, Marinette, Shawano, Brown, Kewaunee, Door, and Manitowoc Counties. The fire displaced an estimated 3,000 people, killed an estimated 1,152 people, and left another 350 people missing. This event represents the greatest single loss of human life by fire in American history; however, the Great Chicago Fire occurred at the same time and received much more publicity than this historic Wisconsin fire.

1891: The Comstock Fire destroyed about 64,000 acres in Barron and Washburn Counties, including the entire Village of Barronett (Washburn County) and structures in the City of Shell Lake (Washburn County).

1894: On July 27, the Phillips Fire burned over 100,000 acres in Price County, destroying 400 homes and much of the downtown area in the City of Phillips. 13 people died trying to escape by swimming across Long, Duroy, and Elk Lakes.

1930-34: In the dust bowl era, severe droughts ravaged the state. During this four-year period, about 2,950 fires burned 336,000 acres annually in Wisconsin.

1959: On May 1, a running crown fire in Burnett County burned 17,560 acres, causing $201,889 in reported damages.

1977: The entire state suffered two years of severe drought. Nearly 49,000 acres burned in 1977 alone. Over 170 structures were destroyed or damaged. Jackson, Washburn, Douglas, and Wood Counties were the worst hit. The Saratoga Fire in Wisconsin Rapids (Wood County) burned 6,159 acres and destroyed 90 buildings; the Brockway Fire in the Black River Falls area (Jackson County) burned 17,590 acres; and the Five-Mile Fire in Washburn and Douglas Counties burned 13,375 acres and destroyed 83 buildings.

1980: Over two days in April, the Ekdall Church Fire in Burnett County and the Oak Lake Fire in Washburn County together burned over 16,000 acres and destroyed more than 200 buildings.

2003: The Crystal Lake Fire in Marquette and Waushara Counties burned 572 acres. Nearly 200 buildings were threatened and several were destroyed.

2005: On May 5, the Cottonville Fire burned a swath 1.5 miles wide and seven miles long through the Towns of Big Flats, Preston, and Colburn (Adams County). It took nearly 200 personnel to suppress the wildfire in about 11 hours. Over 100 people were evacuated for several days while crews extinguished smaller fires. There were nine year-round residences, 21 seasonal homes, and at least 60 outbuildings destroyed in the 3,410 acre fire. 300 buildings were saved due to firefighting efforts.

2007: On April 29, a fire in Bayfield County burned 1,167 acres of US Forest Service land. Though this was the biggest fire in terms of acreage since the Cottonville Fire, only one structure was burned, and another 30 were saved.

3.8.3 Wildland-Urban Interface Fires

Throughout the twentieth century, housing was concentrated mainly in the larger metropolitan statistical areas, but people began moving to the outer fringe of cities and suburbs in the latter part of the 1900s. As housing development continues to occur into more rural areas, the dynamics of fire suppression and control have changed drastically (DNR, 2011).

Wildfire danger grows as homes and other man-made objects are moved into forests, grasslands, and other areas with highly flammable vegetation, creating what is known as the wildland-urban interface (WUI). According to the DNR, "the WUI can be a lone house in the middle of a forest, a subdivision on the edge of a pine plantation, or homes surrounded by grassland" (DNR, 2011). Locating man-made structures in areas that have burned naturally in the past both interrupts the natural recurrent cycle of wildfires and adds fuel to wildfires.

People continue to move to WUI areas, increasing dangers to their lives, property, and the natural resources surrounding them. Until residents adapt to the dangers around them, fire officials continue their efforts to promote and protect the safety of people and property in WUI areas with highly flammable vegetation. There is particular concern with homes located in remote areas where access roads and driveways are too narrow or sandy to allow emergency vehicles to properly service the homes. Furthermore, the addition of homes increases danger through use of power lines, liquid propane tanks, hazardous materials, and increased vehicular traffic (DNR, 2011).

Another factor increasing concern for the WUI areas is that the increase in the number of available, skilled firefighters and equipment is not keeping pace with increase in rural development. In these fire-prone WUI areas, firefighters often work as volunteers, and may be unaware of the additional challenges posed by WUI fires in their communities, such as the need for evacuation plans or the simultaneous confrontation of structure fires and wildfires. That type of demand requires a high level of training which may not always be available.

3.8.4 Probability of Occurrence

Wildfires are an ongoing threat to both rural areas and WUI communities. The number of acres burned has dropped significantly from 9,740 acres in 1988 to 988 acres in 2008, which was a 22 year low. However, the potential for wildfire persists due to the standing, constantly renewing fuel load.

There is a 100% probability that there will be at least one fire in Wisconsin every year. Wildfire managers prioritize the protection of lives, property, and resources – in that order. The challenge is to minimize the damage done by wildfire, while at the same time ensuring the safety of everyone involved.

Since fires occur annually in Wisconsin, the risk is inevitable. Preventing damages relies heavily on the education of residents and visitors to WUI areas to prevent starting wildfires, and to keep people and property safe when a wildfire does occur.

3.8.5 National Firewise Communities

The National Firewise Communities Program is a multi-agency effort between agencies, tribes, organizations, fire departments, and communities across the US to reduce loss of life, property, and resources to wildland fire by building and maintaining communities in a way that is compatible with natural surroundings. This goal is accomplished by actively involving homeowners, community leaders, planners, developers, and others in the effort to protect life, property, and resources from the risk of wildland fire before a fire starts. The Firewise Communities approach emphasizes community responsibility for planning and designing a safe community, effective emergency response, and individual responsibility for safer home design, construction, landscaping, and maintenance.

There are three main Firewise concerns in fire-prone areas:

1. **Buildings:** emphasis is on flammability of residential buildings/areas and outbuildings
2. **Surrounding vegetation:** does vegetation help spread fire or promote fire suppression?
3. **Access:** can emergency vehicles and workers service the area if a fire is burning

The Firewise Program recommendations are primarily focused on "The Home Ignition Zone (HIZ)," an area extending 100 to 200 feet beyond each side of all buildings on a property. In a well designed site, the HIZ should provide enough distance between buildings and a wildfire and modify vegetation around the structure so it acts as a fire break, rather than a spreading aid. Creating such defensible space increases the chance of buildings surviving a wildfire without outside help (DNR, 2011).

3.8.6 Communities-at-Risk

In 2003, the National Association of State Foresters produced the Field Guidance for Identifying and Prioritizing Communities-at-Risk (CARs). The purpose of the guide was to provide states with a nationally-consistent approach for assessing and displaying the risks to communities from wildfire. The Wisconsin DNR, in cooperation with its federal and tribal partners, began working on a statewide assessment of CAR in 2004, which was finished in March 2011.

CAR is a model used to identify broad areas of the state that are at relatively high risk of resource damage from wildfire. Results of the model can then be used by local governments developing Community Wildfire Protection Plans (CWPP), and by the DNR to reduce local risks of wildland fire by prioritizing hazard mitigation and fire protection efforts.

The approach used in this risk assessment model is based on the "Methodology" section of the National Association of State Foresters Field Guidance document which recommends assessing and mapping four factors: 1) historic fire occurrence; 2) hazard; 3) values protected; and 4) protection capabilities. Modifications to this methodology were made to fit the data layers available for Wisconsin.

The DNR uses three factors to assess CAR to wildfire damage:

1. **Hazard:** the relative likelihood that an ignited wildfire will achieve sufficient intensity to threaten life or property based on land cover type, and historic fire regime.
2. **WUI (Values at Risk):** the relative vulnerability of each 2000 census block to wildfire damage based on housing density and spatial relationships with undeveloped vegetation in the WUI. Wisconsin's WUI was layered with a weighted vegetation layer to accentuate proximity to flammable vegetation.
3. **Ignition Risk:** the relative likelihood of a wildfire ignition within a given 30m pixel based on historic fire occurrence, population density, and proximity to a potential ignition source.

From these factors, models were developed in GIS to create statewide grids representing each of the three input factors. Finally, a statewide composite grid was created using a weighted overlay of hazard (40%), WUI (30%), and ignition risk (30%). This composite grid represents CAR on a zero to nine scale of threat, with zero representing little to no threat (i.e. low or high intensity urban development) and nine representing a very high threat (i.e. a jack pine or red pine forest). Statistics could then be calculated by municipal civil division (MCD). MCD was chosen since city or village boundaries change as land is annexed to plan for development. This measure provided consistency in reporting, and this is the level used in development of CWPPs (DNR, 2011).

Each of Wisconsin's 1,864 towns, villages, and cities was defined as a "community." Using a combination of natural breaks and field verification, quantitative markers were assigned for five threat levels: very low, low, moderate, high, and very high. Ultimately, those "communities" determined to have a high or very high threat of wildfire were considered to be CARs. 337 communities were determined to be "at risk."

Communities in Wisconsin vary considerably in size, particularly when comparing northern, more rural, communities to southern, more urban, communities. Because of this variation in size, the potential for missing areas of high risk was greater for larger towns. For this reason, the DNR incorporated a “Community-of-Concern” (COC) category to identify those towns with portions of their land at high risk of wildfire, but which were not otherwise included as a CAR. A COC was defined as a community that contained at least two contiguous square miles at high or very high risk; 237 communities were named as COCs.

The breakdown of communities is shown below in Table 3.8.6-1, and depicted graphically in Figures 3.8.6-1 and 3.8.6-2 on the following pages.

TABLE 3.8.6-1 WILDFIRE RISK LEVELS FOR WISCONSIN COMMUNITIES

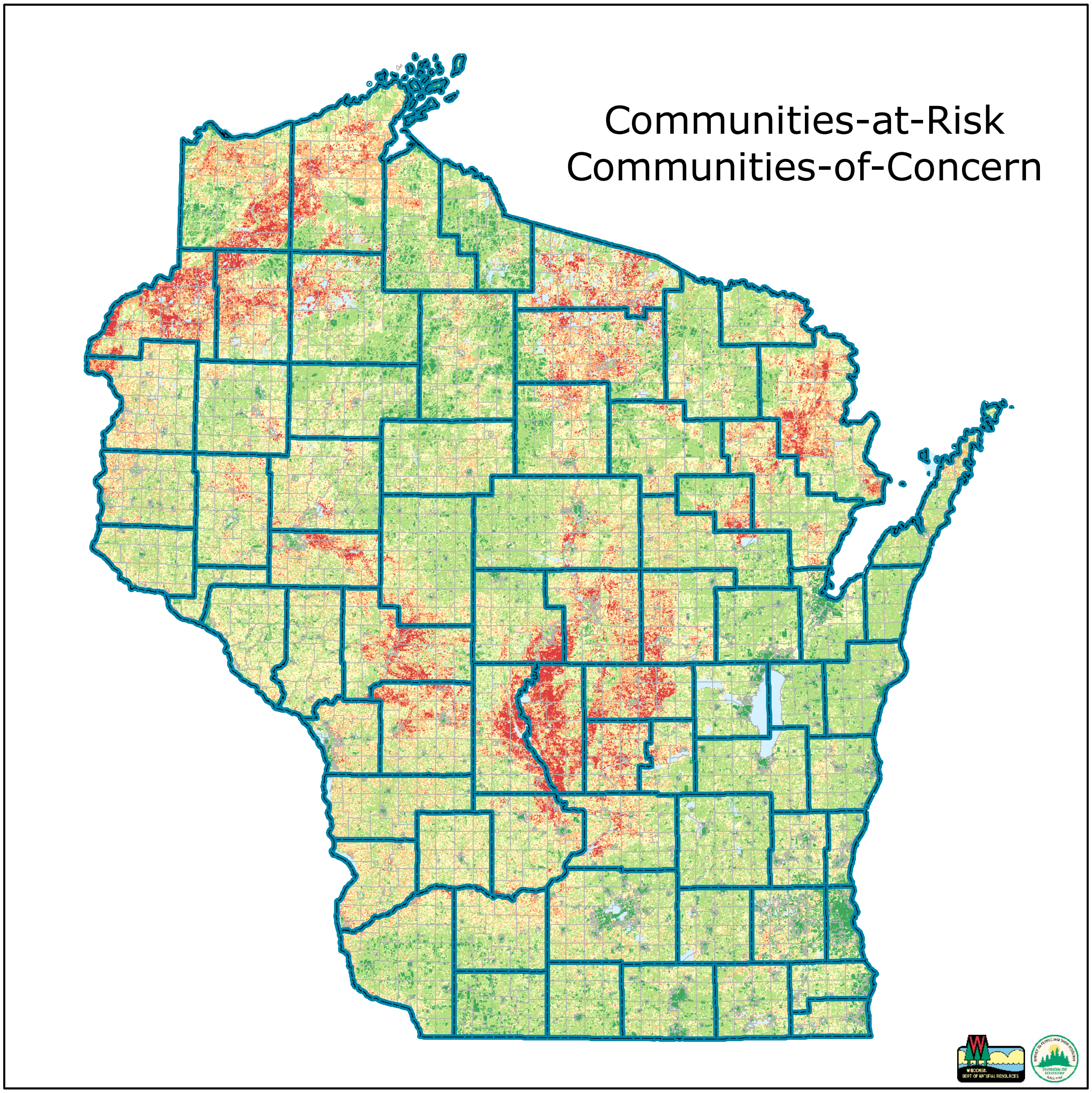
Risk Level	Number	Percent of Communities	Number of Cities	Number of Villages	Number of Towns	Percent of Land Area
Very High (CAR)	93	5	2	12	79	6
High (CAR)	244	13	10	47	187	16
Concern (COC)	237	13	8	6	223	20
Totals	**574**	**31**	**20**	**65**	**489**	**42%**

Source: Wisconsin Department of Natural Resources, 2011.

3.8.7 Hazard Ranking

TABLE 3.8.7-1 HAZARD RANKING FOR WILDFIRE

Evaluation Criteria	Description	Ranking
Probability	• The hazard impacts the state occasionally, but not annually • The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs • The methodology for identifying events is not well-established, or is not applied across the entire state	Medium
Mitigation Potential	• Mitigation methods are established • The state or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard • Some mitigation measures are eligible for federal grants • There is a limited range of effective mitigation measures for the hazard • Mitigation measures are cost-effective only in limited circumstances • Mitigation measures are effective for a reasonable period of time	Medium



Introduction to the CAR Composite Grid

The composite grid is a model generated with Wisconsin datasets compiled from three input grids: Hazard (40%), WUI (30%), Risk (30%) (see table). Each 150-m pixel is attributed a value from 0 to 9, with 9 representing the highest risk of exposure to wildfire damage. These values are represented in the map as Very High to Very Low.

The composite grid is used to determine Communities-at-Risk. To identify a Community-at-Risk, the mean of all values within a Municipal Civil Division (MCD) must fall above CAR thresholds. Thresholds were determined using statistical methods and field verification.

Composite Grid Inputs

For north: Surface fuel flammability (50%) *For south:* Integrated Moisture Index (25%) Presettlement Veg (25%)	= Historic Fire Regime (50%) *For state:* Wiscland (vegetation) (50%)	HAZARD (40%)	Composite Grid
	WUI (50%) Wiscland (vegetation) (50%)	WUI (30%)	
	Population Density (50%) Historic Fire Occurrence (25%) Distance to Rd or RR (25%)	RISK (30%)	

* *Percent (%) equals weighted value into the next level of analysis.*

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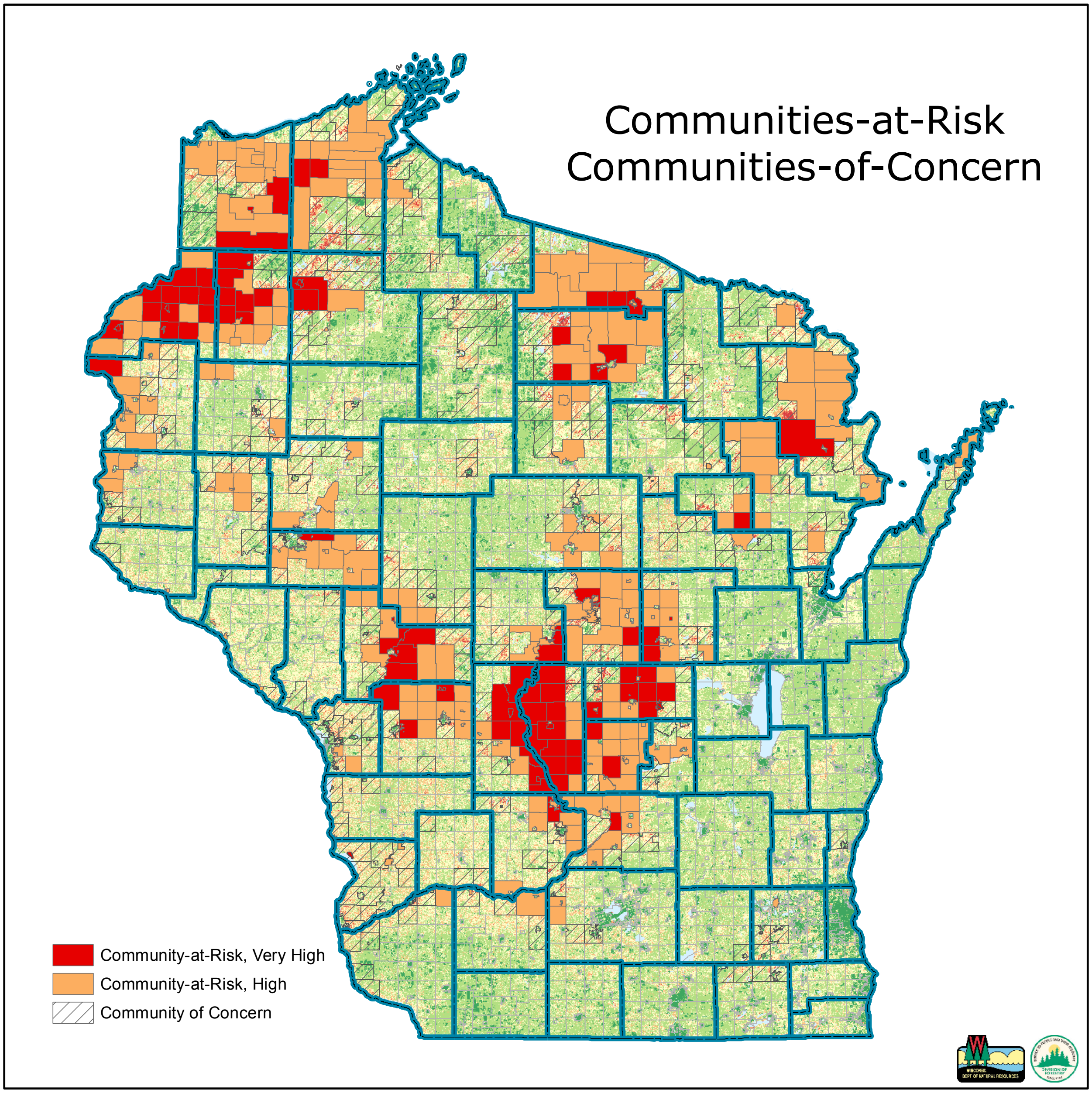
Figure 3.8.6-1 Communities-at-Risk, Communities-of-Concern Composite Map
Source: Wisconsin Department of Natural Resources, 2011.



Introduction to Communities-at-Risk

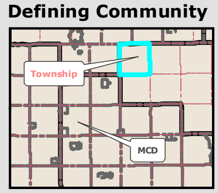
The purpose of this model is to identify broad areas of the state that are at relatively high exposure to resource damage due to wildfire.

As mandated by the NASF, Wisconsin's Communities-At-Risk are divided into three categories:

1) Very High
2) High
3) Community of Concern*

** A Community of Concern is a Wisconsin DNR concept whereby it is demonstrated that a significant portion of the community (more than 2 adjoining square miles) are at high or very high risk, but where the community as a whole falls below the Community-at-Risk threshold.*

Defining Community



For Wisconsin, Communities-at-Risk are reported at the MCD (municipal civil division) level*. MCD was chosen due to its identifiable legal boundaries, ease in reporting, and usage in the development of Community Wildfire Protection Plans.

** Menominee County is an exception due to its lack of MCD's (civil townships). Therefore, Menominee county is reported by legal township.*

Figure 3.8.6-1 Communities-at-Risk, Communities-of-Concern Map
Source: Wisconsin Department of Natural Resources, 2011.

3.8.8 Sources for Wildfire

TABLE 3.8.8-1 SOURCES FOR WILDFIRE	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Subpart E: Other Natural Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
FEMA Wildfire Information Site	http://www.fema.gov/hazard/wildfire/index.shtm
National Interagency Fire Center	http://www.nifc.gov/
NOAA Wildfire Information site	http://www.noaawatch.gov/themes/fire.php
Natural Hazards Center, University of Colorado Boulder	http://www.colorado.edu/hazards/
Wisconsin DNR Division of Forestry	http://dnr.wi.gov/forestry/
Wisconsin DNR Current Fire Danger	http://dnr.wi.gov/forestry/Fire/Fire_Danger/Wis_Burn/StateCounties.asp
Wisconsin DNR Forest Fire Program	http://dnr.wi.gov/forestry/fire/
Wisconsin DNR Fire Management (PDF)	http://dnr.wi.gov/forestry/Publications/Guidelines/PDF/chapter17.pdf
Wisconsin DNR Major Wildfire Event History	http://dnr.wi.gov/wnrmag/html/supps/2005/apr05/timeline.htm
National Climatic Data Center Storm Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

Cardille, Jeffrey A., Stephen J. Ventura, and Monica G. Turner. 2001. Environmental and social factors influencing wildfires in the upper Midwest, United States. Ecological Applications. 11(1): 111-127.

Cleland, David T., Thomas R. Crow, Sari C. Saunders, Donald I. Dickmann, Ann L. Maclean, James K. Jordan, Richard L. Watson, Alyssa M. Sloan and Kimberly D. Brosofske. 2004. Characterizing historical and modern fire regimes in Michigan (USA): A landscape ecosystem approach. Landscape Ecology. 19: 311-325.

Finley, Robert W. Data 1976, Map 1999 (Nina Janicki). Finley's Presettlement Vegetation. publ. in: Ecological Landscapes of Wisconsin.

Haight, Robert G., David T. Cleland, Roger B. Hammer, Volker C. Radeloff, and T. Scott Rupp. 2004. Assessing Fire Risk in the Wildland-Urban Interface. Journal of Forestry. Oct/Nov: 41-48.

Radeloff, V.C., R. B. Hammer, S.I. Stewart, J.S. Fried, S.S. Holcomb, and J.F. McKeefry. 2005. The wildland urban interface in the United States. Ecological Applications. 15(3): 799-805.

Stewart, Susan I., Volker C. Radeloff, Roger B. Hammer, and Todd J. Hawbaker. 2007. Defining the Wildland-Urban Interface. Journal of Forestry. June: 201-207.

Sturtevant, Brian R, Patrick A Zollner, Eric J Gustafson, and David T. Cleland. 2004. Human influence on the abundance and connectivity of high-risk fuels in mixed forests of northern Wisconsin, USA. Landscape Ecology. 19: 235-253.

US Department of the Interior (USDI) and US Department of Agriculture (USDA). 2001. Urban wildland interface communities within vicinity of federal lands that are at high risk from wildfire. Federal Register. 66(3): 751-777.

3.9 DROUGHT

3.9.1 Nature of the Hazard

Drought is the result of a natural decline in the expected precipitation over an extended period of time, and occurs in virtually every climate on the planet, including areas of high and low precipitation. The severity of drought can be aggravated by other climatic factors, such as prolonged high winds and low relative humidity (FEMA). Drought is a complex natural hazard which is reflected in the following four definitions commonly used to describe it:

1. **Meteorological drought:** degree of dryness, expressed as a departure of actual precipitation from expected average or normal amount, based on monthly, seasonal, or annual time scales
2. **Hydrological drought:** effects of precipitation shortfalls on streamflows, reservoir, lake, and groundwater levels
3. **Agricultural drought:** soil moisture deficiencies relative to water demands of crop life
4. **Socioeconomic drought (or water management drought):** demand for water exceeds the water supply, resulting in a water shortage

A drought's severity depends on numerous factors:

- Duration
- Intensity
- Geographic extent
- Water supply demands, for both human use and vegetation

Due to its multi-dimensional nature, drought is difficult to define in exact terms, partly because of the ways it differs from other natural hazards:

- The onset and end of a drought are difficult to determine due to the slow accumulation and the lingering of effects after its apparent end.
- The lack of an exact and universally accepted definition adds to the confusion of existence and severity.
- The impact of drought is less obvious and may be spread over a larger geographic area.

These characteristics have hindered the preparation of drought contingency or mitigation plans by many governments and can make it difficult to perform an accurate risk assessment analysis.

Droughts may cause a shortage of water for human and industrial consumption, hydroelectric power, recreation, and navigation. Water quality may also decline and the number and severity of wildfires may increase. Severe droughts may result in the loss of agricultural crops and forest products, undernourished wildlife and livestock, and lower land values, among other outcomes.

Wisconsin is most vulnerable to agricultural drought. The state has approximately 15.2 million acres of farmland on 78,000 farms and was ranked ninth in the country in overall farm receipts in 2010 (National Agricultural Statistics Service). Even small droughts of limited duration can significantly reduce crop growth and yields, adversely affecting farm incomes and local economies. Droughts significantly increase the risk of forest fires and wildfires. Additionally, the loss of vegetation in the absence of sufficient water can result in flooding, even from average rainfall, following drought conditions.

3.9.2 Wisconsin Drought Event History

During the 20th century, nine notable droughts have occurred in Wisconsin.

1929-34

The Drought of 1929-1934 was probably the most significant in Wisconsin history, considering its duration and severity. This drought had a 75-year recurrence interval in most of the state and over 100-year recurrence interval in certain areas. The austere economic aspects of the Great Depression compounded its effects. The drought continued with somewhat decreased effect until the early 1940s in some parts of the state.

1948-50

The 1948-1950 Drought was most significant in the northern part of the state. In the most severely affected areas, the drought had a recurrence interval of greater than 70 years.

1955-59

The 1955-1959 Drought had a recurrence interval of 30 to 70 years in all but the northwestern corner of Wisconsin.

1976-77

Estimates suggest that the 1976-1977 Drought in the Great Plains, Upper Midwest, and far Western States caused direct losses of $10 to $15 billion (FEMA). The drought of 1976-1977 was most severe in a wide band stretching from north to south across the state. Stream flow measuring stations recorded recurrence intervals from 10 to 30 years. State agricultural losses during this drought were set at $624 million. 64 counties were declared Federal Drought Areas and deemed eligible for assistance under the Disaster Relief Act. Additionally, numerous private and municipal wells went dry. Federal assistance was used to help communities drill new wells and obtain new water supplies.

1987-88

Some people believe the Drought of 1987-1988 to be most severe ever experienced in Wisconsin and much of the Midwest. It was characterized by not only below normal precipitation, but also persistent dry air and above normal temperatures. Stream flow measuring stations indicated a recurrence interval of 75 to 100 years. Its effects were most severe in north-central and northeastern Wisconsin. The drought occurred early in the growing season and resulted in a 30% to 60% crop loss, with state agricultural losses set at $1.3 billion. 52% percent of the state's 81,000 farms were estimated to have had crop losses of 50% or more, with 14% of the farms suffering estimated losses of 70% or more (FEMA). A combination of state and federal drought assistance programs helped Wisconsin farmers recover a portion of their losses. All Wisconsin counties were designated eligible for this drought assistance. In total, the drought in the Central and Eastern States during 1987-89 caused an estimated $39 billion in damages (FEMA).

The effect of this drought on municipal and private water supplies was not as severe; there were only a few reports of individual wells drying up. Several municipal water utilities experienced maximum use of their water delivery systems. Many water utilities imposed some type of water-use reduction rules or restrictions, usually involving the limitation of lawn sprinkling and yard watering.

2003

In August 2003, drought conditions returned to parts of south-central and southeast Wisconsin. The jet stream and associated low pressure systems stayed north of Wisconsin, resulting in few cold front passages. Conditions worsened from abnormally dry (D0 rating) to a moderate drought (D1 rating) as the month progressed. This drought continued into September 2003 and ultimately reached the severe category (D2). Crop and fruit tree farms without irrigation capability were especially affected. The hottest day of the summer in Milwaukee (Milwaukee County) occurred on August 21 when 96 degrees was recorded. Madison (Dane County) topped out at 94 degrees on August 26. Milwaukee experienced six days during the month with maximum temperatures of 90 degrees or higher. The three-month summer period of June through August was the driest in three decades in West Bend (Washington County), where only 5.11 inches of rain fell (7.82 inches below normal). Similar conditions were experienced throughout southern Wisconsin.

2007

Between January and July 2007, drought gradually returned to most of Wisconsin, spreading from north to south. The jet stream pattern kept low pressure systems and associated thunderstorms northwest of Wisconsin while summer temperatures averaged one to three degrees above normal. Eventually moderate (D1 rating) to extreme drought (D3 rating) covered 85% of the state. Only the southern tier of counties had normal conditions to abnormally dry conditions (D0 rating). Crop yields were reduced. Moderate to heavy rains across central and southern Wisconsin in August broke the back of the drought in those areas, but the drought only gradually left the northern part of the state by December 2007.

3.9.3 Probability of Occurrence

The future incidence of drought is highly unpredictable, and may also be localized, making it difficult to determine probability with any accuracy; however, the NWS and National Integrated Drought Information System (NIDIS) are improving methodology to accurately forecast drought conditions. Both organizations use a combination of current and historical precipitation, streamflow, ground water, and crop data to perform short-term and long-term forecasts.

The Palmer Index determines long term drought forecasts, profiling several months at a time; however, it does not provide accurate short-term forecasts (several weeks). It uses a ranking of zero as normal, with drought shown in terms of negative numbers and excessive moisture in terms of positive numbers. The scale and conditions from July 2011 are pictured in Figure 3.9.3-1 on the following page. The NWS updates the Palmer Index on a weekly basis. Current Palmer Drought Severity Index information can be found online at the NWS Climate Prediction Center's Drought Monitoring website, at: http://www.cpc.ncep.noaa.gov/products/monitoring_and_data/drought.shtml.

On the other hand, the US Drought Monitor indicates which parts of the country are experiencing short-term drought conditions. The US Drought Monitor can be accessed at the NIDIS website, at: http://www.drought.gov. Figure 3.9.3-2 shows the short-term drought conditions for the beginning of July 2011. The lack of any color shading over Wisconsin indicated that there were no short-term drought conditions in Wisconsin. This contrasts markedly with the extreme ongoing D4 (exceptional drought) conditions in Texas and New Mexico, which have over 240 and 180 reported impacts, respectively (NIDIS, 2011).

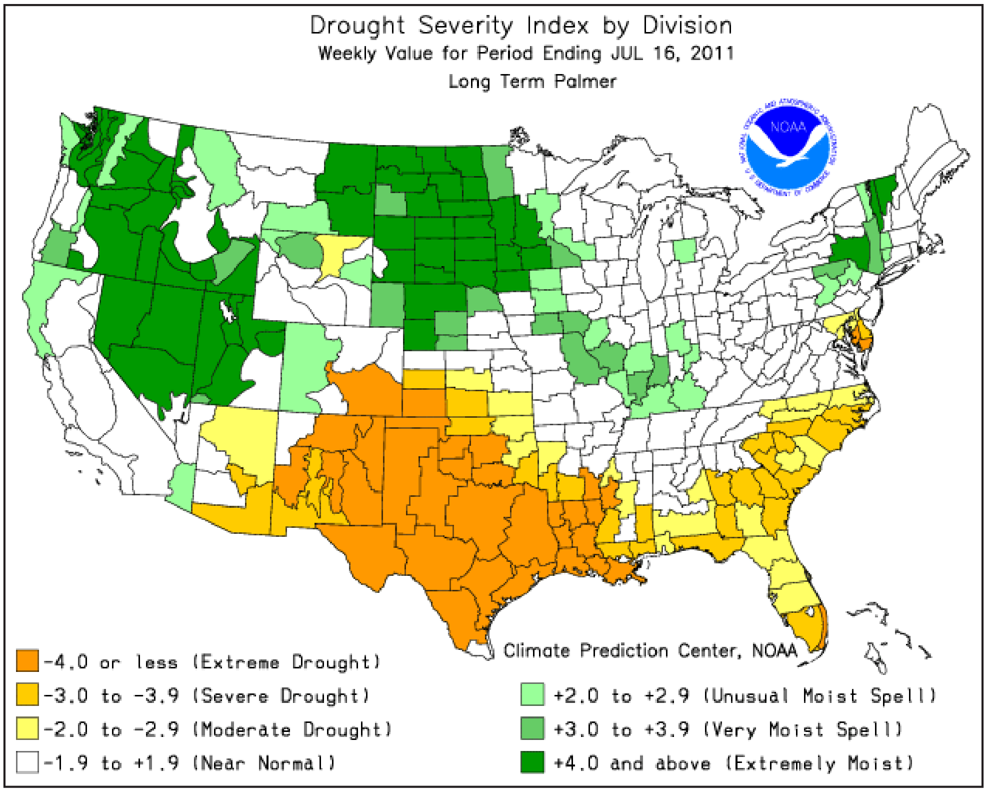


Figure 3.9.3-1 Palmer Drought Severity Index, July 16, 2011
Source: NOAA Climate Prediction Center, 2011.

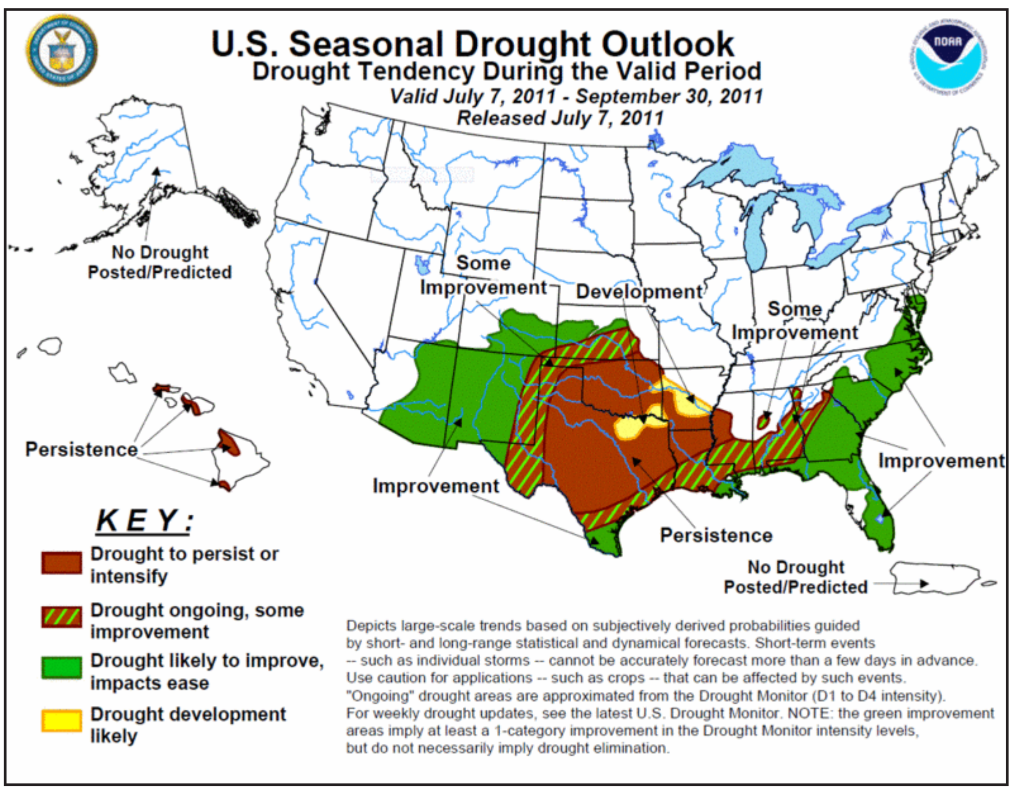


Figure 3.9.3-1 Palmer Drought Severity Index, July 16, 2011
Source: NOAA Climate Prediction Center, 2011.

3.9.4 Hazard Ranking

TABLE 3.9.4-1 HAZARD RANKING FOR DROUGHT		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard impacts the state occasionally, but not annually • The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs • The methodology for identifying events is not well-established, or is not applied across the entire state	Medium
Mitigation Potential	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The state or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under Federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor.	Low

3.9.4 Sources for Drought

TABLE 3.9.5-1 SOURCES FOR DROUGHT	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Subpart E: Other Natural Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
NOAA Drought Information Theme Site	http://www.noaawatch.gov/themes/droughts.php
NOAA US Drought Assessment	http://www.cpc.ncep.noaa.gov/products/expert_assessment/drought_assessment.shtml
Natural Hazards Center, University of Colorado Boulder	http://www.colorado.edu/hazards/
U.S. Drought Monitor	http://www.drought.unl.edu/dm/monitor.html
National Integrated Drought Information System	http://www.drought.gov
NOAA Drought Information Center	http://www.drought.noaa.gov/
NOAA State/Regional/National Moisture Status	http://www.ncdc.noaa.gov/sotc/drought/#regional-status
Wisconsin DNR Division of Water	http://dnr.wi.gov/environmentprotect/water.html
National Climatic Data Center Weather Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

3.10 EXTREME HEAT

3.10.1 Nature of the Hazard

Extreme summer heat is the combination of very high temperatures and exceptionally humid conditions. If such conditions persist for an extended period of time, it is called a heat wave. When possible, the National Weather Service (NWS) take precautions to warn people and agencies that extreme heat conditions are forecast:

- **Excessive Heat Outlook:** issued when conditions for an excessive heat event may occur in the next three to seven days; provides information to those who need to plan for heat (i.e. emergency management, public health officials, utility companies)
- **Excessive Heat Watch:** issued when conditions for an excessive heat event will occur in the next twelve to 48 hours
- **Excessive Heat Warning/Advisory:** issued when an excessive heat event is expected to happen (i.e. has a very high probability to occur) in the next 36 hours

NWS will issue an outlook, watch, or warning/advisory when the heat index (or how hot it really feels) is expected to exceed 105ºF to 110ºF for two consecutive days (NWS, 2011). At a heat index of 105ºF or higher, the heat is extreme enough to cause disorders associated with exposure to heat and/or physical activity.

Figure 3.10.1-1, below, shows the National Oceanic and Atmospheric Administration (NOAA) NWS Heat Index values. As indicated, the heat index is a function of the actual temperature and the relative humidity. The categories in light orange, dark orange, and red indicate when the heat index values are of concern, and precautions limiting sun exposure should be taken.

Temperature (ºF)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	126	130					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Streuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Figure 3.10.1-1 NOAA's NWS Heat Index Scale
Source: NOAA National Weather Service, 2011.

Table 3.10.1-1, below, shows the danger categories and heat disorders with their corresponding heat index values. Note that caution should be taken when the heat index value approaches 90°F.

TABLE 3.10.1-1 HEAT INDEX AND DISORDERS

Danger Category		Heat Disorder	Heat Index Value (°F) (How Hot It Feels)
IV	Extreme Danger	Heatstroke or sunstroke imminent.	>130°F
III	Danger	Sunstroke, heat cramps, or heat exhaustion likely; heat stroke possible with prolonged exposure and physical activity.	105°F -130°F
II	Extreme Caution	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and physical activity.	90°F -105°F
I	Caution	Fatigue possible with prolonged exposure and physical activity.	89°F - 90°F

Source: NOAA National Weather Service, 2008.

Extreme heat is of great concern since exposure causes serious life-threatening conditions for humans. The risk to humans is grave, as heat is the number-one weather killer nationwide, killing 162 people annually, according to ten-year average from 2000-2009 (NWS). There are different stages of heat disorders associated with exposure to heat:

- **Heatstroke:** an often fatal medical emergency occurring when the body's responses to heat stress are insufficient to prevent a substantial rise in the body's core temperature, typically exceeding 105°F; even with rapid cooling and treatment, the average fatality rate is 15%
- **Heat Exhaustion:** less serious medical condition characterized by dizziness, weakness, or fatigue; body temperatures may be normal or slightly to moderately elevated; with fluid treatment, prognosis is typically good
- **Heat Syncope:** a sudden loss of consciousness, typically associated with people exercising who are not acclimated to warm temperatures; causes little or no harm to the individual
- **Heat Cramps:** may occur in people unaccustomed to exercising in the heat

In addition to affecting people, severe heat places significant stress on plants and animals. Severe heat may reduce the yields of crops, or contribute to the loss of crops. Similarly, livestock may become overheated, leading to reduced milk production and other problems (Garcia, September 2002).

3.10.2 Wisconsin Extreme Heat Event History

Wisconsin has had several notable extreme heat events since the last century; the first major one was the Dust Bowl. Lasting primarily from 1934 to 1936, the US was struck with extremely hot, dry conditions that exacerbated the already difficult economic times. July, 1936 saw some of the hottest temperatures on record for Wisconsin and the nation.

Many of those records still stand. Over 5,000 deaths nationwide were attributed to this heat wave (NWS).

Many of Wisconsin's all-time maximum daily temperatures were recorded during the Dust Bowl. On July 13, 1936, the highest temperature ever recorded in Wisconsin, 114°F, occurred in the Wisconsin Dells (Central Wisconsin). Table 3.10.2-1, at right, lists some of the Wisconsin locations that set all-time records for high temperatures during the Dust Bowl.

TABLE 3.10.2-1 WISCONSIN ALL-TIME HIGH TEMPERATURES SET DURING THE DUST BOWL

Municipality	Temperature	Date
Wisconsin Dells	114°F	July 13, 1936
Mondovi	110°F	July 14, 1936
Richland Center	110°F	July 14, 1936
Hatfield	108°F	July 14, 1936
La Crosse	108°F	July 14, 1936
Lancaster	108°F	July 14, 1936
Viroqua	108°F	July 13, 1936
Appleton	107°F	July 14, 1936
Madison	107°F	July 14, 1936
Oshkosh	107°F	July 13, 1936
Mather	106°F	July 14, 1936
Milwaukee	105°F	July 24, 1934
Green Bay	104°F	July 13, 1936
Medford	104°F	July 13, 1936

Source: NOAA National Weather Service, 2008.

After the Dust Bowl, the way that meteorologists record excessive heat events changed significantly. It was not until 1979 that the NWS adopted the Heat Index Scale, forever changing the way that heat waves were documented.

The most significant heat event in Wisconsin did not occur until 1995, when the state experienced two major heat waves: one in June, one in July. Between the two heat waves, 1,021 people died nationwide.

During the first of the 1995 heat waves, June 17-27, high temperatures were into the mid to upper 90s with heat index values of 98 to 104 degrees. Nine people in Wisconsin died directly from the heat.

During the second of the 1995 heat waves, July 12-15, Wisconsin witnessed the greatest number of weather-related deaths in state history, when 141 people died directly or indirectly from the heat. 85 of them were in Milwaukee alone (NWS). High temperatures were 100°F to 108°F with heat index values between 120°F and 130°F.

The relative humidity during the July heat wave produced heat index values of 120°F to 130°F, which are rarely reached. These high heat index values were the main contributing factor in the large number of fatalities in Wisconsin. In urban areas, such as Milwaukee County, heat index values were higher, due to the concentration of buildings, concrete, and asphalt. This phenomenon is known as the "urban heat island effect." The urban heat island effect intensified the effects of the heat. Figures 3.10.2-1 and 3.10.2-2, on the following page, depict the temperature, dew point, and heat index trend-lines for Milwaukee General Mitchell Field on July 13-14, 1995. Note that the high heat index values barely fell below 100°F overnight on July 13th.

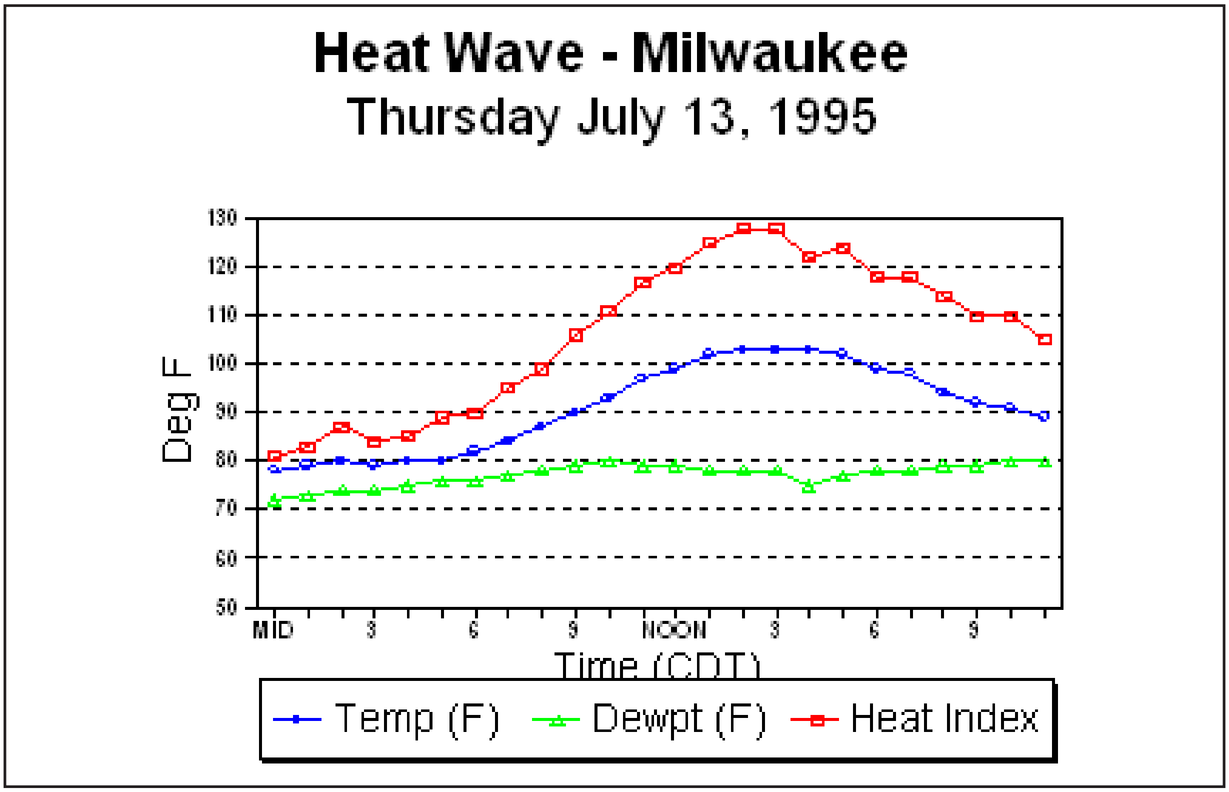


Figure 3.10.2-1 Meteorological Parameters at Milwaukee's Mitchell Field, July 13, 1995
Source: NOAA National Weather Service WFO, 2008.

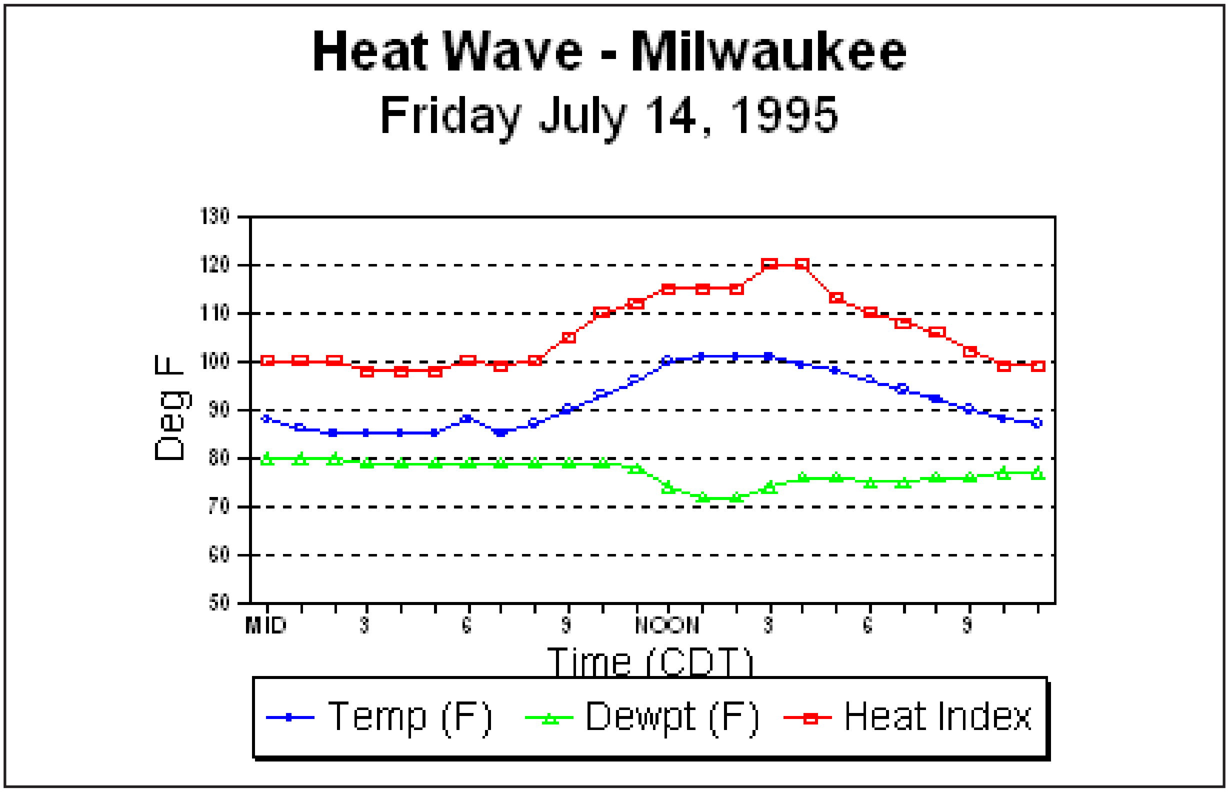


Figure 3.10.2-2 Meteorological Parameters at Milwaukee's Mitchell Field, July 13, 1995
Source: NOAA National Weather Service WFO, 2008.

Another heat wave struck Wisconsin during the last two weeks of July 1999 and peaked July 28-31. During those four days, high humidity and temperatures in the 90s and 100s produced heat index values of 110°F to 125°F. The heat wave resulted in twelve direct and eight indirect deaths (NWS). There was a record peak demand for electric power in the Milwaukee-area during this time, mirroring the record set during the same time period in the Midwest as a region.

Several heat waves from mid-July to early August 2001 claimed 15 lives (10 direct fatalities, five indirect) across Wisconsin. At least 300 people were treated at hospitals for heat exhaustion as temperatures topped out in the mid to upper 90s. However, on August 7, the temperature rose to 102°F at Mount Mary College (Milwaukee County), and 101°F in Buffalo and Trempealeau Counties.

In 2011, Wisconsin experienced its most widespread and probably most oppressive heat wave since July 1995. During the 4.5 day stretch of July 17-21, maximum heat indices peaked in the 105 to 115 range over much of the state. Air temperatures reached 95 to 100 while overnight minimum temperatures remained mostly in the 72 to 82 range. Three heat related fatalities occurred during this heat wave (NWS).

Figures 3.10.2-3 and 3.10.2-4, on the following pages, highlight heat wave events in Wisconsin from 1982 to 2010. Figure 3.10.2-3 shows the heat wave days per county, indicating the number of calendar days on which a heat advisory or excessive heat warning was observed. Southeastern Wisconsin has had a higher concentration of heat wave days, with Milwaukee, Kenosha, and Walworth Counties all experiencing 61 days total, with a 2.1 day annual average.

Figure 3.10.2-4 displays the number of heat wave events per county. This map, along with Figure 3.10.2-3, indicates that individual heat events have a tendency to last for multiple days at a time. In southeastern Wisconsin, where there are the most heat wave days and heat wave events, an event will last between 3.5 and 3.8 days, on average. Pepin and Crawford counties have also seen a higher number of heat wave events than the surrounding counties, with fifteen events each.

Extreme heat is the number-one weather killer in Wisconsin. Statewide there were 116 directly-related deaths from 1982-2010, and an additional 95 indirectly-related fatalities. This averages out to 4.1 directly-related fatalities and 3.4 indirectly-related fatalities per year (NWS). Most of the fatalities in Wisconsin occurred during the two major heat waves in June and July, 1995.

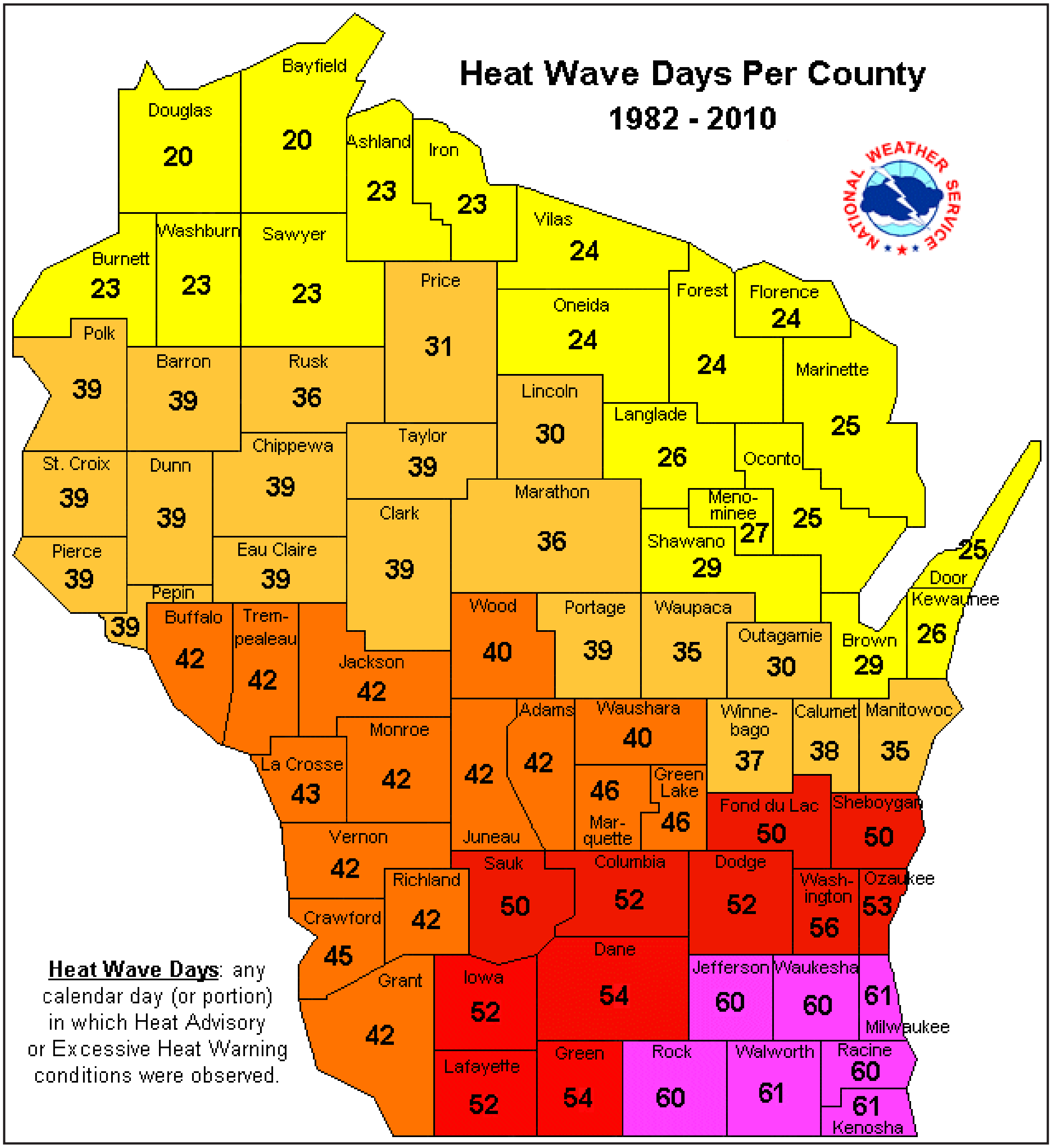


Figure 3.10.2-3 Heat Wave Days per Wisconsin County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

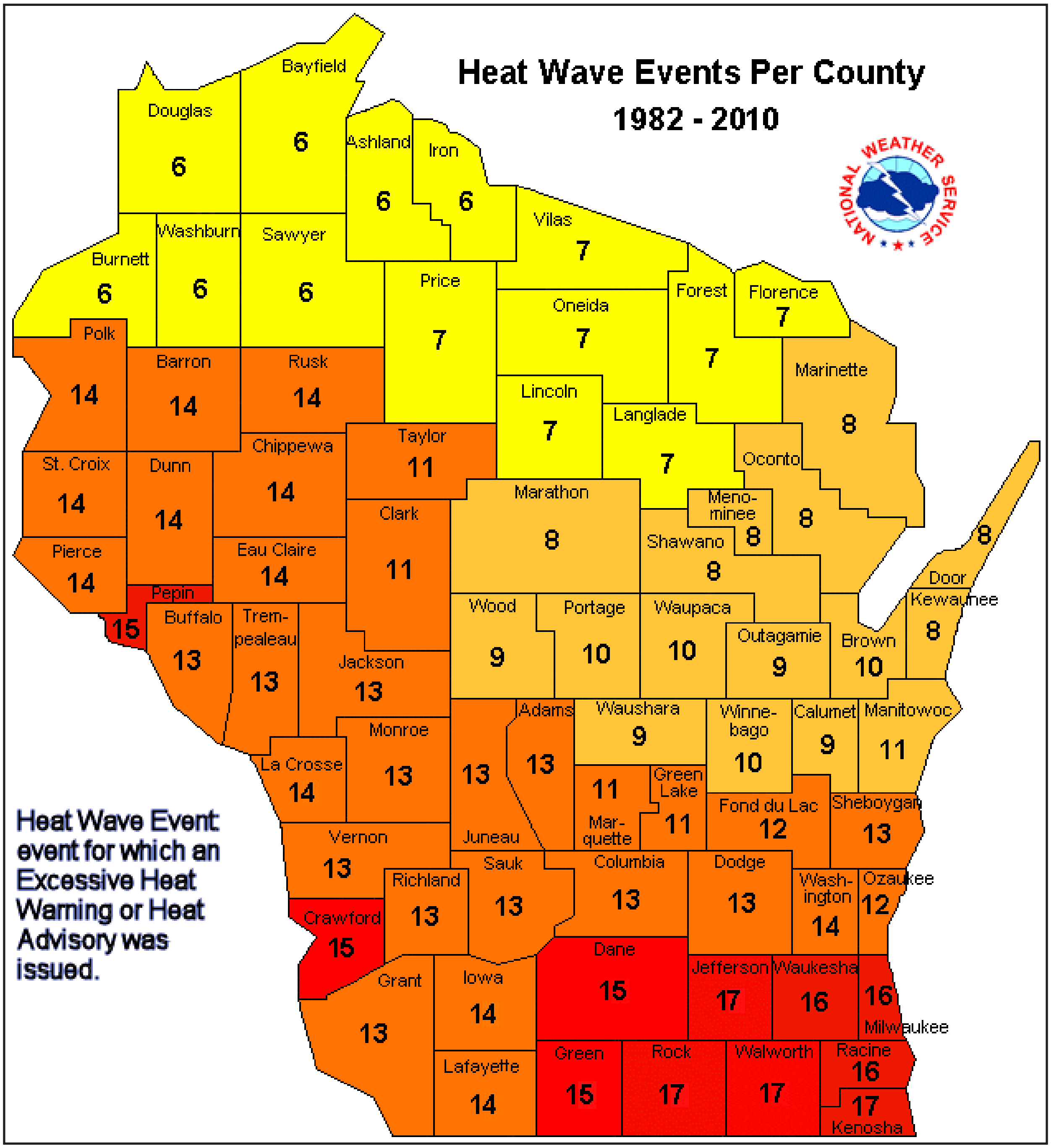


Figure 3.10.2-4 Heat Wave Events per Wisconsin County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Table 3.10.2-2, below, summarizes heat-related deaths in Wisconsin from 1986 to 2010. A death is considered to be "direct" if the medical examiner ruled that heat was the primary cause of death. If heat was a contributing factor (not main cause) of death, the examiner ruled that death to be "indirect." 1995 had the highest death count, as a result of the 1995 heat waves.

TABLE 3.10.2-2 HEAT-RELATED DEATHS IN WISCONSIN

Year	Direct Deaths	Indirect Deaths
1986	1	0
1987	0	0
1988	1	0
1989	0	0
1990	0	0
1991	0	0
1992	0	0
1993	2	0
1994	0	0
1995	82	72
1996	0	0
1997	1	0
1998	0	0
1999	13	8
2000	0	0
2001	10	5
2002	3	5
2003	0	4
2004	0	0
2005	0	0
2006	3	1
2007	0	0
2008	0	0
2009	0	0
2010	0	0
Totals	**116**	**95**

Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Figure 3.10.2-5, below, shows the number of direct heat wave deaths per county from 1982 to 2010. Only 25 Wisconsin counties have experienced at least one direct heat-related death; of these counties, very few have had more than one or two heat-related deaths. Specifically, with 50, Milwaukee County alone has had more direct deaths than any other county. The next highest counties are Sheboygan, Manitowoc, Racine, and Fond du Lac, with eight, seven, seven, and six direct heat deaths, respectively.

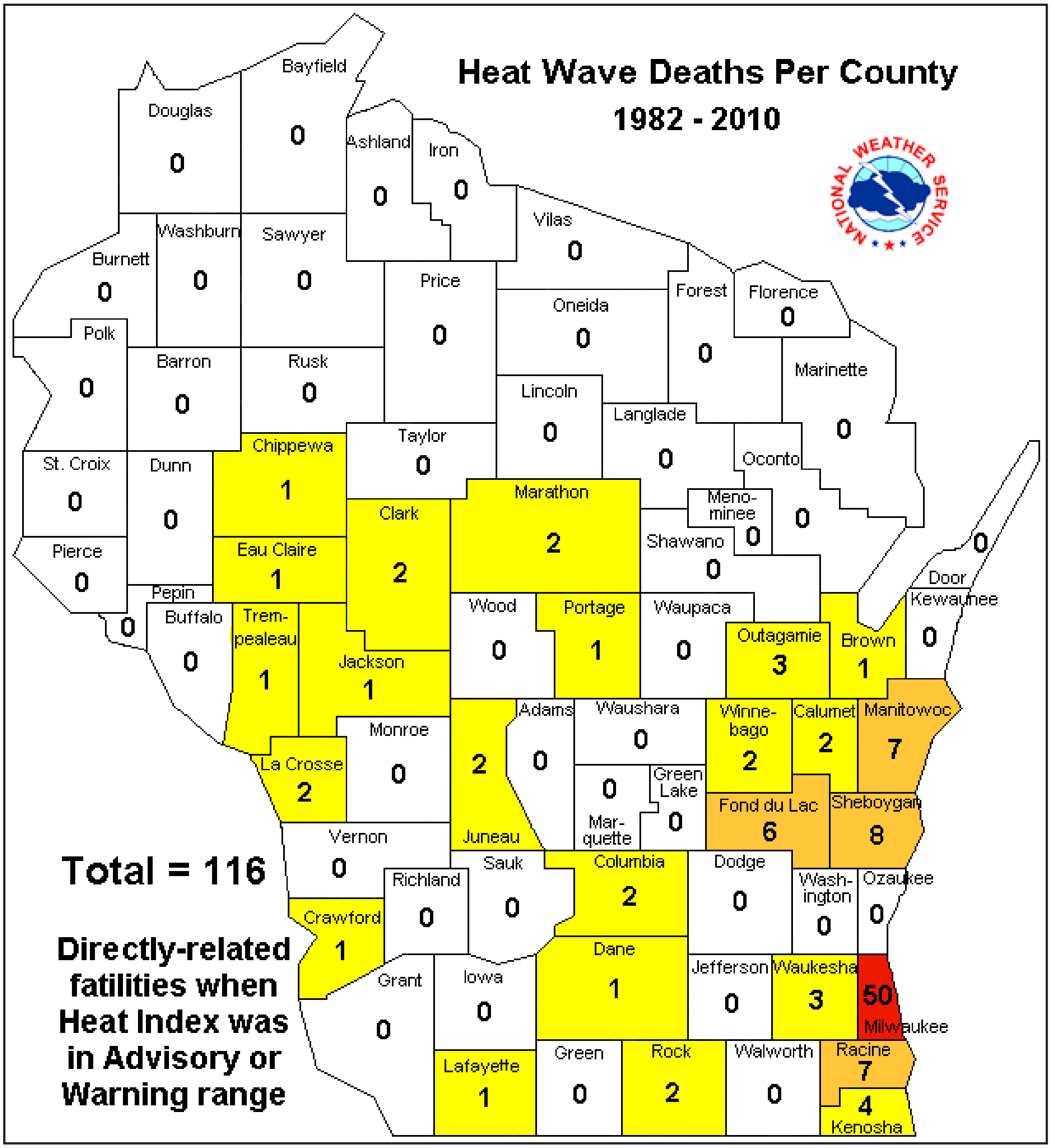


Figure 3.10.2-5 Heat Wave Deaths per Wisconsin County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.10.3 Probability of Occurrence

The probability of exceeding 89°F is high (danger category I in Table 3.10.1-1), but temperatures are not the only determinant of effects that also include humidity, duration, and timing of the extreme temperature event.

3.10.4 Hazard Ranking

TABLE 3.10.4-1 HAZARD RANKING FOR EXTREME HEAT

Evaluation Criteria	Description	Ranking
Probability	• The hazard has impacted the state annually, or more frequently • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The state or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor	Low

3.10.5 Sources for Extreme Heat

TABLE 3.10.5-1 SOURCES FOR EXTREME HEAT

Source Title	Link to Resource
FEMA's Multi-Hazard Identification and Risk Assessment, "Part 1: Atmospheric Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
Occupational Safety and Health Administration (OSHA)'s Campaign to Prevent Heat Illness in Outdoor Workers	http://www.osha.gov/SLTC/heatillness/index.html
Environmental Protection Agency (EPA's) *Excessive Heat Events Guidebook*	http://www.epa.gov/heatisland/about/heatguidebook.html
NWS Heat Information Site	http://www.nws.noaa.gov/om/heat/index.shtml
NOAA Heat Wave Information site	http://www.noaawatch.gov/themes/heat.php
NWS Weather Forecast Office, Milwaukee/Sullivan, WI	http://www.crh.noaa.gov/mkx/
NWS Weather Forecast Office, Green Bay, WI	http://www.crh.noaa.gov/grb/
NWS Weather Forecast Office, La Crosse, WI	http://www.crh.noaa.gov/arx/
NWS Office of Climate, Water, and Weather Services Natural Hazard Statistics	http://www.nws.noaa.gov/om/hazstats.shtml

TABLE 3.10.5-1 CONTINUED	
Source Title	**Link to Resource**
National Climatic Data Center Weather Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
NOAA's Natural Disaster Survey Report on July 1995 Heat Wave	http://www.nws.noaa.gov/om/assessments/pdfs/heat95.pdf
"Dealing with Heat Stress in Dairy Cows" by Alvaro Garcia, South Dakota State University	http://pubstorage.sdstate.edu/AgBio_Publications/articles/ExEx4024.pdf

3.11 SEVERE WINTER WEATHER

3.11.1 Nature of the Hazard

Winter storms vary in size and strength and include heavy snowstorms, blizzards, freezing rain, sleet, ice storms, and considerable blowing and drifting snow conditions that can close roads. Additionally, another dangerous winter weather situation is the combination of extremely cold temperatures and strong winds that can result in wind chills that cause bodily injury such as frostbite and death due to exposure (hypothermia). Severe winter and ice storms can cause unusually heavy rain or snowfall, high winds, extreme cold, and ice storms throughout the continental US.

Winter storm occurrences tend to be very disruptive to transportation and commerce. Trees, cars, roads, and other surfaces develop a coating or glaze of ice, making conditions extremely hazardous to motorists and pedestrians. The most prevalent impacts of heavy accumulations of ice and snow are slippery roads and walkways that lead to vehicle and pedestrian accidents; collapsed roofs from fallen trees and limbs and heavy ice and snow loads; and felled trees, telephone poles and lines, electrical wires, and communication towers. As a result of severe winter storms, telecommunications and power can be disrupted for days. Such storms can also cause exceptionally high rainfall that persists for days, resulting in heavy flooding due to snow melt.

A variety of weather phenomena and conditions can occur during winter storms. The following are National Weather Service (NWS) approved descriptions of winter storm elements:

- **Heavy snowfall:** accumulation of six or more inches of snow in a twelve-hour period or eight or more inches in a 24-hour period
- **Blizzard:** sustained wind speeds or frequent wind gusts of at least 35 mph accompanied by heavy snowfall or large amounts of blowing or drifting snow
- **Ice storm:** rain freezing upon contact with the ground and/or exposed objects near the ground; at least ¼ inch of ice must accumulate within twelve hours
- **Freezing drizzle/freezing rain:** drizzle or rain freezes upon impact on objects with a temperature of 32ºF or below
- **Sleet:** solid grains or pellets of ice formed by the freezing of raindrops or the re-freezing of largely melted snowflakes; does not cling to surfaces
- **Wind chill:** an apparent temperature describing the combined effect of wind and low air temperatures on exposed skin; measurement is based on the rate of heat loss from exposed skin caused by wind and cold

  If the temperature is 0ºF, with a 15 mph wind, the wind chill is -19ºF. At this wind chill temperature, exposed skin can freeze in 30 minutes, as shown in Figure 3.11.1-1, below. In general, the NWS regional offices will issue Wind Chill Advisories when wind chill values are expected to drop to -20 to -34ºF with winds 10 mph or higher.

Similarly, Wind Chill Warnings are issued in Wisconsin for wind chill values of -35ºF or lower along with winds 10 mph or higher.

If one knows the air temperature (T) in degrees Fahrenheit and the wind speed (V) in miles per hour, wind chill (WC) in degrees Fahrenheit can be calculated using the following formula:

WC = 35.74 + 0.6215(T) – 35.75(V 0.16) + 0.4275(T)(V 0.16)

Temperature (ºF)

Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

Wind Chill (ºF) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$

Where, T= Air Temperature (ºF) V= Wind Speed (mph)

Effective 11/01/01

Figure 3.11.1-1 NWS Windchill Chart
Source: NOAA National Weather Service, http://www.nws.noaa.gov/om/windchill/index.shtml.

3.11.2 Wisconsin Severe Winter Weather Event History

Generally, the winter storm season in Wisconsin runs from October through March. Severe winter weather has occurred, however, as early as September and as late as the latter half of April and into May in some locations.

Despite the fact that Wisconsin's harsh winter temperatures have become slightly milder over the past couple of decades, the number of severe winter storms shows an increasing trend. This may be partially related to better documentation generated by the NWS, but may also be related to the fact that warmer air can hold more moisture which ultimately can fall as snow. Figure 3.11.2-1, on the following page, shows the number of severe winter weather events that affected at least one Wisconsin county for the winter seasons of 1974-75 through 2009-10. The thick red line depicts the five-year running average, which aside from the winters of 2004-2005 and 2005-2006, has been higher than in years past.

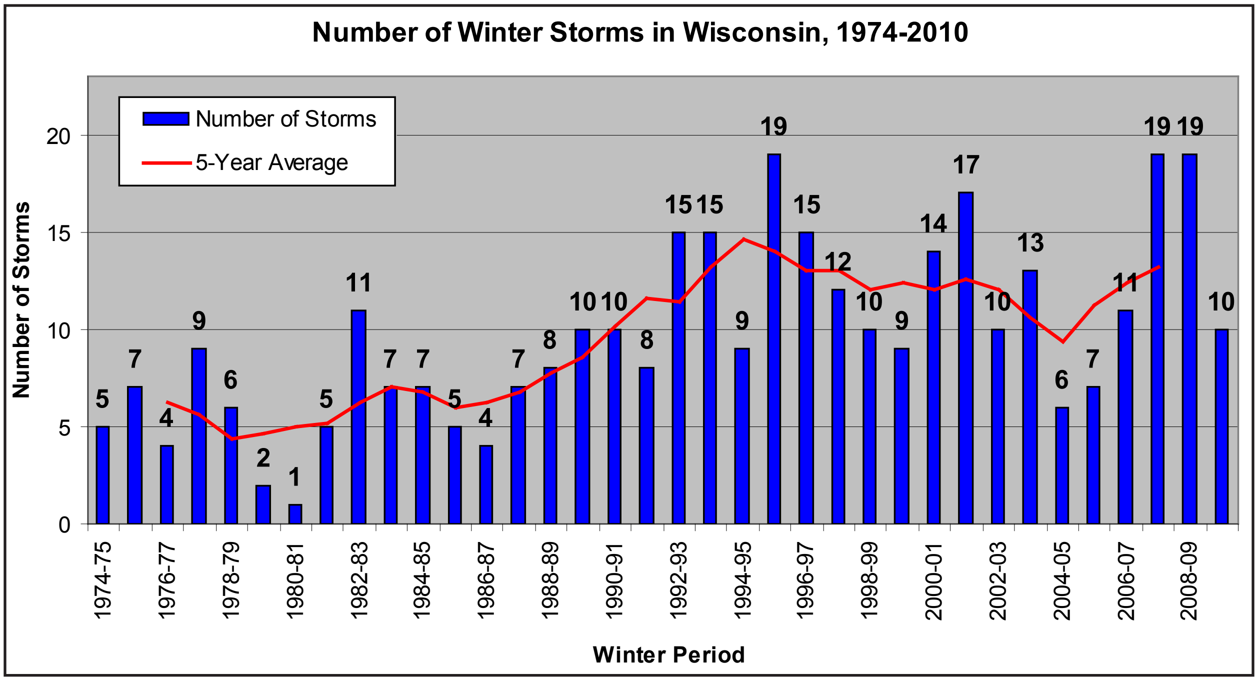


Figure 3.11.2-1 Number of Wisconsin Winter Storms per Winter, 1974-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Much of the snowfall in Wisconsin occurs in small amounts of one to three inches per occurrence. Heavy snowfalls that produce at least six inches of accumulation in one county happen on the average about 10 to 12 times per winter. The northwestern and north-central portions of Wisconsin can experience early and late season storms, while any part of Wisconsin can receive heavy mid-winter snows.

Snowfall in Wisconsin varies between the seasonal average of approximately 30 inches in the extreme south-central area of the state to 120 to 160 inches in the Lake Superior snowbelt in Ashland and Iron Counties. Annual snowfall distribution across Wisconsin is shown in Figure 3.11.2-2 on the following page. Though this data represents the years 1971 through 2000, it is the most up-to-date available. The NWS is in the process of updating its graphics and new graphics will be incorporated in the 2014 Plan Update.

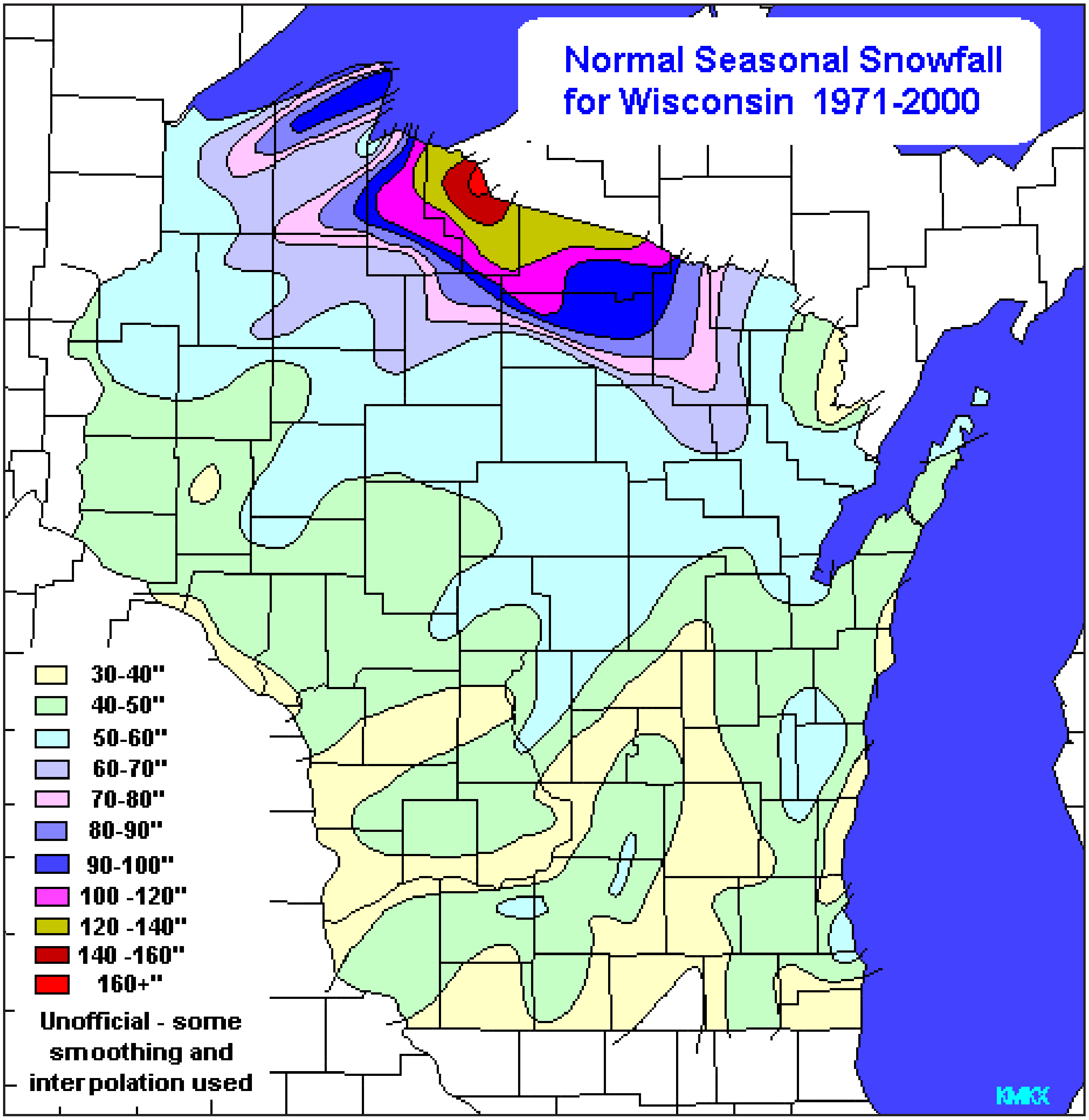


Figure 3.11.2-2 Annual Mean Snowfall Across Wisconsin, 1971-2000
Source: NOAA National Weather Service: http://www.weather.gov/mkx.

In Figure 3.11.2-3, on the following page, a count of Wisconsin blizzard events by county is shown for the winters from 1982-83 through 2009-10. Though the northern part of the state receives higher precipitation, more high-wind accumulations and drifting events occur in the southern half of the state, on average. Counties closer to Lake Michigan have had a higher number of blizzard events, due in part to the strong winds off of the lake, with Manitowoc, Calumet, Door, and Milwaukee counties all having five blizzards each. The map also indicates that there were no direct deaths or injuries during this time period, although it should be noted that vehicular accident fatalities and injuries are not included in this dataset.

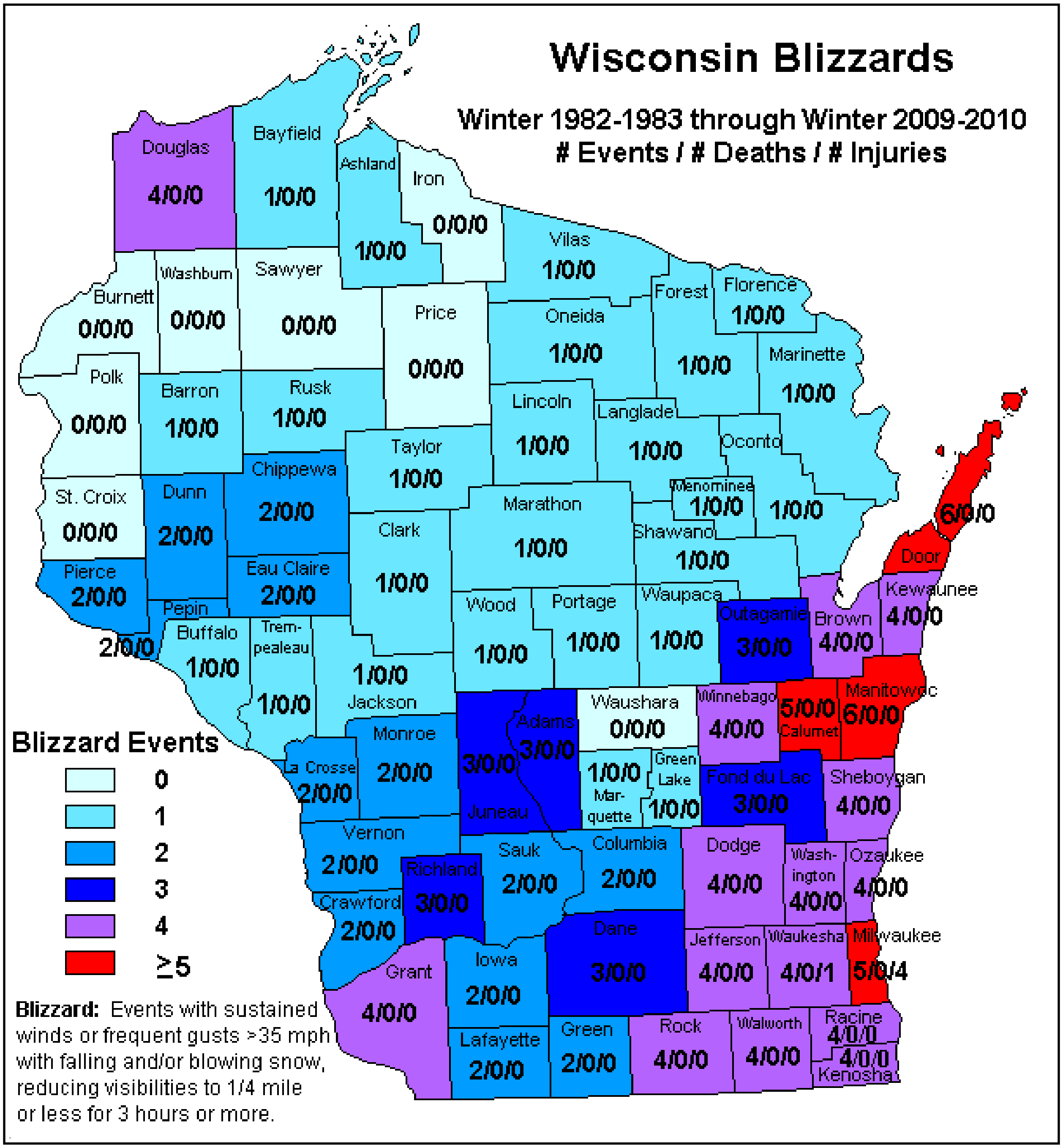


Figure 3.11.2-3 Wisconsin Blizzard Events per County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Ice and sleet storms can occur anytime throughout the winter season from October through April. Early and late season ice and sleet storms are generally restricted to northern Wisconsin, such as the November 7-8, 1943 and April 16-17, 1939 storms. Otherwise, the majority of these storms occur from west-central through northeast Wisconsin. On average, a major ice storm occurs on a frequency of about once every other year. If ½-inch of rain freezes on trees and utility wires, extensive damage can occur, especially if accompanied by high winds that compound the detrimental effects of the weight of the ice. In addition, between three and five instances of glazing (less than ¼-inch of ice) occur throughout Wisconsin during a normal winter. A county distribution of ice storms for the winters 1982-83 through 2009-10 is shown below in Figure 3.11.2-4.

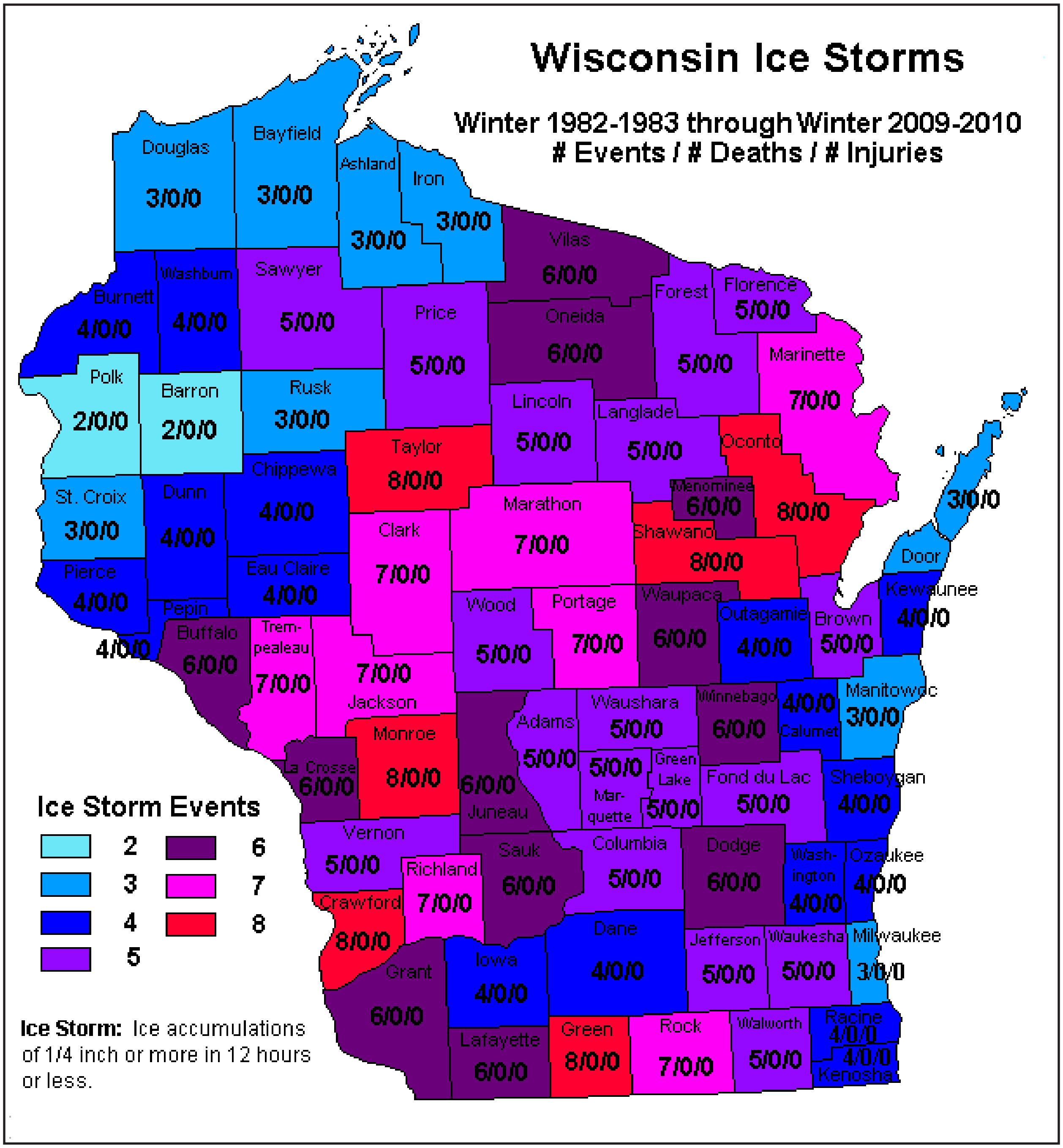


Figure 3.11.2-4 Wisconsin Ice Storm Events per County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Combining winter storms, blizzards, and ice storms together on a county-by-county basis leads to a final distribution shown in Figure 3.11.2-5, on the following page. This map reveals which counties have been affected by some kind of severe winter weather event for the period of 1982 through 2010. The northern counties of Wisconsin are most likely to experience major winter systems. Iron County has experienced the most winter weather events in this time period, with 170 total, followed by Ashland with 159. Pepin County is the only county in Wisconsin with fewer than 70 winter weather events. There exists a fairly easy to see stratification of winter weather event occurrences, with color-groupings clustered together.

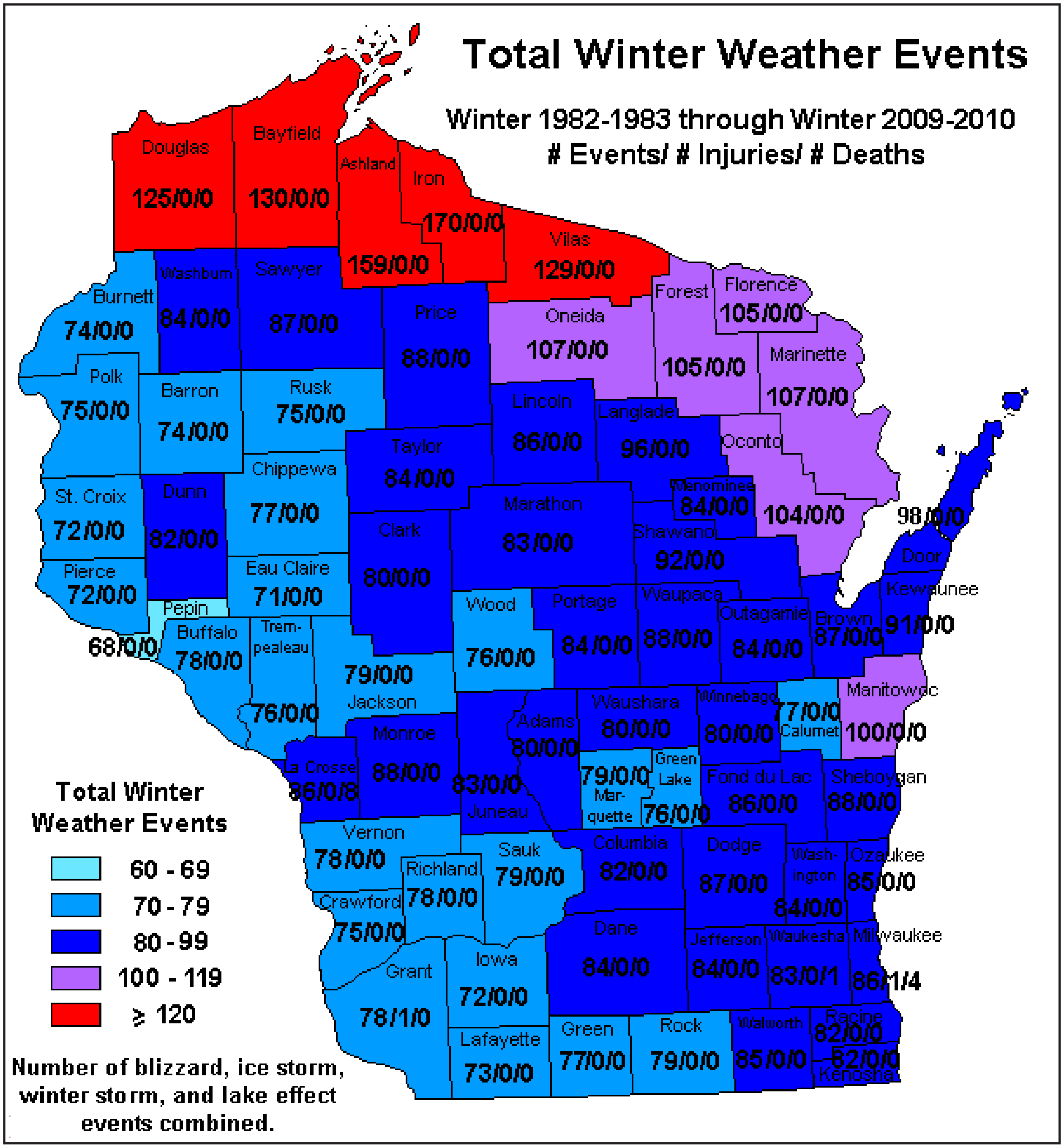


Figure 3.11.2-5 Wisconsin Winter Weather Events per County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

Figure 3.11.2-6, on the following page, indicates the annual average number of severe winter weather events per winter for each county. This was calculated taking the total number of events and dividing by the number of winter seasons. This map helps to reveal the "banding" of number of storm events, with a higher concentration in the northern counties of Douglas, Bayfield, Ashland, Iron, and Vilas.

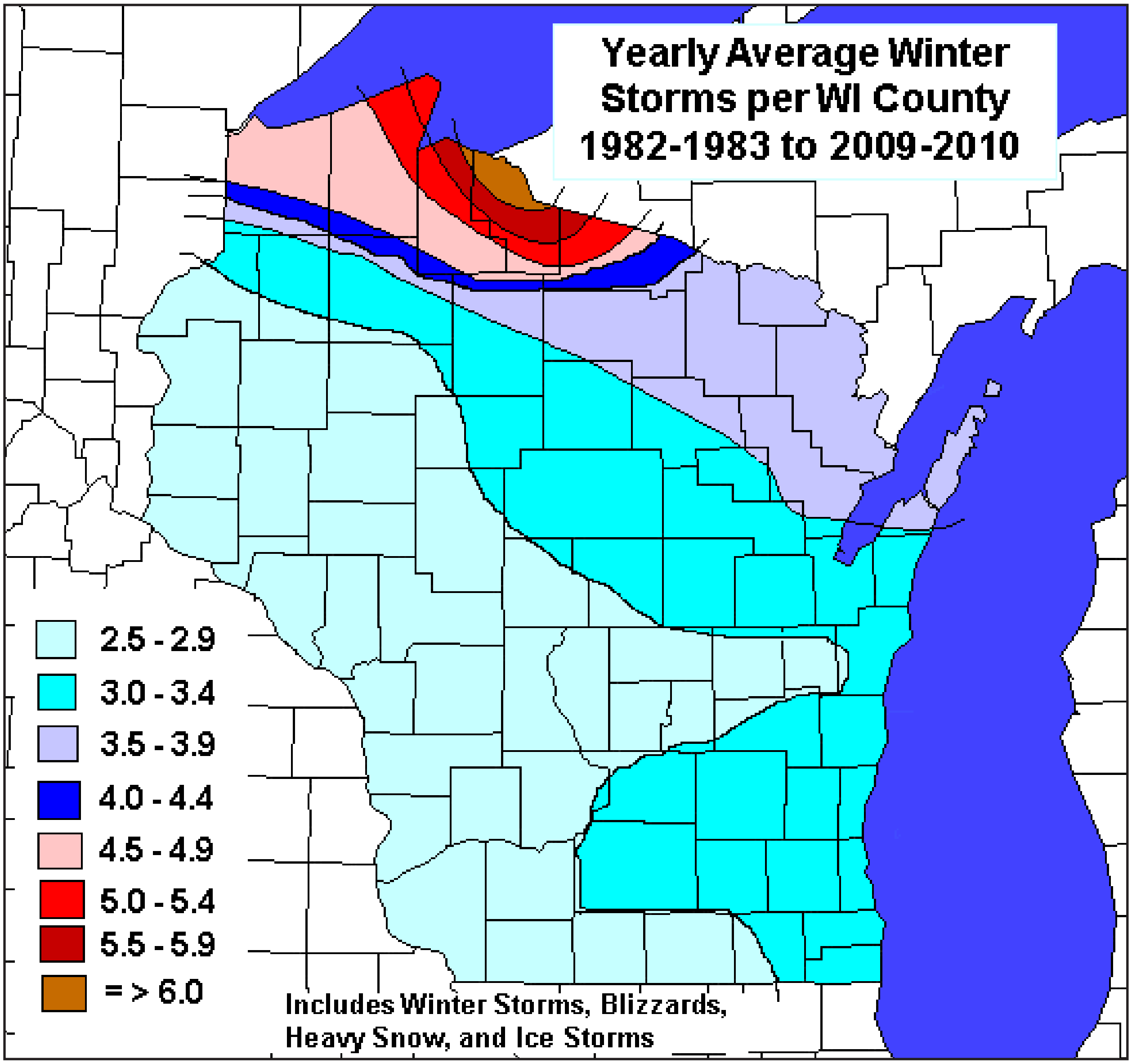


Figure 3.11.2-6 Annual Average Number of Severe Winter Weather Events per County, 1982-2010
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

There have been many noteworthy winter events occurring in Wisconsin in recent years.

1976

In March 1976, an ice storm of disastrous proportions occurred in southern Wisconsin. This storm was of such magnitude and caused so significant an amount of damage that a Presidential Disaster Declaration was obtained. The storm affected 22 counties, resulted in extensive power outages, and caused more than $50 million in damage.

1979

Near blizzard conditions also existed in January 1979 when record snowfalls were recorded in many areas of Wisconsin and winds gusted to over 30 mph. Many people were isolated from assistance and services as roads drifted shut and highway crews were unable to keep them open. Conditions were extremely hazardous in the City of Milwaukee and Racine County where a Presidential Emergency Declaration was obtained to assist in snow removal operations.

1981-82

Blizzard-like conditions also occurred during the winter of 1981-82 when extremely cold temperatures were accompanied by wind speeds gusting to 50 mph. Wind chill factors reached -100ºF and severely affected the health and safety of those who ventured outdoors.

1990

A statewide blizzard occurred December 2-4, 1990, depositing over ten inches of snow across the central and southern portions of Wisconsin. Snowfalls of 22 inches were recorded in Juneau and Adams Counties, 20 inches in Marquette County, 19 inches in Dodge and Washington counties, and 17-18 inches in Columbia and Dane Counties. This excessive snowfall throughout such a large area severely taxed the state's capability to clear and remove snow.

1991

A storm lasting from October 31 to November 2, 1991 left large amounts of snow in northwest Wisconsin, with 35 inches in areas of Douglas County and more than 30 inches of snow in Bayfield, Polk, St. Croix, and Pierce counties. In late November 1991, a snowstorm struck northwestern Wisconsin and left accumulations of 18 to 20 inches in Sawyer County and over 10 inches of snow in Bayfield, Douglas, Burnett, Polk, St. Croix, Barron, Washburn, Ashland, and Iron counties. A heavy snowstorm the previous week dumped 10 or more inches of snow in a diagonal band from Vernon, La Crosse, and Buffalo Counties in the south to Iron, Vilas, and Forest counties in the north.

1994

During another storm in February 1994, 15 or more inches of snow were deposited in areas of Vernon, Juneau, Dane, Dodge, and Columbia Counties.

1996-97

The record for seasonal snowfall belongs to Hurley, Wisconsin (Iron County). Over an eight month period in the winter of 1996-97, a total of 301.8 inches, or 25.2 feet, of snow fell. As that winter progressed, it became difficult to clear the streets because there was no place to put the snow.

1998-99

The winter of 1998-99 was quite mild as far as temperatures were concerned; however, a heavy snowfall and blizzard occurred January 1-3, 1999. Over ten inches fell in most southern counties with parts of Kenosha, Milwaukee, Ozaukee, Walworth, Washington, and Waukesha counties affected. Snow drifts of four to eight feet were reported in southeastern Wisconsin with northeast wind gusts from 45 to 63 mph. This winter storm/blizzard severely tasked snow plow crews and many roads were closed for a day or more.

2000

December 2000, in contrast, was one of the ten coldest Decembers on record throughout most of the state. In addition to low temperatures, record or near-record snow depths of 15 to 34 inches occurred in much of the southern part of Wisconsin during December. 14 counties (Columbia, Dane, Door, Green, Kenosha, Kewaunee, Manitowoc, Milwaukee, Ozaukee, Racine, Rock, Sheboygan, Walworth, and Waukesha) received a Presidential Emergency Declaration (EM-3163) as a result of record snowfalls. In total, these counties received $5,483,097 in federal funds to cover costs associated with snow removal and emergency response efforts.

2001

The first significant winter event of 2001 was an ice storm that left a ¼ inch of ice over large portions of Oneida and Forest counties. In addition, several heavy snowfalls were recorded in northern Wisconsin. The first heavy snow of the year occurred February 24-25, covering Douglas County with 20 inches of snow. A November 26-28 storm left 12 to 20 inches in a band from Burnett to Vilas County. A series of lake-effect snowfalls from Lake Superior left accumulations of one to four feet from Douglas to Vilas County.

2003

In February 2003, two waves of snow pushed through the northern part of Wisconsin when a low-pressure system passed through the region. Totals reached up to 16.5 inches at Presque Isle (Vilas County) and 12 inches at Phelps (Vilas County). Reports of 12 to 20 inches were received to the northeast of Park Falls (Price County). In the southeast portion of the state, light freezing rain and drizzle glazed roadways and caused multiple accidents. Ice thickness reached up to nearly four inches near La Valle (Sauk County).

2004-05

A major winter storm with lake-effect enhancement during the period of December 11-13, 2004, buried Iron County with up to 26 inches of snow. Yet another major winter storm on

March 18-19, 2005, plastered west-central Wisconsin with 14 to 16 inches and 18 to 23 inches in parts of Buffalo and Jackson counties.

2006

A powerful two-day winter storm on March 13-14, 2006, buried northwestern Wisconsin under 17 to 24 inches of snow from St. Croix County up to Iron County. Gile (Iron County) measured 32 inches in this storm.

2007

Three rounds of winter storms with heavy snow and blowing snow affected much of Wisconsin during the period of February 23-26, 2007. The first two rounds each left from six to 15 inches, while the third round affected mostly northeastern Wisconsin with six to 14 inches. Collectively the three rounds of snow severely taxed snowplow crews.

2007-08

The 2007-08 winter season was "one-for-the ages." Numerous winter storms, including a couple of blizzards and four ice storms, pounded the southern half of the state. Winter snowfall totals of 70 to 122 inches across the southern counties established new all-time winter snowfall records at many locations. These totals were roughly 200 to 240% of normal, and many communities simply ran out of salt, or were unable to purchase additional supplies to meet increased demand.

The worst storm of the winter occurred on February 5-6, 2008 southeast of a line from Dubuque, Iowa to Madison (Dane County) to Sheboygan (Sheboygan County). 12 to 21 inches of snow combined with northeast winds of 20 to 30 mph and some gusts to 50 mph to create near-blizzard conditions. Major vehicle backups occurred in both southbound and northbound lanes on Interstate 39/90 in Dane and Rock Counties after several trucks could not make it up hills during intense snowfall rates of one to two inches per hour at the height of the storm. At least 1,548 vehicles and trucks were stranded for ten to 20 hours thanks to snowfalls of up to 21 inches in that area. Orfordville (Rock County) measured the maximum amount of 21 inches. Up to 20 inches fell in the Saukville (Ozaukee County) and Jackson (Washington County) areas. Several other major roads in southeast Wisconsin were closed by the intense snowfalls and blowing snow. As a result of this storm, eleven counties (Dane, Dodge, Green, Jefferson, Kenosha, Milwaukee, Racine, Rock, Walworth, and Waukesha) received federal funds to help with costs of maintaining safe roads and providing emergency response in Presidential Emergency Declaration (EM-3285).

The 2007-08 winter season snowfall totals through the end of March, 2008, across southern Wisconsin are shown in Figure 3.11.2-7, on the following page. Though additional snowfalls of up to 1.5 inches occurred in April 2008 in some locations, the map captures practically the entire total snowfall for winter 2007-08.

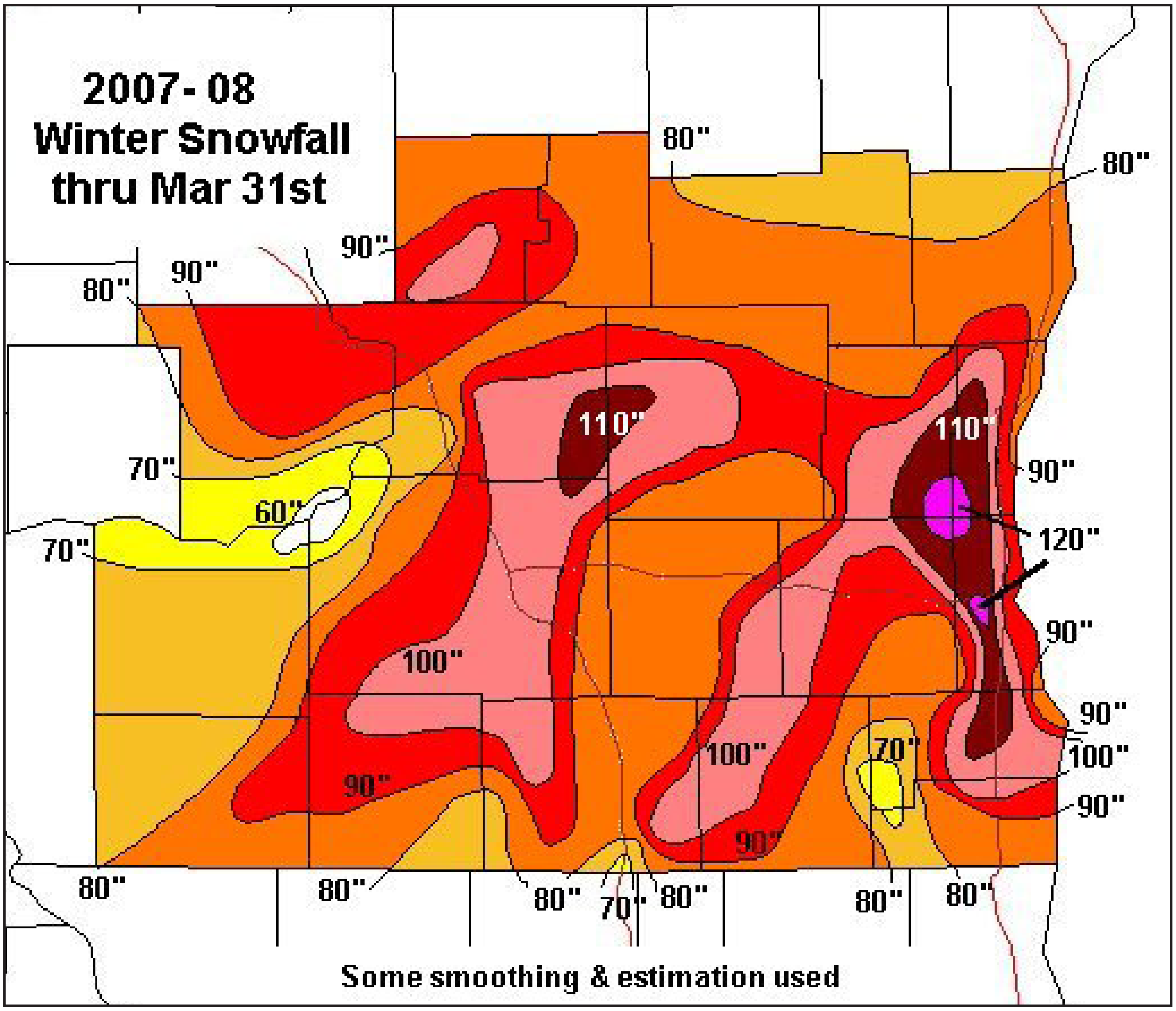


Figure 3.11.2-7 2007-08 Winter Snowfall Accumulations through March 31st
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

By the end of May, 2008, the total 2007-08 winter season snowfall reached 122.1 inches in West Allis (Milwaukee County), which was the highest value in southeastern Wisconsin, and a new all-time winter season record for West Allis. Likewise, the 101.4 inches measured at Truax Field in Madison smashed the old winter record of 76.1 inches set during winter 1978-79. The winter snowfall at Milwaukee Mitchell Field of 99.1 inches was the second highest winter total on record.

2011

On February 1-2, 2011, southern Wisconsin was hit with the Groundhog Day Blizzard when a powerful low pressure center passed south of the state. Figure 3.11.2-8, on the following page, displays the total snowfall for the event. In Milwaukee, 19.8 inches snow fell from the mid-afternoon on Tuesday night through Wednesday morning, the fourth highest amount for any 24-hour period on record. Other areas, such as West Bend

(Washington County), saw over 22 inches of snow. Adding to the dangerous conditions were the blizzard-condition sustained winds of between 40 and 50 mph in many areas, with peak gusts of up to 55 mph in some locations. These winds caused snow drifts of three to eight feet in most areas, with report of drifts reaching 12 to 15 feet in many rural areas throughout southern Wisconsin. Wisconsin Emergency Management issued a Civil Danger Warning, urging motorists to stay off roads to avoid dangerous driving conditions. I-43 was closed from Beloit (Rock County) to Mukwonago (Waukesha County), along with portions of I-90. 100 National Guardspeople were mobilized throughout the state to rescue motorists stranded along roadways and to run emergency shelters. The severe winter storm caused the declaration of a Federal Major Disaster (DR-1966), allowing eleven counties (Dane, Dodge, Grant, Green, Iowa, Kenosha, Lafayette, Milwaukee, Racine, Walworth, and Washington) to use Public Assistance funds for emergency work and the repair or replacement of disaster-damaged facilities.

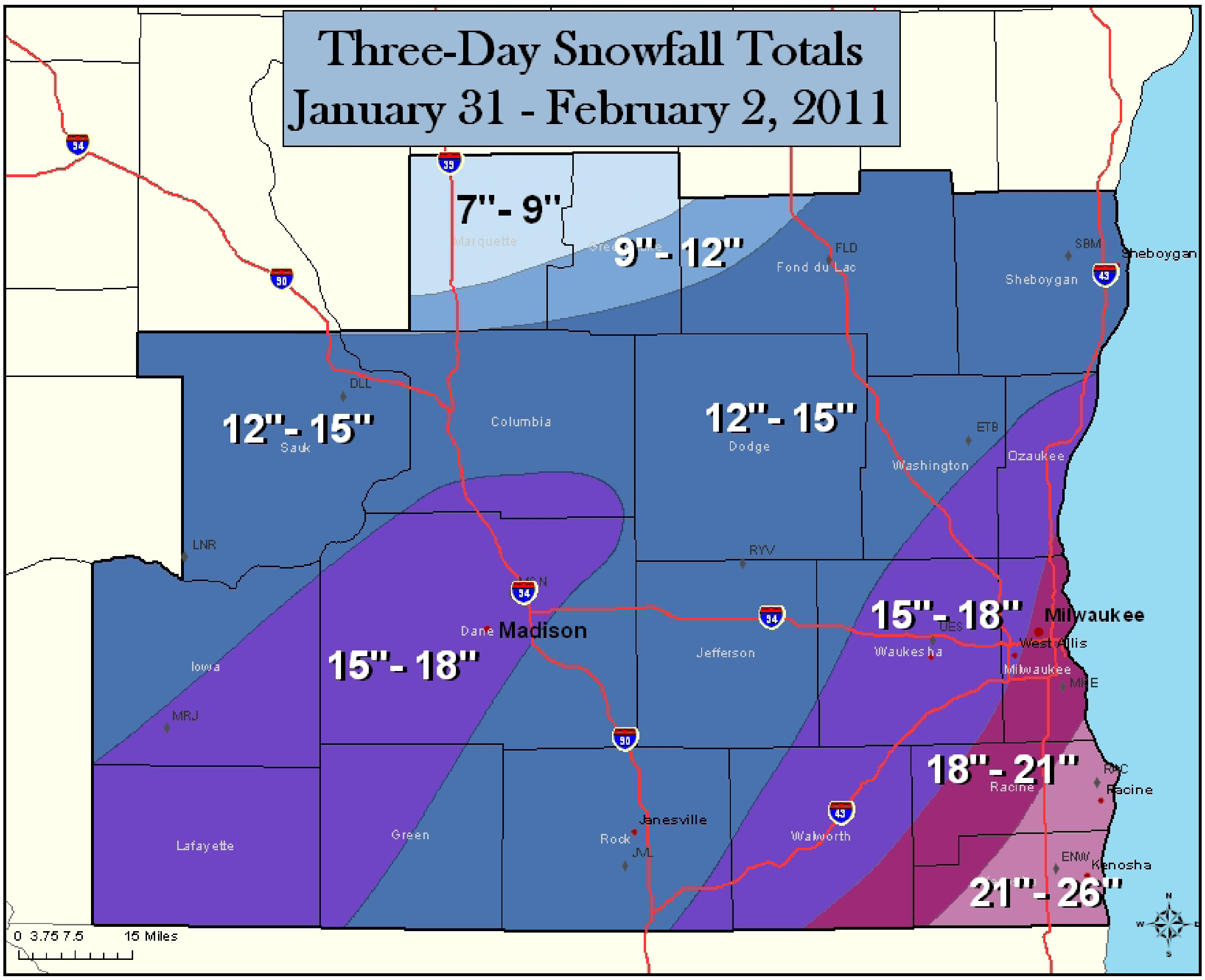


Figure 3.11.2-8 Groundhog Day Blizzard Three-Day Snowfall Totals, Jan. 31-Feb. 2, 2011
Source: NOAA National Weather Service, Milwaukee/Sullivan, WI, 2011.

3.11.3 Probability of Occurrence

Heavy snowfalls are likely to occur in northern Wisconsin in counties along Lake Superior. Though, based on snowfall totals across southern Wisconsin during the 2007-08 winter season, it is possible that winter-season totals of 150 inches or more can occur across southern and central Wisconsin; however, it is rare.

There is no clear pattern about the occurrence of ice storms throughout the state.

Blizzards are more likely to occur in eastern Wisconsin in counties along Lake Michigan.

3.11.4 Hazard Ranking

TABLE3.11.4-1 HAZARD RANKING FOR SEVERE WINTER WEATHER		
Evaluation Criteria	Description	Ranking
Probability	• The hazard has impacted the state annually, or more frequently • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The state or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor	Low

3.11.5 Sources for Severe Winter Weather

TABLE 3.11.5-1 SOURCES FOR SEVERE WINTER WEATHER	
Source Title	Link to Resource
FEMA's Multi-Hazard Identification and Risk Assessment, "Part 1: Atmospheric Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
FEMA Winter Storms Information Site	http://www.fema.gov/hazard/winter/index.shtm
NOAA's Office of Climate, Water, and Weather Services Winter Weather Safety and Awareness Site	http://www.weather.gov/om/winter/index.shtml
NOAA Winter Weather Information site	http://www.noaawatch.gov/themes/winter.php
NWS Hydrometerological Prediction Center, Winter Weather Forecast Site	http://www.hpc.ncep.noaa.gov/wwd/winter_wx.shtml
NWS Weather Forecast Office, Milwaukee/Sullivan, WI	http://www.crh.noaa.gov/mkx/

TABLE 3.11.5-1 CONTINUED	
Source Title	**Link to Resource**
NWS Weather Forecast Office, Green Bay, WI	http://www.crh.noaa.gov/grb/
NWS Weather Forecast Office, La Crosse, WI	http://www.crh.noaa.gov/arx/
Ready America Winter Storms and Extreme Cold Information Site	http://www.ready.gov/america/beinformed/winter.html
National Climatic Data Center Weather Event Database	http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
Red Cross Winter Storms Preparedness Site	http://www.redcross.org/portal/site/en/menuitem.86f46a12f382290517a8f210b80f78a0/?vgnextoid=91435d795323b110VgnVCM10000089f0870aRCRD&vgnextfmt=default
Center for Disease Control and Prevention Winter Weather Site	http://www.bt.cdc.gov/disasters/winter/

3.12 COASTAL EROSION

3.12.1 Nature of the Hazard

Coastal erosion is defined as the wearing away of land and the loss of or displacement of lands along coastlines, beaches, or dune material over a period of time as a result of natural coastal processes or human influences.

Natural processes:

- Lake level change
- Currents
- Tides
- Waves and storm surges
- Winds
- Flooding
- Orientation of shoreline
- Sediment influx
- Littoral processes
- Ice floes
- Overwash

Human influences:

- Dredging
- Jetty and groin construction
- Hardening shorelines with seawalls
- Revetments
- Beach nourishment
- Boat wakes
- Construction of harbors
- Construction of sediment-trapping dams in the river tributaries

Coastal erosion affects Wisconsin along the shoreline of Lakes Michigan and Superior. Along the Great Lakes, cyclical changes in lake levels, disruption of beach building material transport, and storms all influence the rate of erosion. Annual variability in wave climate and lake levels causes the rates of bluff and dune erosion along the shores of the Great Lakes to “vary from near zero to tens of feet per year” (National Research Council, Managing Coastal Erosion, 1990; 40).

Times of high water or wave action accelerate this natural process. Bluff erosion is more likely to occur during major storm events as a result of increased wave action on the shoreline. The effects of wave-induced erosion are usually greater during those periods when the level of water is high.

As lake levels increase, bluff recession rates also increase. Lake level, in other words, is a significant factor in determining rate of erosion along Wisconsin’s coasts.

Other significant factors in the state that involve movement of beach-building sediments cause shoreline erosion. Navigational improvements, shoreline structures and some dredge-material disposal practices deplete both tributary and shoreland sources of sediment. Removing these sediments from the shore system contributes to erosion.

Even with all factors taken into consideration, coastal erosion is usually a gradual process; however, sudden incidents prompting emergency action do occur. These sorts of incidents, such as strong storms with high winds and/or heavy wave action causing bluff failure, are quite rare.

3.12.2 Wisconsin Coastal Erosion History

All 15 coastal counties in Wisconsin experience bluff erosion, coastal flooding, fluctuating water levels, and damage to shoreline structures along Lake Superior and Lake Michigan.

Bluff Erosion

According to the Wisconsin Coastal Management Program's (WCMP) "Needs Assessment and Strategy, 2011-2015," coastal erosion along Lake Michigan occurs along the 185 miles of shoreline from southern-most Kenosha County to Sturgeon Bay Canal (northern tip of Door County), and in the northeastern part of Brown County. Along the remainder of the Lake Michigan shore (from Sturgeon Bay Canal in Door County to Green Bay), bluff erosion is limited to smaller segments of bays and clay banks.

The "Needs Assessment and Strategy, 2011-2015" also describes Lake Superior's entire Wisconsin shoreline as vulnerable to coastal erosion, with the exception of:

- Rocky portions of the Bayfield Peninsula
- Low marshland in Chequamegon Bay
- The mouth of the Bad River

Vulnerability is highest along the high clay bluffs running from Bark Point in Bayfield County to Wisconsin Point in Douglas County, and from Iron County to the White River in Ashland County (Springman and Born, 1979).

Figure 3.12.2-1, at right, displays the vulnerable coastlines in Wisconsin.

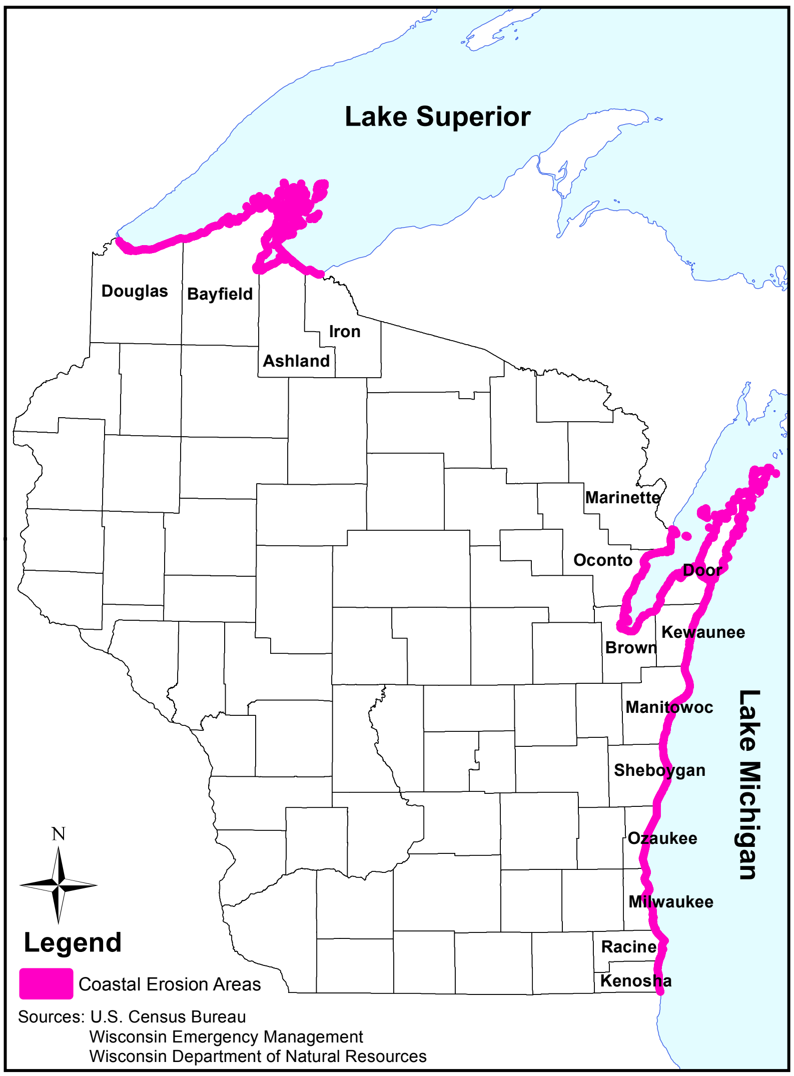


Figure 3.12.2-1 Great Lakes Coastal Erosion Areas in Wisconsin

Coastal Flooding

All 15 coastal counties in Wisconsin experience some coastal flooding; however, it tends to be most serious in the low-lying areas of southern Kenosha County, and from the City of Green Bay to the state line of Upper Peninsula Michigan (WCMP, p. 19). Although the risk of coastal flooding is reduced when lake levels are low, lake levels are only one factor contributing to coastal flooding. Other factors include:

1. **Wind set-up:** the tendency for water levels to increase on downwind lakeshores, and decrease on upwind lakeshores
2. **Wave run-up:** the maximum vertical extent of the rush of water from a breaking wave onto a beach; caused by wind but is also dependent on the shore profile:
   - Waves form more readily where there is a shallow beach profile.
   - Strong winds can cause or exacerbate coastal flooding in these areas.

Water Levels in the Great Lakes

Water levels in the Great Lakes fluctuate on both a seasonal and long-term basis.

Seasonally, the lakes are at their lowest levels during the winter, when much of the precipitation is held on land as snow and ice and the open lake evaporation dominates. The highest seasonal levels are during the summer when snowmelt from the spring thaw and summer rains contribute to the water supply.

Long-term variation of lake levels depends on precipitation and evaporation trends in the Great Lakes watershed as a whole. Lake levels rise when net water supply exceeds outflow and above average lake levels can persist for extended periods even after the conditions that caused them have ended. The water volume of the Great Lakes is large and outflow from natural outlets is limited. Flow regulation structures exist in Lakes Ontario, Michigan, and Superior, but their influence is limited by their size. Controlled releases strive to simulate long-term averages in an effort to serve multiple interests. The source of about 40% of Lake Superior's annual water supply is from the snowpack around its shores. Lakes Michigan and Huron get up to 30% of their yearly supply from Superior's snowmelt when it flows into the lower lakes (Detroit Free Press, March 18, 2000).

Table 3.12.2-1, on the following page, shows the mean, maximum, and minimum lake levels for Lake Superior and Lakes Michigan and Huron.

Coastal property owners are acutely aware of hazards during periods of high-water levels and especially right after a damaging storm or a bluff failure, but this awareness can fade over time if low lake levels slow the erosion rate. Lake levels were above long-term averages from 1996 to 1998. The last period of significantly higher lake levels was in 1985 to 1986, resulting in $16 million of documented damage to public facilities alone (WCMP, 1992). Record snowfall in northern Wisconsin in 1996 was followed by near record high-water levels in 1997. However, unusually mild weather and light snowfall in the winters of 1998-1999 and 1999-2000 began to drop the lake levels once again to below long-term averages. These trends continued throughout the 2000-2007 period where record low Lake Superior water levels were set for the months of August and September in 2007. Lake Michigan water levels also approached record lows for the months of November

TABLE 3.12.2-1 LAKE SUPERIOR AND LAKES MICHIGAN AND HURON MEAN, MAXIMUM, AND MINIMUM WATER LEVELS, 1918-2010

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Lake Superior												
2010	*601.1*	*600.9*	*600.7*	*600.7*	*600.7*	*600.8*	*601.0*	*601.0*	*601.1*	*601.0*	*600.9*	*600.6*
Mean	**601.5**	**601.3**	**601.1**	**601.2**	**601.6**	**601.9**	**602.1**	**602.2**	**602.2**	**602.1**	**601.9**	**601.7**
Max (Year)	602.7 (1986)	602.5 (1986)	602.4 (1986)	602.6 (1986)	602.8 (1986)	602.9 (1986)	603.1 (1950)	603.2 (1952)	603.2 (1985)	603.4 (1985)	603.3 (1985)	603.1 (1985)
Min (Year)	599.8 (1926)	599.6 (1926)	599.5 (1926)	599.5 (1926)	599.6 (1926)	599.9 (1926)	600.3 (1926)	600.4 (2007)	600.5 (2007)	600.7 (1925)	600.4 (1925)	600.1 (1925)
Lakes Michigan and Huron												
2010	*577.9*	*577.8*	*577.7*	*577.8*	*577.9*	*578.1*	*578.3*	*578.2*	*578.0*	*577.7*	*577.3*	*577.0*
Mean	**578.54**	**578.51**	**578.54**	**578.84**	**579.13**	**579.36**	**579.46**	**579.40**	**579.23**	**579.00**	**578.81**	**578.64**
Max (Year)	581.30 (1987)	581.07 (1986)	581.10 (1986)	581.46 (1986)	581.63 (1986)	581.79 (1986)	581.99 (1986)	581.99 (1986)	581.96 (1986)	582.35 (1986)	581.96 (1986)	581.56 (1986)
Min (Year)	576.12 (1965)	576.08 (1964)	576.05 (1964)	576.15 (1964)	576.57 (1964)	576.64 (1964)	576.71 (1964)	576.67 (1964)	576.64 (1964)	576.44 (1964)	576.28 (1964)	576.1 (2007)

Source: USACE, Long Term Average Min Max Water Levels, http://www.lre.usace.army.mil/greatlakes/hh/greatlakeswaterlevels/historicdata/longtermaveragemin-maxwaterlevels/.

through February during the winter of 2007-2008. During the 2008 year, the entire Great Lakes basin received above average precipitation. As a result, both Lake Superior and Lake Michigan water levels have risen from record or near record low levels to levels within 0.5 to 1.0 feet from their long term averages.

3.12.3 Probability of Occurrence

All of Wisconsin's coastal counties experience coastal erosion. The coastal erosion county-level analysis risk assessment provides additional information on the risk of coastal erosion. It should be noted, that coastal erosion is a function of rainfall and local conditions.

15 counties border the Great Lakes in Wisconsin. Coastal counties account for 19% of the area of the state, but comprise 36% of the population. Coastal counties range from very sparsely populated (i.e. Iron County) to highly urban (i.e. Milwaukee County).

The Great Lakes coast in Wisconsin can be divided into three sections based on population density characteristics.

1. **Southeastern Coastal Counties**
   This area includes the four southern-most coastal counties: Kenosha, Racine, Milwaukee, and Ozaukee. According to the 2010 Census, the Southeastern Coastal Counties have a population density of 1,293 persons per square mile. Much of the southeast Wisconsin coast is part of the urban corridor that stretches between

Milwaukee and Chicago. The southern counties include the coastal cities of Cudahy (Milwaukee County), Kenosha (Kenosha County), Mequon (Ozaukee County), Milwaukee (Milwaukee County), Oak Creek (Milwaukee County), Port Washington (Ozaukee County), Racine (Racine County), and St. Francis (Milwaukee County).

2. **Northern Lake Michigan Coastal Counties**
   This area contains seven counties: Brown, Door, Kewaunee, Manitowoc, Marinette, Oconto, and Sheboygan. The Northern Lake Michigan Coastal Counties have a moderate population density of 118 people per square mile. This section includes the coastal cities of Algoma (Kewaunee County), Green Bay (Brown County), Kewaunee (Kewaunee County), Manitowoc (Manitowoc County), Marinette (Marinette County), Oconto (Oconto County), Sheboygan (Sheboygan County), Sturgeon Bay (Door County), and Two Rivers (Manitowoc County). Much of the shoreline fronts Green Bay. Door County possesses the most extensive Great Lakes shoreline in Wisconsin at 240 miles.
3. **Northwestern Coastal Counties**
   This area borders Lake Superior and includes the counties of Ashland, Bayfield, Douglas, and Iron. This section has a low population density of approximately 17.8 people per square mile. Northwestern counties include cities of Ashland (Ashland County), Bayfield (Bayfield County), Superior (Douglas County), and Washburn (Bayfield County).

3.12.4 Vulnerability and Risk Assessment

Methodology

Existing maps depicting rates of coastal erosion and the FEMA HAZUS-MH inventory of structures in the coastal zone provided the basis for estimating the potential vulnerability and losses from this hazard. The number and types of structures subjected to high and low risk of erosion were determined from HAZUS-MH, which uses 2000 Census data, the best available for this simulation. The erosion risk zones were established based on the distance in miles from the Coastal Area Boundary.

1. High-Risk Erosion Zone – the area within 1/4 mile of the Coastal Area Boundary
2. Low-Risk Erosion Zone – the area within 1/2 mile of the Coastal Area Boundary

Based upon structure type and dimensions (including square footage), replacement values of structures were estimated. The estimated replacement value was assumed to be equal to the value of a total loss of the structure due to erosion.

Results

Table 3.12.4-1, on the following page, shows the loss estimation for the high-risk erosion zone. Within areas subjected to a high risk of erosion, Door County has the largest number of residential units (7,889), followed by Milwaukee (6,446) and Racine counties (4,125). Counties with the highest number of commercial structures are Kenosha, Milwaukee, and Door, with 110, 67, and 66 structures, respectively. For the governmental structures, the counties with the highest numbers include Ashland (5) and Ozaukee (2). With 7,956 structures, Door County has the most vulnerable structures in the high-risk area, followed by Milwaukee (6,513) and Racine (4,168).

Overall, Milwaukee County has the highest loss potential ($313 million), followed by Door ($254 million) and Ozaukee ($119 million) counties.

TABLE 3.12.4-1 HIGH-RISK EROSION ZONE LOSS ESTIMATION

County	Number of Structures			Total	Loss Estimation			Risk
	Residential	Commercial	Government		Residential	Commercial	Government	
Ashland	937	32	5	974	$11,220,780	$427,480	$71,060	Low
Bayfield	1,764	44	1	1,809	$31,007,020	$792,680	$19,420	Low
Brown	1,523	17	0	1,540	$46,697,640	$438,380	$0	Low
Door	7,889	66	1	7,956	$252,104,420	$2,074,860	$14,140	High
Douglas	1,185	15	0	1,200	$15,681,420	$183,720	$0	Low
Iron	34	0	0	34	$334,560	$0	$0	Low
Kenosha	2,185	110	0	2,295	$56,476,360	$477,340	$0	High
Kewaunee	1,374	13	1	1,388	$24,912,580	$203,400	$15,800	Low
Manitowoc	2,576	43	0	2,619	$42,246,160	$647,480	$0	High
Marinette	740	0	0	740	$12,367,300	$0	$0	Low
Milwaukee	6,446	67	0	6,513	$309,670,740	$3,817,400	$0	High
Oconto	406	0	0	406	$8,016,400	$0	$0	Low
Ozaukee	2,198	25	2	2,225	$118,415,560	$706,580	$49,640	High
Racine	4,125	43	0	4,168	$96,541,080	$561,400	$0	High
Sheboygan	3,077	2	0	3,079	$64,448,260	$27,180	$0	High
Total	**36,459**	**477**	**10**	**36,946**	**$1,090,140,280**	**$10,357,900**	**$170,060**	

Source: WEM, 2008.

Table 3.12.4-2, on the following page, shows losses sustained in low-risk erosion areas. Milwaukee County has the largest number of residential (15,669) and commercial structures (302) in the low-risk erosion zone. Door County has the second largest number of residential units (9,654) and the third largest number of commercial structures (92). Manitowoc County has the largest number of governmental structures (8), followed by Milwaukee County (6). The county with the most vulnerable structures in the low-risk area is Milwaukee (15,977), followed by Door County (9,747) and Racine County (7,401).

Furthermore, Milwaukee County has the highest loss potential ($1.2 billion) in the low-risk erosion zone, followed by Door ($604 million) and Ozaukee ($395 million) counties.

TABLE 3.12.4-2 LOW-RISK EROSION ZONE LOSS ESTIMATION

County	Number of Structures			Total	Loss Estimation			Risk
	Residential	Commercial	Government		Residential	Commercial	Government	
Ashland	1,873	34	5	1,912	$47,087,720	$896,320	$142,120	Low
Bayfield	2,565	49	2	2,616	$89,632,960	$1,748,840	$67,440	High
Brown	2,138	49	0	2,187	$127,852,760	$2,295,840	$0	High
Door	9,654	92	1	9,747	$598,461,600	$5,896,840	$28,280	High
Douglas	2,407	16	0	2,423	$62,880,680	$339,920	$0	High
Iron	34	0	0	34	$669,120	$0	$0	Low
Kenosha	4,416	136	4	4,556	$206,497,480	$1,724,080	$34,320	High
Kewaunee	1,977	14	1	1,992	$68,407,240	$435,480	$31,600	Low
Manitowoc	4,919	86	8	5,013	$160,909,560	$2,515,400	$224,000	High
Marinette	1,180	5	2	1,187	$35,641,920	$124,600	$49,840	Low
Milwaukee	15,669	302	6	15,977	$1,221,789,640	$21,579,320	$524,440	High
Oconto	474	0	0	474	$18,453,520	$0	$0	Low
Ozaukee	3,799	66	2	3,867	$390,146,560	$4,917,800	$99,280	High
Racine	7,345	56	0	7,401	$295,093,240	$1,399,360	$0	High
Sheboygan	5,377	32	0	5,409	$210,716,120	$1,027,240	$0	High
Total	**63,827**	**937**	**31**	**64,795**	**$3,534,240,120**	**$44,901,040**	**$1,201,320**	

Source: WEM, 2008.

Data Limitations

Replacement values for coastal structures were estimated and could be verified in future risk assessments.

Future Growth and Development Considerations

Increased population growth and development also increases the vulnerability of counties as property values increase and areas that may once have been undeveloped become developed. Because coastal erosion is fairly site-specific, the effect of increased development and population growth is more easily measured in terms of risk and vulnerability.

Although the Wisconsin coastal counties as a whole experienced an overall population gain from 2000 to 2010, six of the 15 counties experienced population losses (Ashland, Door, Iron, Manitowoc, and Marinette).

<u>Northwestern Coastal Counties</u>
The Northwestern Coastal Counties along Lake Superior experienced an overall loss of 781 persons or about 1% of its total population.

<u>Northern Lake Michigan Coastal Counties</u>
The Northern Lake Michigan Coastal Counties experienced an overall 4.2% population increase. Though Door, Manitowoc, and Marinette lost 0.6%, 1.8%, and 3.8%, respectively, the rest of the counties saw significant increases of over 1%. Brown County witnessed a 9.4% population increase during the ten year period.

This increase in Brown County comes from outside the Green Bay area, which is growing fastest. From 2000 to 2006, Green Bay experienced a 2.4% decrease in population. This population loss may decrease the number of people affected by coastal flooding, as Green Bay is among the lowest-lying areas in the state. However, according to the Bay-Lake Regional Planning Commission, the Northwestern portion of Brown County is one of the areas at greatest risk for coastal flooding.

<u>Southeastern Coastal Counties</u>
This area experienced an overall population gain of 2.6%, with all counties experiencing growth ranging from 0.8% in Milwaukee County to 11.3% in Kenosha County. The 11.3% increase in Kenosha County is particularly concerning, since it is the lowest-lying area of the County. The City of Kenosha, which experienced almost 6% growth from 2000 to 2006, may need to examine ways to mitigate this increased population exposure to coastal hazards.

Careful and strict enforcement of shore land and floodplain ordinances will be the key to preventing losses in these areas.

3.12.5 Hazard Ranking

TABLE 3.12.5-1 HAZARD RANKING FOR COASTAL EROSION		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard has impacted the state annually, or more frequently • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Methods for reducing risk from the hazard are technically reliable • The state or counties have experience in implementing mitigation measures • Mitigation measures are eligible under federal grant programs • There are multiple possible mitigation measures for the hazard • The mitigation measure(s) are known to be cost-effective • The mitigation measures protect lives and property for a long period of time, or are permanent risk reduction solutions	High

3.12.6 Sources for Coastal Erosion

TABLE 3.12.6-1 SOURCES FOR COASTAL EROSION

Source Title	Link to Resource
FEMA's Multi-Hazard Identification and Risk Assessment, "Subpart C: Hydrologic Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
NOAA Coastal Services Center	http://www.csc.noaa.gov/
NOAA Ocean & Coastal Resource Management	http://coastalmanagement.noaa.gov/
U.S. Army Corps of Engineers Lake Michigan Potential Damages Study	http://www.lre.usace.army.mil/greatlakes/hh/greatlakestudies/lakemichiganpotentialdamagesstudy/
Wisconsin Coastal Management Program	http://www.doa.state.wi.us/section.asp?linkid=65&locid=9
Wisconsin Coastal Management Program *Needs Assessment Strategy, 2011-2015*	http://doa.wi.gov/docview.asp?docid=8442&locid=9
Springman and Born, *Wisconsin's Shore Erosion Plan: An Appraisal of Options and Strategies*	http://www.gpo.gov/fdsys/pkg/CZIC-tc224-w6-s6-1979/html/CZIC-tc224-w6-s6-1979.htm
DNR Shoreland Management Program	http://www.dnr.state.wi.us/org/water/wm/dsfm/shore/
Bay-Lake Regional Planning Commission "Guide to Hazard Mitigation Planning for Wisconsin Coastal Communities"	http://www.baylakerpc.org/media/46893/coastal%20hazards%20planning%20guide_june%202007.pdf
University of Wisconsin Sea Grant Institute	http://www.seagrant.wisc.edu/home/
National Research Council, *Managing Coastal Erosion.*	http://www.nap.edu/openbook.php?record_id=1446&page=R1

3.13 EARTHQUAKES

3.13.1 Nature of the Hazard

An earthquake is "a sudden motion or trembling caused by an abrupt release of accumulated strain in the tectonic plates that comprise the earth's crust" (FEMA 1997, p. 187). Dense, rigid tectonic plates move slowly over the earth's less-dense interior at a rate of about two inches per year, or a distance of 30 miles in about one million years.

Along plate boundaries, plates converge, diverge, or move against each other (i.e. transform plate boundaries), which may cause stress to accumulate along fault lines (plate boundaries). When this stress exceeds the elastic limit of the rock, pressure is released in the form of an earthquake, immediately causing sudden ground motion and seismic activity. Secondary hazards may also occur, such as surface faulting, sinkholes, and landslides. While the majority of earthquakes occur near the edges of the tectonic plates, earthquakes may also occur at the interior of plates.

Earthquake severity is a function of ground motion (waves) and seismic activity (magnitude and intensity).

Ground Motion

Ground motion describes the vibration or shaking of the ground during an earthquake. The severity of ground motion generally increases with the amount of energy released and decreases with distance from the fault or epicenter of the earthquake. Ground motion causes waves both in the earth's interior, known as body or seismic waves, and along the earth's surface, known as surface waves.

Seismic Waves (Interior Waves)

- **P-waves (primary waves)** are longitudinal or compressional waves that are the initial waves produced by an earthquake. The wave compresses (pushes) and dilates (pulls) rock in a back-and-forth oscillation, similar to a sound wave. P-waves travel very quickly at a speed of up to 15,000 mph through all forms of solid rock and liquid materials, such as magma or water.
- **S-waves (secondary or shear waves)** are slower than P-waves and cause structures to vibrate from side-to-side (horizontal motion) due to particle motion at right-angles to the direction of wave travel. Unreinforced buildings are more susceptible to damage from horizontal motion in S-waves than by vertical motion.

Surface Waves

- **Love waves** move the ground side-to-side horizontally, but differ from S-waves since Love waves have no vertical displacement and are much slower. These waves do not propagate through water. Love waves are the fastest of the surface waves, but still move slower than seismic waves.

- **Rayleigh waves** move the ground like ocean waves, both vertically and horizontally. They tend to move slower than Love waves, but can propagate through liquid since they move vertically.

Seismic Activity

Seismic activity is commonly described in terms of magnitude and intensity. Magnitude describes the total energy released and intensity subjectively describes the effects at a particular location. Although an earthquake has only one magnitude, its intensity varies by location.

Magnitude is the measure of the amplitude of the seismic waves and is expressed using the Richter scale. The Richter scale is a base-10 logarithmic measurement, where an increase in the scale by one whole number represents a tenfold increase in measured amplitude of the earthquake. For example, an earthquake measuring a 8.0 on the Richter scale has shaking amplitude that is ten times larger than one measuring 7.0.

Intensity is a measure of the strength of the shock at a particular location and is expressed by the Modified Mercalli Intensity (MMI) Scale. The MMI scale rates felt intensity on a 12-point scale.

Another way of expressing an earthquake's severity is to compare its acceleration to the normal acceleration due to gravity. If an object is dropped while standing on the surface of the earth, it will fall towards earth and accelerate faster until reaching terminal velocity. The acceleration due to gravity, referred to in calculations as g, is equal to 9.8 meters per second squared (980 cm/sec2). In other words, the velocity of an object falling towards earth increases by 9.8 meters per second or 980 centimeters per second, all other things constant. Peak ground acceleration (PGA) measure the acceleration of an earthquake on the ground. It does so using a calculation of the rate of change of motion relative to the rate of acceleration due to gravity. For example, acceleration of the ground surface of 244 cm/sec2 equals a PGA of 25.0% (i.e. 244/980 = 0.25 or 25%).

Figure 3.13.1-1, on the following page, displays the PGA in Wisconsin as reported in a 2008 U.S. Geological Survey (USGS) study. As shown in the map, the southeastern portion of the state has a PGA of between 4% and 6% (between 39.2 and 58.8 cm/sec2), while most of the state has a PGA of between 2% and 4% (between 19.6 and 39.2 cm/sec2). The northwestern corner of the state has very low PGA less than 2% of gravity (less than 19.6 cm/sec2). These lower PGA values indicate that earthquake damages are not likely to be high, due to the slower acceleration of the continental crust in the state.

It is possible to approximate the relationship between PGA, the Richter scale, and the MMI, as shown in Table 3.13.1-1 on the following page. The relationships are, at best, approximate, and also depend upon earthquake event details, such as the distance from the epicenter and depth of the focus. An earthquake with 10.0% PGA (98 cm/sec2) would roughly correspond to an MMI intensity of V or VI.

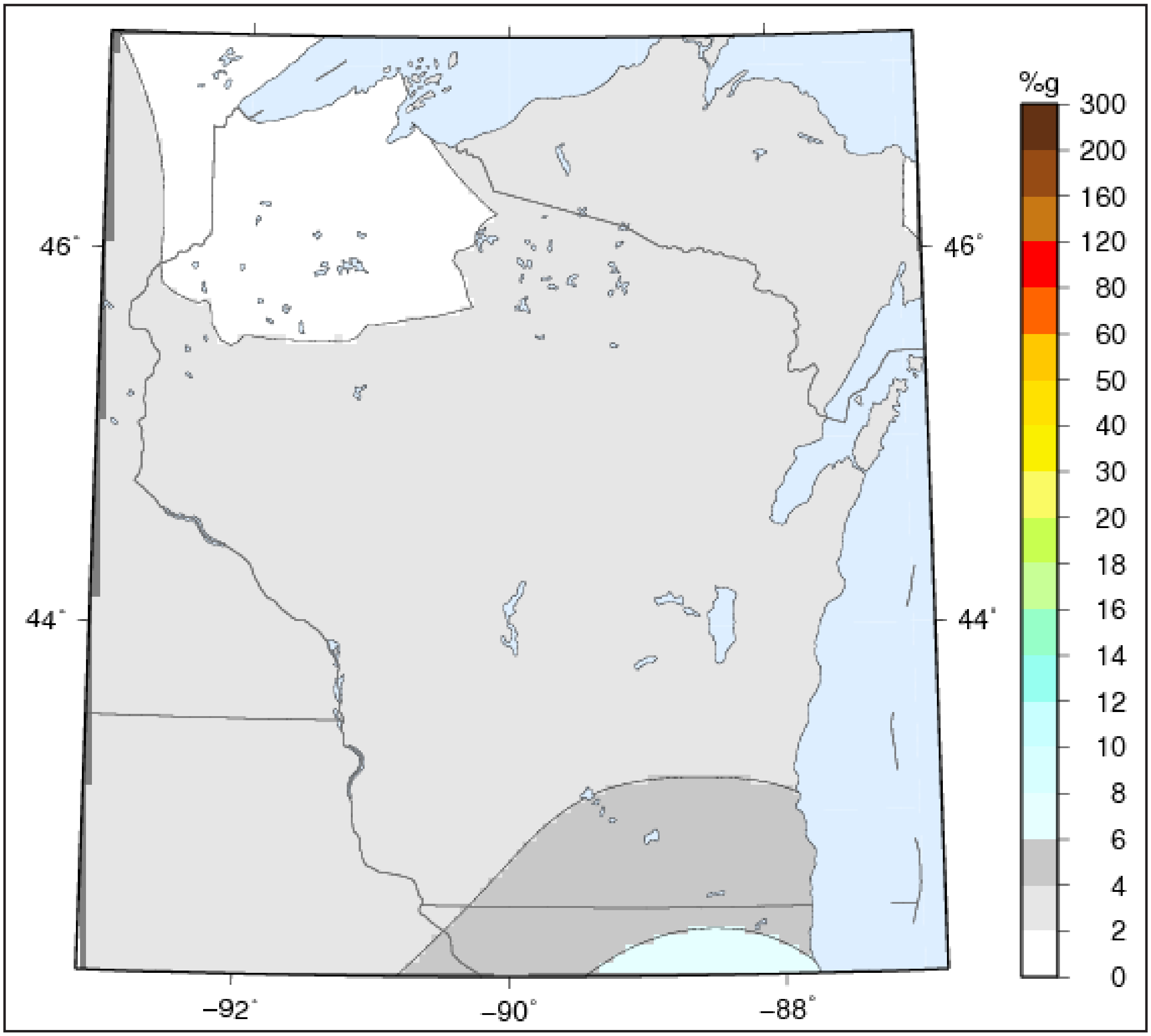


Figure 3.13.1-1 PGA in Wisconsin
Source: USGS, Custom Hazards Mapping, https://geohazards.usgs.gov/hazards/apps/cmaps/, 2008.

TABLE 3.13.1-1 EARTHQUAKE PGA, MAGNITUDE, AND INTENSITY COMPARISON

PGA (%*g*)	Magnitude (Richter Scale)	Intensity (MMI)	Description (MMI)
<0.17	1.0-3.0	I	I. Not felt except by a very few under especially favorable conditions.
0.17-1.4	3.0-3.9	II-III	II. Felt only by a few persons at rest, especially on upper floors of buildings. III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

TABLE 3.13.1-1 CONTINUED			
PGA (%*g*)	**Magnitude (Richter Scale)**	**Intensity (MMI)**	**Description (MMI)**
1.4-9.2	4.0-4.9	IV-V	IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
9.2-34	5.0-5.9	VI-VII	VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
34-124	6.0-6.9	VIII-IX	VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
>124	>7.0	>X	X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: Wald, Quitoriano, Heaton, and Kanamori, 1999.

3.13.2 Wisconsin Earthquake Event History

Moderate shaking was reported in many places in Wisconsin on August 31, 1886 as the result of a strong earthquake centered near Charleston, South Carolina. The intensity at Beloit (Rock County), Janesville (Rock County), and Milwaukee (Milwaukee County) was estimated to be V on the MMI Scale.

Table 3.13.2-1, on the following page, lists the locations and dates of the 24 recorded earthquakes that have occurred in Wisconsin since 1899, with none causing significant damage. Figure 3.13.2-1 shows the data on a map with PGAs for Wisconsin. The causes of these local quakes are poorly understood and are thought to be the result of continuing rebound of the earth's crust after the retreat of the last glacial ice.

TABLE 3.13.2-1 EARTHQUAKE HISTORY IN WISCONSIN, 1899-1990							
Location	**Year**	**Date**	**Latitude North**	**Longitude West**	**Felt Area (square km)**	**Maximum Intensity**	**Magnitude**
Kenosha	1899	Oct. 12	42° 34’	87° 50’	--	II	3.0
Marinette	1905	Mar. 13	45° 08’	87° 40’	--	V	3.8
Shorewood	1906	Apr. 22	43° 03’	87° 55’	--	II	3.0
Milwaukee	1906	Apr. 24	43° 03’	87° 55’	--	III	--
Marinette	1907	Jan. 10	45° 08’	87° 40’	--	III	--
Beloit	1909	May 26	42° 30’	89° 00’	800,000	VII	5.1
Madison	1914	Oct. 7	43° 05’	89° 23’	--	IV	3.8
Madison	1916	May 31	43° 05’	89° 21’	--	II	3.0
Fond du Lac	1922	July 7	43° 47’	88° 29’	--	V	3.6
Madison	1931	Oct. 18	43° 05’	89° 23’	--	III	3.4
Stoughton	1933	Dec. 6	42° 54’	89° 15’	1,200	IV	3.5
Dubuque, IA	1938	Nov. 7	42° 30’	90° 43’	--	II	3.0
Dubuque, IA	1938	Nov. 8	42° 30’	90° 43’	--	II	3.0
Dubuque, IA	1938	Nov. 8	42° 30’	90° 43’	--	II	3.0
Thunder Mountain	1943	Feb. 9	45° 11’	88° 10’	--	III	3.2
Milwaukee	1947	May 6	43° 00’	87° 55’	8,000	V	4.0
Lake Mendota	1948	Jan. 15	43° 09’	89° 41’	--	IV	3.8
Oostburg	1956	July 18	43° 37’	87° 45’	--	IV	3.8
Oostburg	1956	July 18	43° 37’	87° 45’	--	IV	3.8
South Milwaukee	1956	Oct. 13	42° 55’	87° 52’	--	IV	3.8
Beaver Dam	1957	Jan. 8	42° 32’	98° 48’	--	IV	3.6
Bill Cross Rapids	1979	Feb. 28	45° 13’	89° 46’	Instrumental	--	<1.0 MoLg
Madison	1981	Jan. 9	43° 05’	87° 55’	Local	II	--
Madison	1981	Mar. 13	43° 05’	87° 55’	Local	II	--
Oxford	1981	June 12	43° 52’	89° 39’	Local	IV-V	--
Milwaukee	1987	Feb. 12	42° 95’	87° 84’	Local	IV-V	--
Milwaukee	1987	Feb. 12	43° 19’	87° 28’	Local	IV-V	--
W. Kenosha Co.	1990	June 18	42 60	88 20	160	III	--

Source: USGS, University of Wisconsin-Extension, Geological and Natural History Survey. List of Earthquakes in Wisconsin, M.G. Mudrey, Jr., Open File Report 84-1, 12/11/84. Ron Friedel, Department of Geological and Geophysical Sciences, UW-Milwaukee, 1987. Table has most current information available.

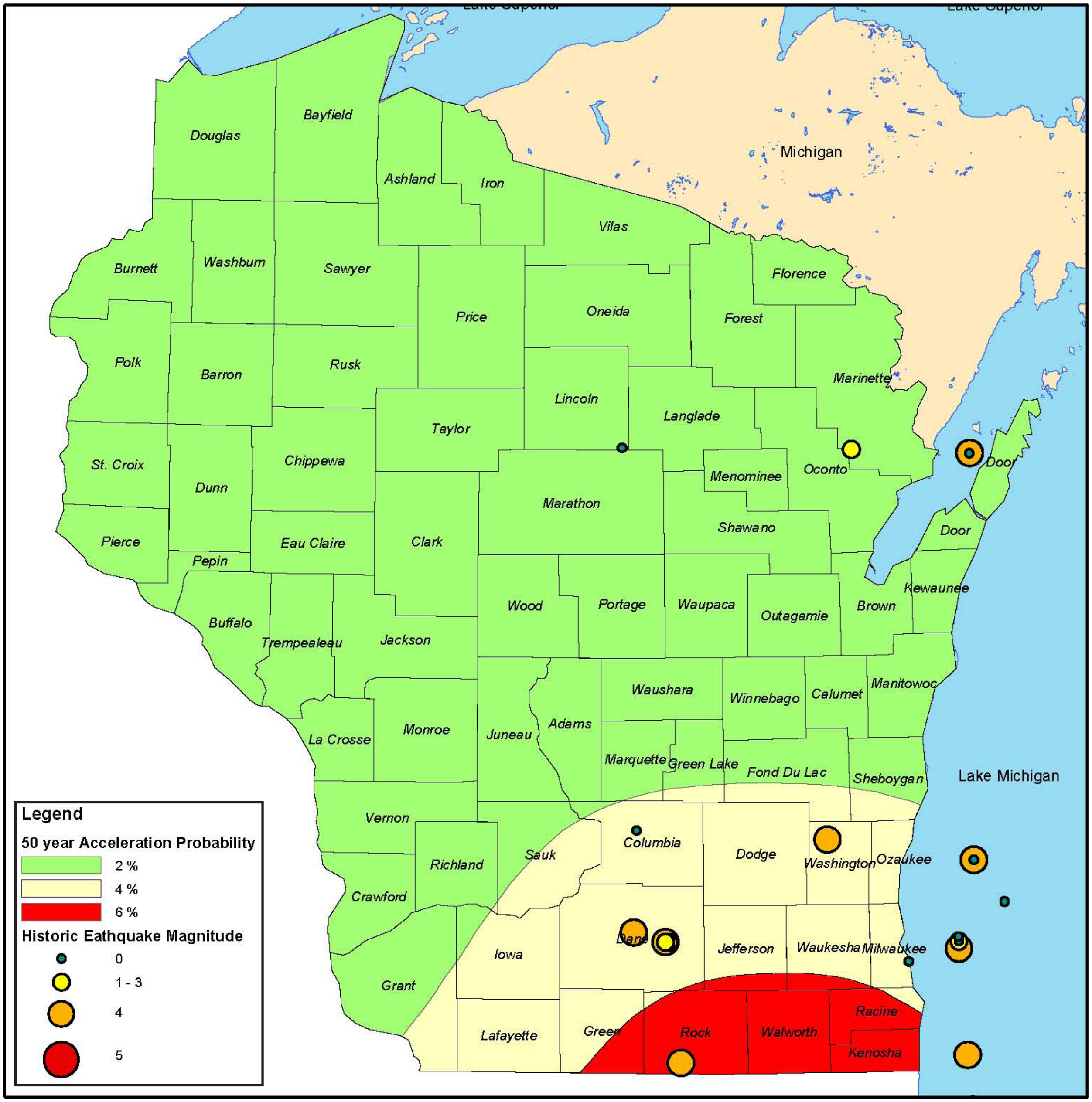


Figure 3.13.2-1 Wisconsin PGA and Historical Earthquakes, 1899-2003

Source: USGS, University of Wisconsin-Extension, Geological and Natural History Survey. List of Earthquakes in Wisconsin.

On May 26, 1909, an earthquake damaged many chimneys in Aurora, Illinois, and caused MMI VII effects over a considerable area from Bloomington, Illinois to Platteville, Wisconsin (Grant County). Two more moderate shocks affected the same area on January 2, 1912. The first tremor was MMI-VI in northern Illinois and was followed by a lighter shock. People as far away as Madison (Dane County) and Milwaukee noticed the tremor.

Scattered felt reports in Wisconsin were noted from a major earthquake in the St. Lawrence River region near La Malbaie, Quebec, Canada on February 28, 1925. The magnitude 7.0 earthquake encompassed an area of approximately 3.1 million square miles. Intensity at La Crosse (La Crosse County) and Milwaukee was estimated at MMI-III.

Another strong Canadian earthquake (magnitude 6.25) affected a large area of the north-eastern and north-central US on November 1, 1935. The quake was felt in an area of more than 1.6 million square miles and included most of eastern Wisconsin (MMI-I through MMI-III) and scattered points elsewhere in the state.

A short, but moderately strong, earthquake centered just south of Milwaukee caused only minor damage on May 6, 1947. No injuries were reported. The 4:25 a.m. tremor shook buildings and rattled windows in communities in a 4,800 square mile area of south-eastern Wisconsin. There were a few reports of broken windows in Kenosha (Kenosha County) and residents of other communities reported that dishes and glasses had fallen from shelves, indicating an intensity of MMI-V. Some of the frightened Milwaukee residents ran into the streets in their belief that there had been a serious explosion. The shock encompassed a 160-kilometer wide strip from Sheboygan (Sheboygan County) to the Wisconsin/Illinois border and extended from the lakeshore to Waukesha (Waukesha County), 24.9 miles inland. The earthquake lasted only about a half a second and could have caused serious damage if it had continued for as long as a typical major earthquake (30 seconds or more).

The strongest earthquake to occur in the central US in 74 years happened on November 9, 1968 in south-central Illinois. The shock was felt over an area of approximately 930,000 square miles, including all or portions of 23 states and southern Ontario, Canada. Measured at a magnitude of 5.3, maximum intensity reached VII in Illinois, Indiana, Kentucky, and Missouri. In Wisconsin, MMI-V was reported from Jefferson (Jefferson County) and Kenosha, and MMI-I through MMI-IV, at Baraboo (Sauk County), La Crosse, Milwaukee, Port Washington (Ozaukee County), Portage (Columbia County), Prairie du Chien (Crawford county), and Sheboygan. Press reports indicate the shock was also felt at Beloit, Janesville, and Madison.

A September 14, 1972, tremor (magnitude 3.7) was felt over 404,000 square miles, including Michigan, Minnesota, Missouri, Ohio, and Wisconsin. Cracked plaster (MMI-V) was noted at Kewaskum (Washington/Fond du Lac County), Milton (Rock County), Nashotah (Waukesha County), and Zenda (Walworth County). A report from Browntown (Green County) said that water pipes leaked after the shock.

Reports were received from Kansasville (Racine County), Mount Hope (Grant County), and Trevor (Kenosha County) following a magnitude 4.0 earthquake on April 3, 1974 centered near the 1968 epicenter in southern Illinois. Within one hour or so, a number of tornadoes passed through the area that was affected by the earthquake. Some of the reports may have confused the effects caused by the earthquake and those caused by the tornadoes (abridged from Carl A. Von Hake, Earthquake Information Bulletin, May/June 1978).

Two recent earthquakes have been felt by residents in southeastern Wisconsin. Both quakes occurred early in the morning and woke sleeping residents and shook furniture. The first occurred on June 28, 2004, centered eight miles northwest of Ottawa, Illinois.

The 4.1 magnitude earthquake was felt in Illinois, Indiana, Michigan, Missouri, and Wisconsin. In Milwaukee, the intensity was MMI-IV.

The second quake, of magnitude 5.4, occurred on April 18, 2008. Centered in southeastern Illinois, six miles from West Salem near Mount Carmel, the earthquake was felt in 18 states throughout the central and southeastern US. The epicenter of this earthquake is shown below in Figure 3.13.2-2.

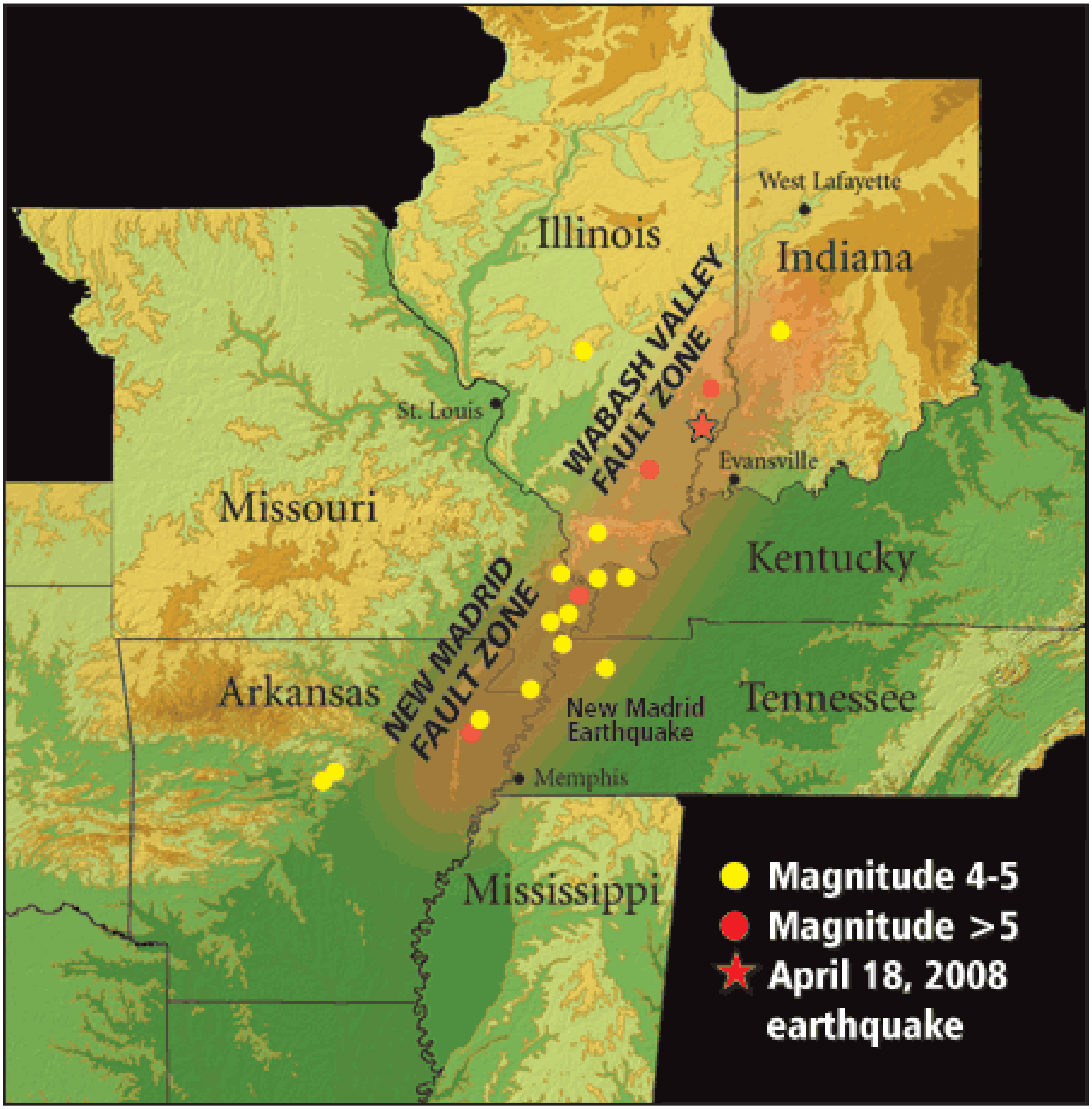


Figure 3.13.2-2 Active Seismic Zones near Wisconsin
Source: Purdue University College of Science, https://www.science.purdue.edu/insights/SP08/earthquake.php.

3.13.3 Probability of Occurrence

The earthquake threat to Wisconsin is considered low. Historically, few earthquakes of noticeable intensity and considerable magnitude have occurred in Wisconsin, relative to other states. Though there is a low probability of a significant earthquake occurring in Wisconsin, there are two active seismic areas with significant activity near the state: New Madrid Seismic Zone and the Wabash Valley Seismic Zone, depicted in Figure 3.13.2-2 on the previous page.

<u>New Madrid Seismic Zone (NMSZ)</u>

The NMSZ is located in northeast Arkansas, southeast Missouri, southern Illinois, western Kentucky, and western Tennessee. This fault produced two extremely strong earthquakes of 7.0 to 8.0 on the Richter scale in 1811 and 1812. If a strong earthquake of the same magnitude occurred in the NMSZ again, the effects would be devastating and far reaching, as the area has developed significantly in the two centuries since the events. If this sort of event were to occur today, Kenosha, Milwaukee, Racine, Rock, Walworth, and Waukesha Counties could experience localized severity of MMI-V to MMI-VII.

Another potential effect of a major NMSZ earthquake to the state could be decreased supply of both natural gas and petroleum, as major transmission pipelines pass through the NMSZ. A massive shortage would have far reaching economic and social impacts throughout Wisconsin and surrounding states. A depiction of the regional intensity that could result from a major earthquake at the NMSZ is shown below in Figure 3.13.3-1.

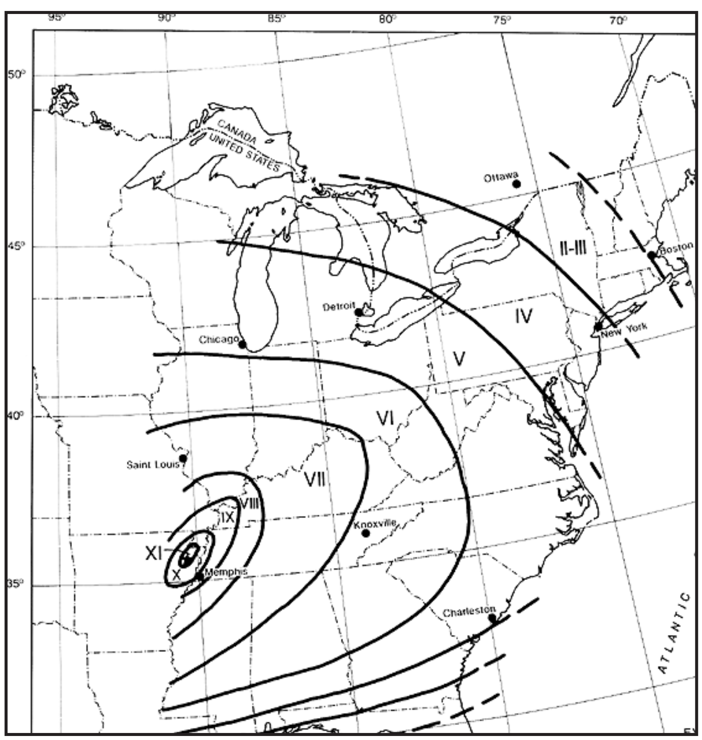


Figure 3.13.3-1 Regional Intensity from 1811-Strength Earthquake in NMSZ
Source: Mid-America Earthquake Center, University of Illinois at Urbana-Champaign.

Wabash Valley Seismic Zone (WVSZ)
Located along the Wabash River in southeastern Illinois and Indiana, this area has had active seismic activity for over 20,000 years (Mid-American Earthquake Center Report 09-03, p. 3). This area does not produce earthquakes on the same magnitude as the NMSZ; however, in 2008, the WVSZ produced a 5.2 magnitude quake detailed in Section 3.13.2.

Minor damages, such as plaster cracking, have occurred in Wisconsin, but most often the only results have been windows rattling and ground shaking. There is little risk posed to the state, except to poorly constructed structures.

Probabilistic ground motion maps are typically used to assess the magnitude and frequency of seismic events. These maps measure the probability of exceeding a certain ground motion, expressed as peak ground acceleration PGA, over a specified period of years. Figure 3.13.3-2, below, is a PGA map of the central and eastern US.

Overall, the severity of earthquakes is site specific, and is influenced by proximity to the earthquake epicenter, soil type, and local geologic characteristics, among other factors.

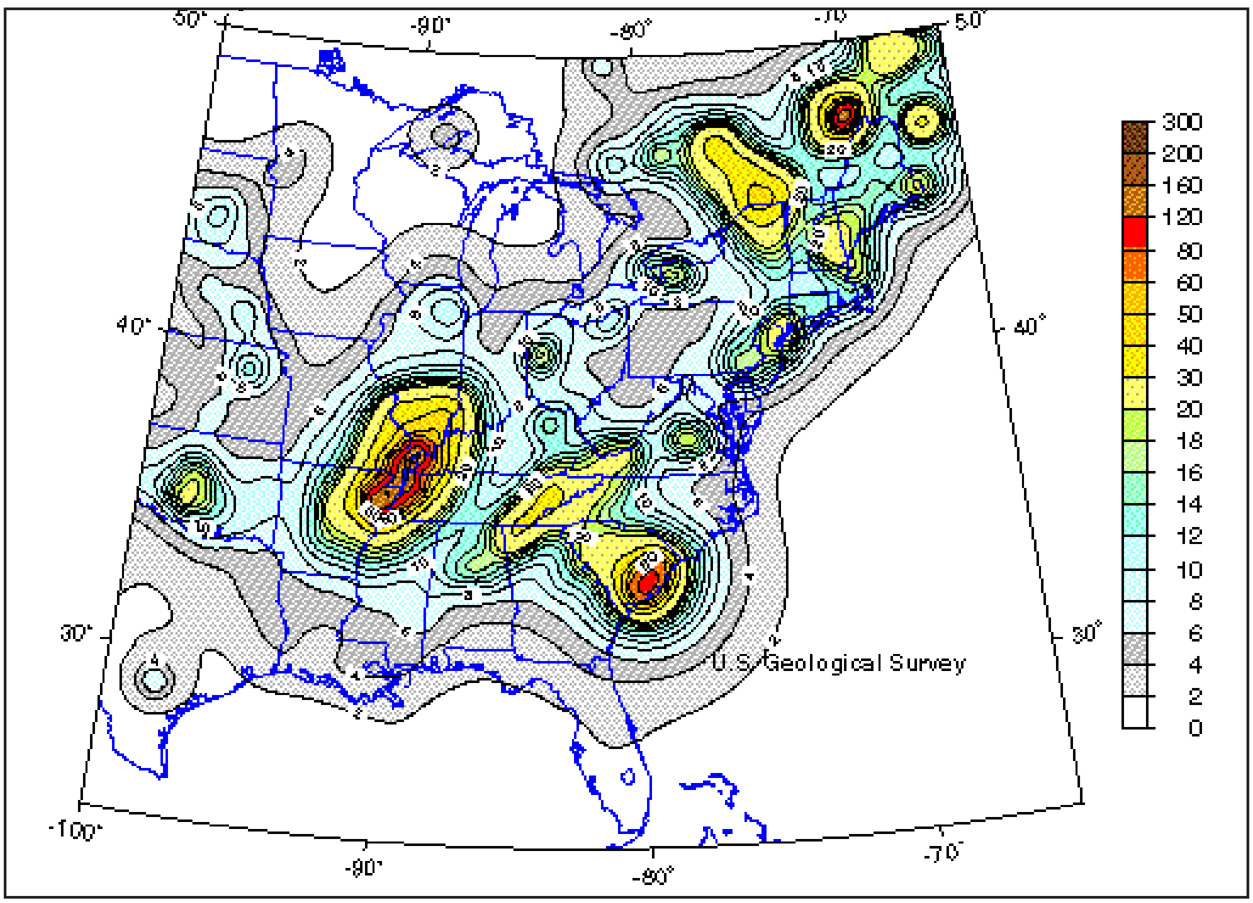


Figure 3.13.3-2 Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
Source: USGS, 2011.

3.13.4 Hazard Ranking

TABLE 3.13.4-1 HAZARD RANKING FOR EARTHQUAKE		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard occurs only very infrequently, generally less than every five years on a large scale, although localized events may be more frequent • The hazard is generally very localized and on a small scale (i.e. sub-county level) • A methodology for identifying event occurrences and/or severities is poorly established in the state, or is available only on a local basis	Low
Mitigation Potential	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The state or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor	Low

3.13.5 Sources for Earthquakes

TABLE 3.13.5-1 SOURCES FOR EARTHQUAKES	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Subpart D: Seismic Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
FEMA Earthquake Information Site	http://www.fema.gov/hazard/earthquake/
USGS Earthquakes Hazard Program	http://earthquake.usgs.gov/earthquakes/
USGS National Earthquake Information Center	http://earthquake.usgs.gov/regional/neic/
USGS Latest Earthquakes in the USA	http://earthquake.usgs.gov/earthquakes/recenteqsus/
USGS Wisconsin Earthquake History	http://earthquake.usgs.gov/earthquakes/states/wisconsin/history.php
Mid-America Earthquake Center, University of Illinois at Urbana-Champaign	http://mae.ce.uiuc.edu/
Mid-America Earthquake Center, "Impact of New Madrid Seismic Zone Earthquakes on the Central USA, Volume 1"	https://www.ideals.illinois.edu/bitstream/handle/2142/14810/ImpactofNewMadridSeismicZoneEarthquakeso%20theCentral%20USAVol1.pdf?sequence=3
University of Memphis Center for Earthquake Research and Information	http://www.ceri.memphis.edu/index.shtml
Wald et al., "Relationship between Peak Ground Acceleration, Peak Ground Motion and Modified Mercalli Intensity in California"	http://ecf.caltech.edu/~heaton/papers/Wald_intensity.pdf

3.14 LANDSLIDE AND LAND SUBSIDENCE

3.14.1 Nature of the Hazard

Landslides

Landslides are the downward and outward movement of slopes. The term refers to various kinds of events, including mudflows, mudslides, debris flows, rock falls, rockslides, debris avalanches, debris slides, and earth flows. Landslides may include any combination of natural rock, soil, or artificial fill, and are classified by the type of movement and the type of material (FEMA, 1997, p. 98). The types of movement include the following:

- **Slides** are downward displacements along one or more failure surfaces of soil or rock. The material may be a single intact mass or a number of pieces. The sliding may be rotational (turning about a point) or translational (movement roughly parallel to the failure surface). The most common type of slide is called a slump. A slump is a rotational slide occurring when a portion of a hillside moves downslope under the influence of gravity.
- **Flows** are a form of rapid mass movement by loose soils, rocks, and organic matter, together with air and water that form a rapidly downhill flowing slurry mixture. Flows are distinguished from slides by high water content and velocities that resemble those of viscous liquids.
- **Lateral spreads** are large movements of rock, fine-grained soils (i.e., quick clays), or granular soils, distributed laterally. Liquefaction may occur in loose, granular soils, and can occur spontaneously due to changes in pore-water pressure or due to earthquake vibrations.
- **Falls** and **topples** are masses of rocks or material that detach from a steep slope or cliff that free-fall, roll, or bounce. Movements typically are rapid to extremely rapid. Earthquakes commonly trigger rock falls.

A combination of two or more landslide movements is referred to as a complex movement.

Almost any steep or rugged terrain is susceptible to landslides under the right conditions. The most hazardous areas are steep slopes on ridges, hill, and mountains; incised stream channels; and slopes excavated for buildings and roads. Slide potentials are enhanced where slopes are destabilized by construction or river erosion. Road cuts and other altered or excavated areas are particularly susceptible to landslides and debris flows. Rainfall and seismic shaking by earthquakes or blasting can trigger landslides.

Debris flows (also referred to as mudslides) generally occur during intense rainfall on water-saturated soil. They usually start on steep hillsides as soil slumps or slides that liquefy and accelerate to speeds as great as 35 miles per hour. Multiple debris flows may merge, gain volume, and travel long distances from their source, making areas downslope particularly hazardous. Surface runoff channels along roadways and below culverts are common sites of debris flows and other landslides (USGS, 2000).

Landslides often occur together with other major natural disasters, thereby exacerbating relief and reconstruction efforts:

- Floods and landslides are closely related and both involve precipitation, runoff, and ground saturation that may be the result of severe thunderstorms or tropical storms.
- Earthquakes may cause landslides ranging from rock falls and topples, to massive slides and flows.
- Landslides into a reservoir may indirectly compromise dam safety or a landslide may even affect the dam itself.
- Wildfires may remove vegetation from hillsides, significantly increasing runoff and landslide potential.

Landslides are a major geologic hazard because they are widespread, occurring in all 50 states and US territories. It is estimated that landslide-related fatalities average from 25 to 50 per year and direct and indirect economic costs to the nation range between one to two billion dollars per year (USGS, 2011). The costs of landslides are increasing rapidly as lands susceptible to failure are developed for highways, housing, industry, and recreation (USGS, 2006). Landslides pose serious threats to highways and structures that support fisheries, tourism, timber harvesting, mining, and energy production, as well as general transportation.

Land Subsidence

Land subsidence occurs when subsurface supports (i.e. bedrock or soils) fail, causing a loss of surface elevation (FEMA, 1997, p. 108). This hazard is primarily caused by human activities in relation to mining and drainage of soils, but is also caused by geologic conditions. Annually in the US, land subsidence and sinkholes account for an average $125 million in damages (FEMA, p. 112).

In certain parts of the state, sinkholes are more likely to be caused by human activity. Some parts of southern and western Wisconsin have experienced sinkholes from collapsed, abandoned underground mines. In urban flooding and storm events, the Milwaukee area has had sinkholes occur in the middle of busy streets above storm sewers.

In other instances, sinkholes causing land subsidence are caused from geologic properties of bedrock, called karst formations. Karst formations are prevalent in areas where carbonate rocks, such as limestone or dolomite, are present. As the limestone rock under the soil dissolves over time from rainfall or flowing groundwater, a hollow area may form underground into which surface soil can sink.

Furthermore, karst features provide direct conduits to groundwater. Areas with karst conditions can be subject to groundwater contaminants from pollutants entering a sinkhole, fissure, or other karst features. Karst features should be identified and considered in a community, especially for land use planning, stormwater management, and hazardous materials planning, to avoid possible damage to structures or contamination of groundwater.

3.14.2 Landslide and Land Subsidence Event History

The bluffs of the "driftless" region that stretches along the Mississippi River are formed of limestone bedrock covered by an ancient mix of clay and river silt. Under most conditions, this provides a solid base for home building, though most counties restrict building to a slope of 20-30%. Homes that are built on "benches" may have much steeper areas above them (or below).

As water particles fill the space between silt particles, the silt and clay first become "plastic" and then "viscous." When "plastic" the soil will move when pressure is applied to it (such as the weight of a home). When "viscous" it begins to slow under its own weight like a glacier, only much more quickly.

Landslides in the form of stream bank erosion and hillside slumping have been a factor in several Wisconsin disasters. In 2000, during Disaster Declaration 1332, a home in Grant County was damaged when its foundation partially collapsed as the hillside slumped from heavy rainfall. Falling rock is also a common problem along the bluffs of the Mississippi River.

In 2001, a home in the City of Superior (Douglas County) was endangered as the entire yard started slipping downhill toward the Namdji River. Although the house was not in the floodplain and 100 yards from the river, stream bank erosion from the spring floods had caused the ground within fifteen feet of the house to slide downhill. The City of Superior applied for and received funding through the Hazard Mitigation Grant Program (HMGP) under Disaster Declaration 1369 to buy the threatened structure from the landowner and demolish it to protect public safety.

In several areas where railroad tracks run along the river, fences have been erected with sensors to detect rock falls that could otherwise damage or derail a train (Ron Hennings, Wisconsin Geological and Natural History Survey, 2002). According to a Wisconsin State Journal article, a 400,000-pound boulder rolled down a bluff in Fountain City (Buffalo County) in July 2002, leveling trees but causing little damage otherwise. The rock was the second to fall from the bluff in the last seven years. In 1995, a 55-ton boulder crashed into a Fountain City house, causing serious damage but fortunately no injuries (Wisconsin State Journal, 2002).

In 2002, seven properties in the Village of Oliver (Douglas County) experienced some severe land subsidence along the St. Louis River. Three of the seven properties were in imminent danger. The Village received HMGP grants in Disaster Declarations 1429 and 1432 to purchase and demolish the three homes. In mid-August 2002, owners of one of the properties discovered cracks in their garage floor. By mid-September, what was once their garage had broken off and dropped about 12 feet from the main garage slab. This property has experienced a large ground failure that has jeopardized the integrity and stability of the home. To date, there has been an 18-foot scarp that is situated approximately one foot from the rear entrance of the home. The slump at this property is approximately 100 yards in width and extends 100 to 150 feet downslope to the river's edge. The slip rate was in excess of 4.5 inches/day early on. Currently the slump is on the order of 1.5 inches/day.

Contributing to the collapse of the property is its location on top of a steep slope next to the St. Louis River (Douglas County). The soil in this area is a thick substrate of red clay, which when dry can sustain a property, but when wet loses that strength. Also, the property is approximately 300 yards from a railroad bridge. Trains passing by cause significant ground vibrations (equivalent to a 3.0 to 4.9 earthquake), disturbing the ground and causing it to collapse.

August 2007 was devastating to Wisconsin along the Upper Mississippi River. Mudslides covered roads and bluffsides collapsed into yards. One yard in the Goose Island area (La Crosse County) had 25 dump trucks of mud removed and Hwy 35 from Goose Island to Stoddard (Vernon County) had mud and debris. Two homes slid onto Hwy 35 south of La Crosse (La Crosse County). A third home near Chaseburg (Vernon County) was destroyed by a mudslide.

On August 20th of 2007, rainfall of 11-15" over two days left the Coulee country from Winona, MN to Genoa and Viroqua (Vernon County), virtually impassable. Mudslides, a few carrying homes with them, littered both major and minor roads. Bridges were awash, as creeks that normally carried a 20 foot creek flooded to 100 feet or flooded entire valleys. Household water wells filled with mud and bacteria. Waterfalls gushing over the rocky bluff faces turned normally stable hillsides into a gelatinous consistency that began an unstoppable flow down the 600 foot high bluffs. Canyons formed were there were none.

3.14.3 Probability of Occurrence

Landslide probability is highly site-specific, and cannot be accurately characterized on a statewide basis, except in the most general sense. Statewide analyses for potential have been performed by the US Geological Survey (USGS) and the Wisconsin Geological and Natural History Survey (WGNHS).

Figure 3.14.3-1, on the following page, displays the karst potential in the state. Most areas at greatest risk of shallow karst potential (less than five feet below surface) can be found in the far western and southwestern portions of the state in Buffalo, Crawford, Grant, Green, Iowa, La Crosse, Lafayette, Monroe, Pepin, Richland, Trempealeau, and Vernon counties. One main outlying area, Door County, is also at risk for shallow karst potential. Deeper karst potential (five to 300 feet below ground surface) is found largely in the eastern portion of the state along the Fox River, and into southeastern Wisconsin.

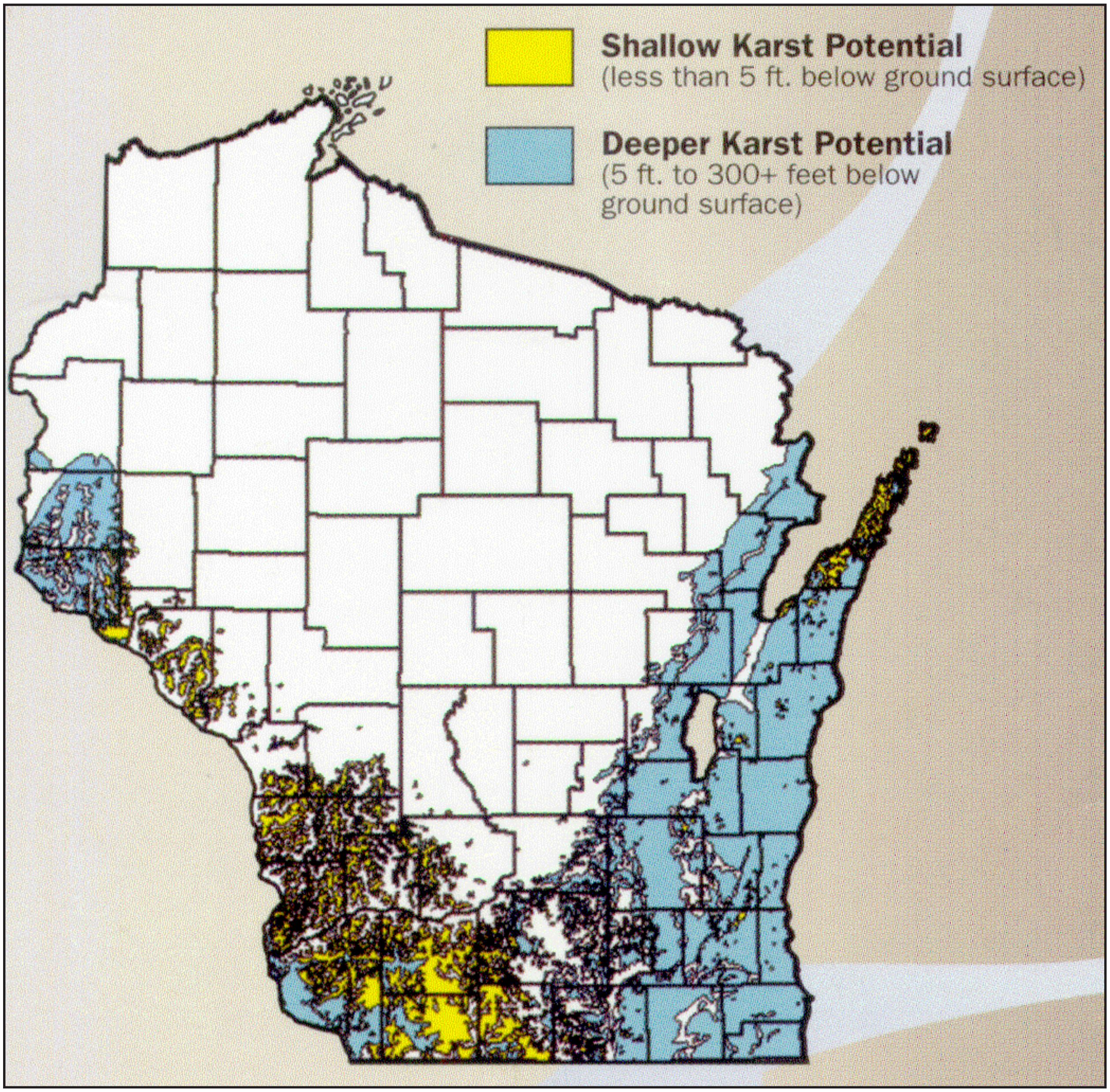


Figure 3.14.3-1 Karst Potential in Wisconsin
Source: Wisconsin Geological and Natural History Survey, 2008.

Figure 3.14.3-2, on the following page shows the areas of high landslide incidence and susceptibility in the state. The dark green areas indicate the portions of the state with high susceptibility and moderate incidence of landslides. This area coincides with the shallow karst potential along the western part of the state in Figure 3.14.3-1 in Buffalo, Crawford, Grant, La Crosse, Pepin, Pierce, Treempealeau, and Vernon counties. The area with the highest incidence, in red, is limited to Douglas County along the St. Louis River, near the City of Superior.

Another area to highlight is the shoreline along Lake Michigan. Racine and Kenosha counties are highly susceptible, due to coastal erosion, but experience low incidence. The rest of the Lake Michigan coastal counties (Door, Kewaunee, Manitowoc, Milwaukee, Ozaukee, and Sheboygan) experience moderate incidence of landslides.

Last, the Fox River valley, along with other areas in the state vulnerable to deeper karst potential, experiences moderate suceptibility, but low incidence of landslide.

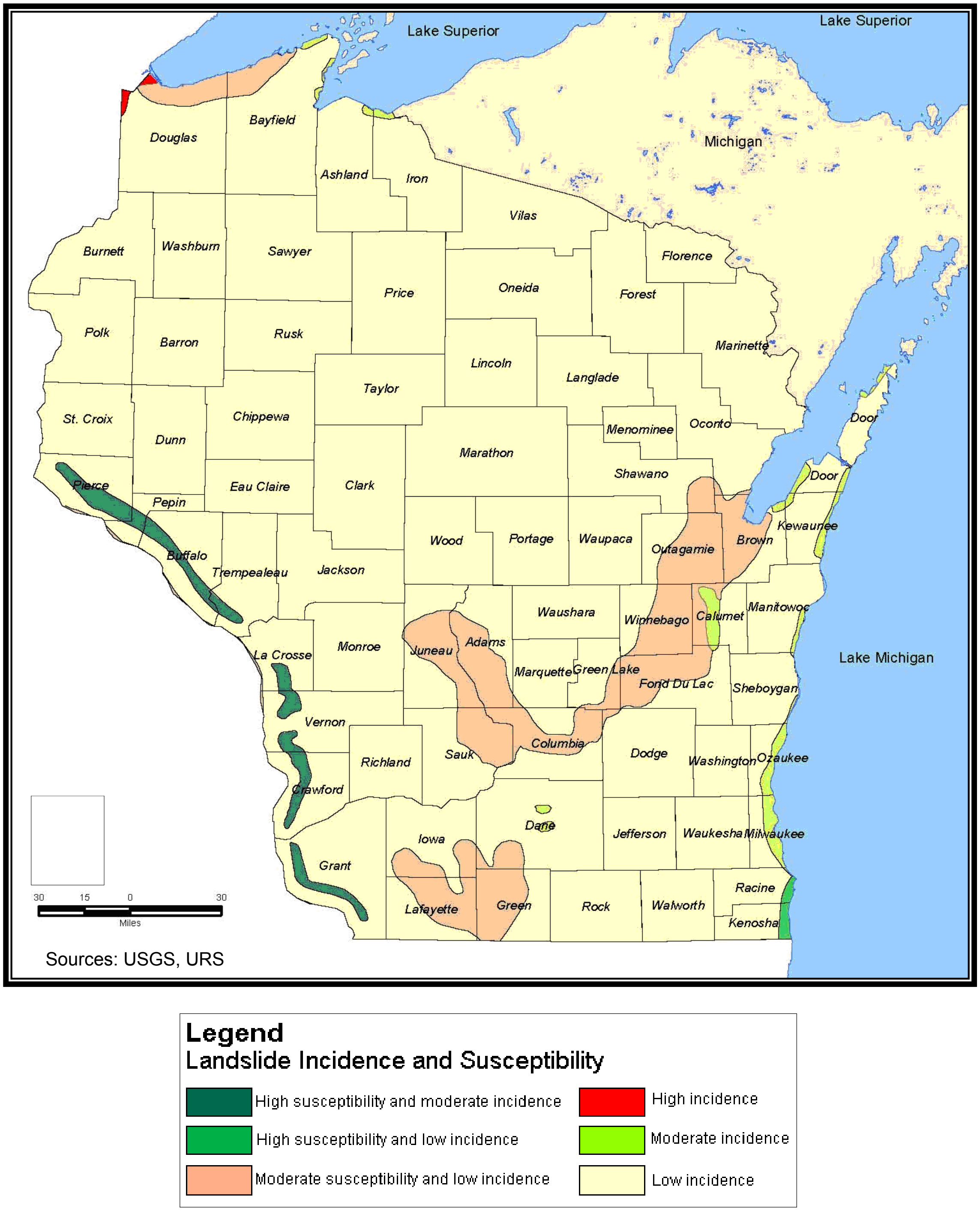


Figure 3.14.3-2 Landslide Incidence and Susceptibility in Wisconsin

3.14.4 Hazard Ranking

TABLE 3.14.4-1 HAZARD RANKING FOR LANDSLIDES AND LAND SUBSIDENCE		
Evaluation Criteria	**Description**	**Ranking**
Probability	• The hazard impacts the state occasionally, but not annually • The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs • The methodology for identifying events is not well-established, or is not applied across the entire state	Medium
Mitigation Potential	• Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental • The state or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them • Mitigation measures are ineligible under federal grant programs • There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative • The mitigation measure(s) have not been proven cost effective and are likely to be very expensive compared to the magnitude of the hazard • The long-term effectiveness of the measure is not known, or is known to be relatively poor	Low

3.14.5 Sources for Landslides and Land Subsidence

TABLE 3.14.5-1 SOURCES FOR LANDSLIDES AND LAND SUBSIDENCE	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Subpart B: Geologic Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
FEMA Landslide and Debris Flow Information Site	http://www.fema.gov/hazard/landslide/index.shtm
USGS Landslide Hazards Program	http://landslides.usgs.gov/
USGS National Landslide Information Center	http://landslides.usgs.gov/nlic/
USGS Landslide Monitoring	http://landslides.usgs.gov/monitoring/
USGS *National Landslide Hazards Mitigation Strategy: A Framework for Loss Reduction*	http://pubs.usgs.gov/of/2000/ofr-00-0450/ofr-00-0450.html
Association of Environmental & Engineering Geologists	www.aegweb.org
Wisconsin Geological and Natural History Survey	http://wisconsingeologicalsurvey.org/
Wisconsin Geological and Natural History Survey Karst Program	http://wisconsingeologicalsurvey.org/karst.htm
Wisconsin DNR Groundwater Site	http://www.dnr.state.wi.us/org/water/dwg/GCC/

3.15 DAM FAILURE

3.15.1 Nature of the Hazard

Wisconsin Dams

A dam is a barrier, typically constructed of earth, rock, concrete, or mine tailings, used to store, control, or divert water. The water impounded behind a dam is referred to as the reservoir and its volume is measured in acre-feet, with one acre-foot being the volume of water that covers one acre of land to a depth of one foot. Due to topography, even a small dam may have a reservoir containing many acre-feet of water (FEMA 1997).

Wisconsin's approximately 3,800 dams serve many purposes. Many of these dams were constructed before 1900 and were used for logging and milling operations – though these are typically not used for their original purpose today. An additional 700 dams were built but have subsequently washed out and no longer exist. Approximately 100 dams have been removed since 1967. Today, the dams are used for agricultural production/land management, recreational uses, electrical power generation, and erosion, water level, and flood control (DNR, 2011). Of the existing dams,

- 60% are owned by individuals or former companies;
- 9% are owned by the State of Wisconsin;
- 17% are owned by municipal governments (i.e. towns and counties); and
- 14% are owned by other groups.

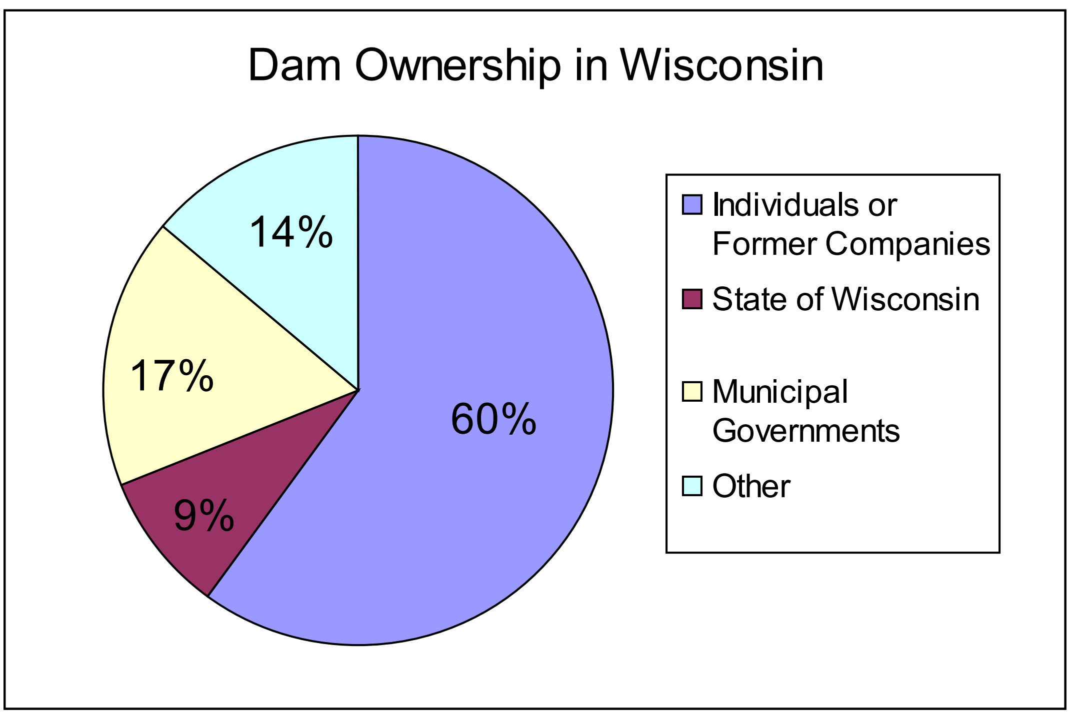


Figure 3.15.1-1 Distribution of Dam Ownership in Wisconsin
Source: Wisconsin Department of Natural Resources, 2011.

About 200 large hydroelectric dams in Wisconsin are federally regulated, while the remaining 3,600 dams are regulated at the state level by the WDNR.

Additionally, State-regulated dams are classified by the DNR as either large or small. Large dams have either

- a structural height of over six feet and impound 50 acre-feet of water or more, or
- a structural height of over 25 feet and impound 15 acre-feet of water or more.

There are approximately 1,160 large dams in the state (DNR, 2011). The remaining dams are classified as small dams, and tend to be subject to less stringent regulation. Figure 3.15.1-2, on the following page, displays the location of large and small State-regulated dams in Wisconsin. Notice the large concentration of small dams along the western part of the state.

Dam Failure

A dam failure is the collapse, breach, or other failure of a dam that causes downstream flooding (FEMA, 1997). Dam failures usually occur when the spillway capacity is inadequate and water overtops the dam or when internal erosion through the dam foundation occurs (also known as piping). If internal erosion or overtopping cause a full structural breach, a high-velocity, debris-laden wall of water is released and rushes downstream, damaging or destroying whatever is in its path. Dam failures may result from one or more the following:

- Prolonged periods of rainfall and flooding (the cause of most failures)
- Inadequate spillway capacity which causes excess overtopping flows
- Landslides into reservoirs
- High winds
- Improper maintenance
- Internal erosion erosions due to embankment or foundation leakage or piping
- Improper design
- Negligent operation
- Failure of upstream dams
- Earthquakes

For emergency planning purposes, dam failures are categorized one of the following:

1. Rainy Day Failures
   Rainy day failures involve periods of excessive precipitation leading to unusually high runoff. This high runoff increases the reservoir level, and if not controlled, the overtopping of the dam or excessive water pressure can lead to dam failure. Normal storm events can also lead to rainy day failures if water outlets are plugged with debris or otherwise made inoperable.
2. Sunny Day Failures
   Sunny day failures occur due to poor dam maintenance, damage/obstruction of outlet systems, or vandalism. This is the worst type of failure and can be catastrophic because the breach is unexpected and there may be insufficient time to properly warn downstream residents.

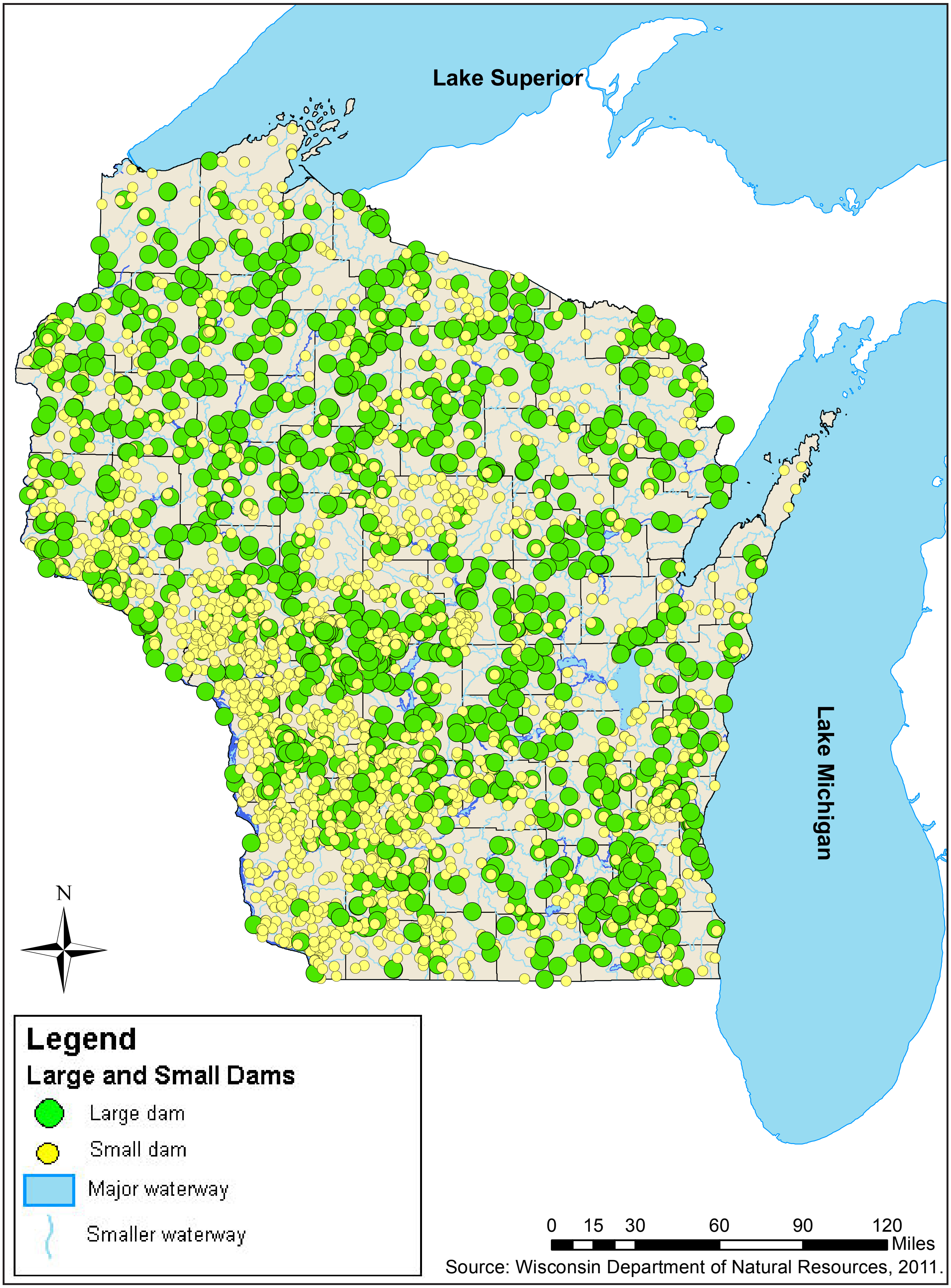


Figure 3.15.1-2 Locations of Large and Small Dams in Wisconsin

Among the 3,800 dams in Wisconsin, there is a wide variance in the potential to cause damage in the event of failure. Very few dams in Wisconsin were built primarily to protect people and property from floods. Most of the dams that provide a flood-control benefit are large hydroelectric dams on major rivers where flood control is a secondary benefit, or they are what are referred to as PL-566 dams, which are dams built through the Watershed Protection and Flood Prevention Act of 1954. Wisconsin has 83 PL-566 dams, located mainly in the western part of the state. The PL-566 dams often hold little or no water in their reservoirs under normal conditions. Since these dams only hold significant amounts of water during floods, they present a special hazard as everyday water-related problems such as seepage cannot be readily seen and corrected.

3.15.2 Wisconsin Dam Failure Event History

Nationwide, the deadliest dam failure in US history occurred in Johnstown, Pennsylvania in 1889. More than 2,200 people died. Another significant failure on June 5, 1976 at the Teton Dam in Idaho killed 11 people and caused approximately $1 billion in damages (FEMA, 1997).

On the night of September 1, 1985, a flooding event nearly overtopped the 66-foot tall Orienta Falls power-generating dam on the Iron River (Bayfield County). Heavy waters overwhelmed the earth embankment and bulldozed away the dam's powerhouse walls. The dam, operated by Northern States Power, was severely damaged. Additionally, three bridges were destroyed, telephone service was cut, many roads and culverts were washed away, and although no one died, two families downstream were evacuated for fear the whole dam would collapse. The flood brought down the Orienta Dam, but changing times prevented its expensive $500,000 repair. The river was returned to its natural state (Katherine Esposito, Wisconsin Natural Resources Magazine, April 1999).

Excessive precipitation (nine inches of rain in four hours) in August 1990 stressed the 50-year old Lake Tomah Dam (Monroe County), imperiling the lives of approximately 2,000 residents of the City of Tomah (Monroe County) who had to be evacuated from their homes. Municipal workers, volunteers, and Wisconsin National Guard personnel averted a breach by using more than 20,000 sand bags to reinforce the structure. A large crane was used to open the floodgates and the level of the lake dropped eight inches in one hour. The excess water emptied into the Lemonweir River, which overtopped its banks and rose approximately two inches per minute until it stabilized.

In March 1993, the Briggsville Dam (Marquette County) failed and washed out the embankment. Fortunately, severe property damage was averted, but a recreational lake was completely drained. This failure was just one of many that occurred in 1993, a record year for precipitation and flooding.

One of the more publicized 1993 incidents involved the Hatfield Dam (Jackson County). A power canal dike at the dam failed due to flooding. Initial reports from the area indicated that the main dam had failed, but this proved to be incorrect. A summary of dam washouts, overtopping, or damages associated with the 1993 floods is provided in Table 3.15.2-1, below.

TABLE 3.15.2-1 1993 DAM FAILURES/DAMAGES IN WISCONSIN			
Season	County	Dam	Event
Winter	Juneau	Partridge Lake Dam	Dam was washed out
Spring	Dodge	Lake Emily Dam	Dam was washed out/damaged
Spring	Dodge	Lowell Dam	Dam was washed out/damaged
Spring	Iowa	Cox Hollow Dam	Dam was washed out/damaged
Spring	Iowa	Wright Dam	Dam was washed out/damaged
Spring	Jefferson	Hebron Dam	Dam was overtopped
Spring	Jefferson	Upper Watertown Dam	Dam was overtopped
Spring	Marquette	Briggsville Dam	Dam was washed out/damaged
Spring	Racine	Waterford Dam	Dam was washed out/damaged
Spring	Sheboygan	Gooseville Dam	Dam was washed out/damaged
Summer	Clark	Humbird Dam	Embankments washed out
Summer	Columbia	Jordan Dam	Emergency repairs made to prevent embankment failure
Summer	Columbia	Cambria Dam	Dam was washed out
Summer	Dodge	Fox Lake Dam	Embankment problems caused seepage
Summer	Eau Claire	Dells Dam	Damage to waterwheel
Summer	Eau Claire	Fairchild Dam	Dike overtopped, road washed out
Summer	Eau Claire	Lake Dam	Dam was washed out
Summer	Eau Claire	Lake Eau Claire Dam	Gate broken in attempt to open it
Summer	Eau Claire	Rock Dam	Dam was washed out
Summer	Jackson	ASP Cranberry Dikes	Two dikes were washed out
Summer	Jackson	Hatfield Dam	Dam was washed out
Summer	Jackson	Roberts Cranberry Dikes	Four dikes were washed out
Summer	Marquette	Packers Bay Dam	Embankment overtopped
Summer	Oconto	Reservoir/Dummy Dams	Lake bypassed through low area, road damage
Summer	Outagamie	Upper Appleton Dam	high head caused grout patch failure, seepage through wall
Summer	Rock	Shopier Dam	Emergency repairs made to fill embankment breach
Summer	Waupaca	Auld & Rohrer Dam	Contractor breached embankment to prevent spillway construction from failing
Summer	Waupaca	Bass Lake Dam	Dam was washed out
Summer	Trempealeau	Blair Dam	Slow gate operation caused downstream road embankment erosion

Source: Wisconsin Department of Natural Resources, 1993.

In September 1994, heavy rainfall in Price County caused concern over the potential failure of the Musser, Jobe, and Weimer Dams. Price County Emergency Management, Wisconsin Emergency Management (WEM), and DNR Dam Safety staff monitored a command post above the Musser dam, while the Wisconsin Conservation Corps coordinated local sandbagging efforts. Evacuation of low-lying areas below the Musser Dam was ordered as construction crews attempted to open the inoperable floodgates. The floodgates were opened, allowing maximum release of water behind the dam and averting a near catastrophic situation at the Musser Dam. Nearby, the Ladysmith Dam (Rusk County) overtopped during this event and partially failed. City, County, and State emergency personnel responded.

The Radigan Dam (Douglas County) sustained major damage from flooding associated with Disaster Declaration 1369 in May 2001. Fortunately, the dam did not completely fail, but the amount of damages exceeded $300,000.

Between 1990 and 1995, over 75 Wisconsin dams failed. Many of these dam failures were associated with the Great Midwest Flood of 1993. Though none of these failures resulted in any loss of life, injuries and extensive property damage occurred during several events.

On September 2, 2002, heavy rains occurred in the far western counties of Wisconsin. In the Village of Osceola (Polk County), heavy rain caused an old milldam to breach, crashing floodwaters through a mobile home park. The torrent continued downstream, overtopping a second dam and causing extensive road damage.

In August of 2007, heavy rains severely affected southwest Wisconsin. Many dams were stressed and overtopped. In Vernon County, many dams were overwhelmed with debris (in the form of large, round hay bails) and water. As a result, the dams either failed, seeped water, or were under significant stress. Major repairs needed to be made to at least 22 dams in Vernon County. Unfortunately, the funds were not available for these repairs. As a result, Vernon County passed a county sales tax referendum in 2008 to assist with funding the repairs. With the additional revenue the county would see from the 0.5% countywide sales tax, an estimated $1.1 million per year will be raised for dam repair.

With the severe flooding in June 2008, many dams in southern Wisconsin were stressed and overtopped. In Sauk County, Dell Creek Dam on Lake Delton overtopped and the lake washed out the isthmus separating it from the Wisconsin River, taking five homes and part of County Highway A with it. Throughout the storm event, Wisconsin DNR Dam Safety staff monitored over 200 stressed dams.

Counties across the State are struggling to find funds for repair and maintenance. In a 2007 report, the American Society of Civil Engineers noted that Wisconsin's "dams are not being inspected as required and repair grants have been curtailed due to lack of funding." The increased number of flooding events exacerbate the problem. Lack of funding is most conspicuous in the state's Dam Maintenance, Repair, Modification, and Removal

Grant, established by the Wisconsin legislature in 1989. At its inception, the grant was funded but since 2001, the grant has gone essentially unfunded (Wisconsin Dams, 2008).

3.15.3 Probability of Occurrence

The direct economic impact of a dam or levee failure includes, but is not limited to, the cost of repair of the dam or levee, the flood damage resulting from the failure, and loss of income due to displaced businesses or workers. Though there have been very few dam failures in Wisconsin resulting in major damages or loss of life, many existing dams are starting to need more frequent repairs.

Since 1917, the DNR has administered the Dam Safety program, under Chapter 31 in the Wisconsin State Statues which regulates all dams and bridges affecting navigable waters in the State (Wisconsin Code § 31). Chapter NR 333 was updated in 1985, changing the way that dam safety is enforced for large dams that are State-regulated in order "to minimize the danger to life, health, and property" (Wisconsin Code § NR 333.01). NR 333 mandates that an Inspection, Operation, and Maintenance (IOM) Plan is approved in accordance with NR 333. Dam IOM Plans are evaluated for compliance in the following situations:

- When a new dam is being designed and constructed
- Within ten years of performing a hazard analysis on an existing dam
- When an existing dam is reconstructed
- After a dam failure analysis is approved by the DNR
- When a dam is adopted in a floodplain zoning ordinance
- When the DNR issues a department directive ordering a dam safety inspection

Figure 3.15.3-1, on the following page, shows the approval status of IOM Plans for large dams. There are about 970 dams without approved IOM Plans as of December 2010. It is important to note that many of these dams have not had a hazard analysis performed or are within the initial ten years of having their hazard analysis performed; however, some of these dams were found to be out of compliance at a later date.

Under NR 333 the DNR assigns hazard ratings to large dams in the state. Two factors are considered when assigning hazard ratings: existing land use and land use controls (zoning) downstream of the dam. Dams are classified in one of three categories that identify the potential hazard to life and property:

1. **High hazard** – failure of dam would probably result in the loss of life
2. **Significant hazard** – failure of dam could result in appreciable property damage
3. **Low hazard** – failure would result in only minimal property damage and loss of life is unlikely

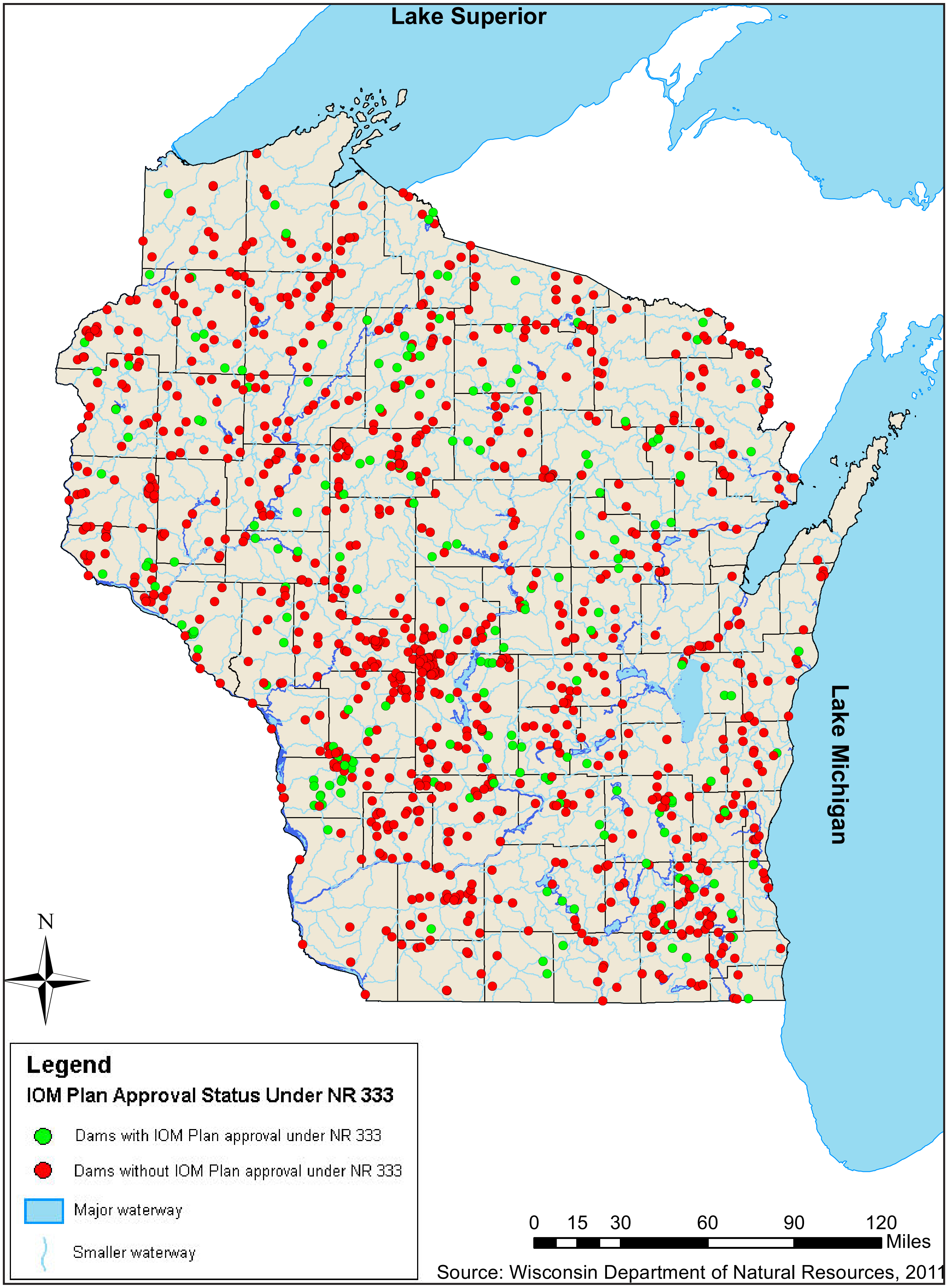


Figure 3.15.3-1 Dam Inspection, Operation, and Maintenance Plan Approval Status in Wisconsin

Figures 3.15.3-2 and 3.15.3-3 are on the following two pages. Figure 3.15.3-2 shows the locations of dams in Wisconsin with high or significant hazard ratings. The map only includes dams on which the DNR has performed a dam failure analysis and rated as high or significant. As previously stated, there are hundreds of dams without dam failure analyses throughout the state. Most dams displayed on the map are large dams, since very few small dams have had hazard analyses performed. Of the dams shown on the map, very few high- or significant-hazard dams are near high population centers such as the Madison or Milwaukee areas.

Figure 3.15.3-3 displays dams that have not had a hazard analysis. A vast majority of these dams are those classified as small dams. There are several large dams and un-classified dams without hazard analyses.

Furthermore, according to the American Society of Civil Engineers (ASCE) "Report Card for America's Infrastructure," 55% of Wisconsin's high hazard dams have no emergency action plan addressing surveillance, response, and evacuation in the event of dam failure (ASCE, 2010).

3.15.4 Hazard Ranking

TABLE 3.15.4-1 HAZARD RANKING FOR DAM FAILURE

Evaluation Criteria	Description	Ranking
Probability	• The hazard has impacted the state annually, or more frequently • The hazard is widespread, generally affecting regions or multiple counties in each event • There is a reliable methodology for identifying events and locations	High
Mitigation Potential	• Mitigation methods are established • The state or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard • Some mitigation measures are eligible for federal grants • There is a limited range of effective mitigation measures for the hazard • Mitigation measures are cost-effective only in limited circumstances • Mitigation measures are effective for a reasonable period of time	Medium

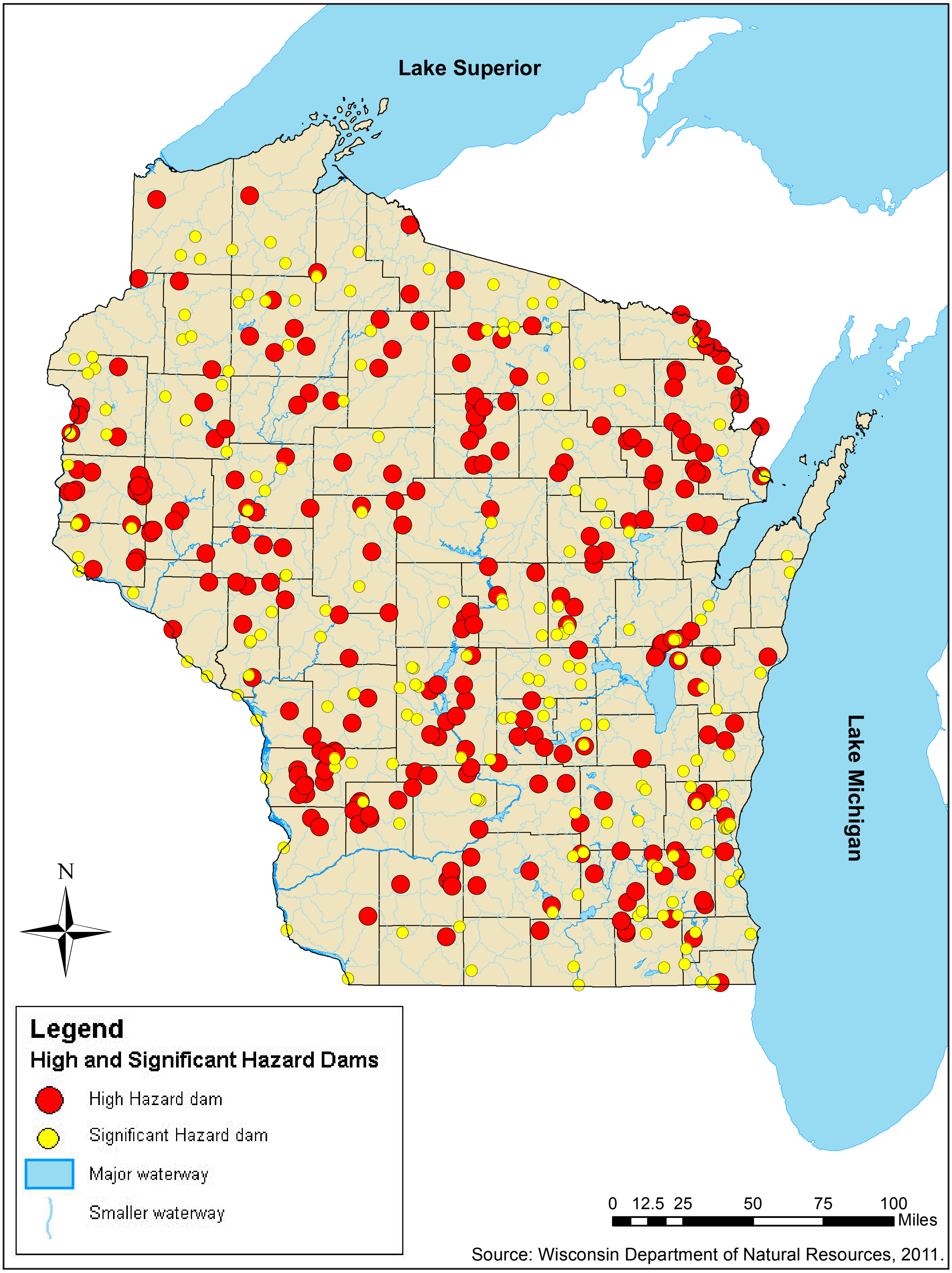


Figure 3.15.3-2 High- and Significant-Hazard Dams in Wisconsin

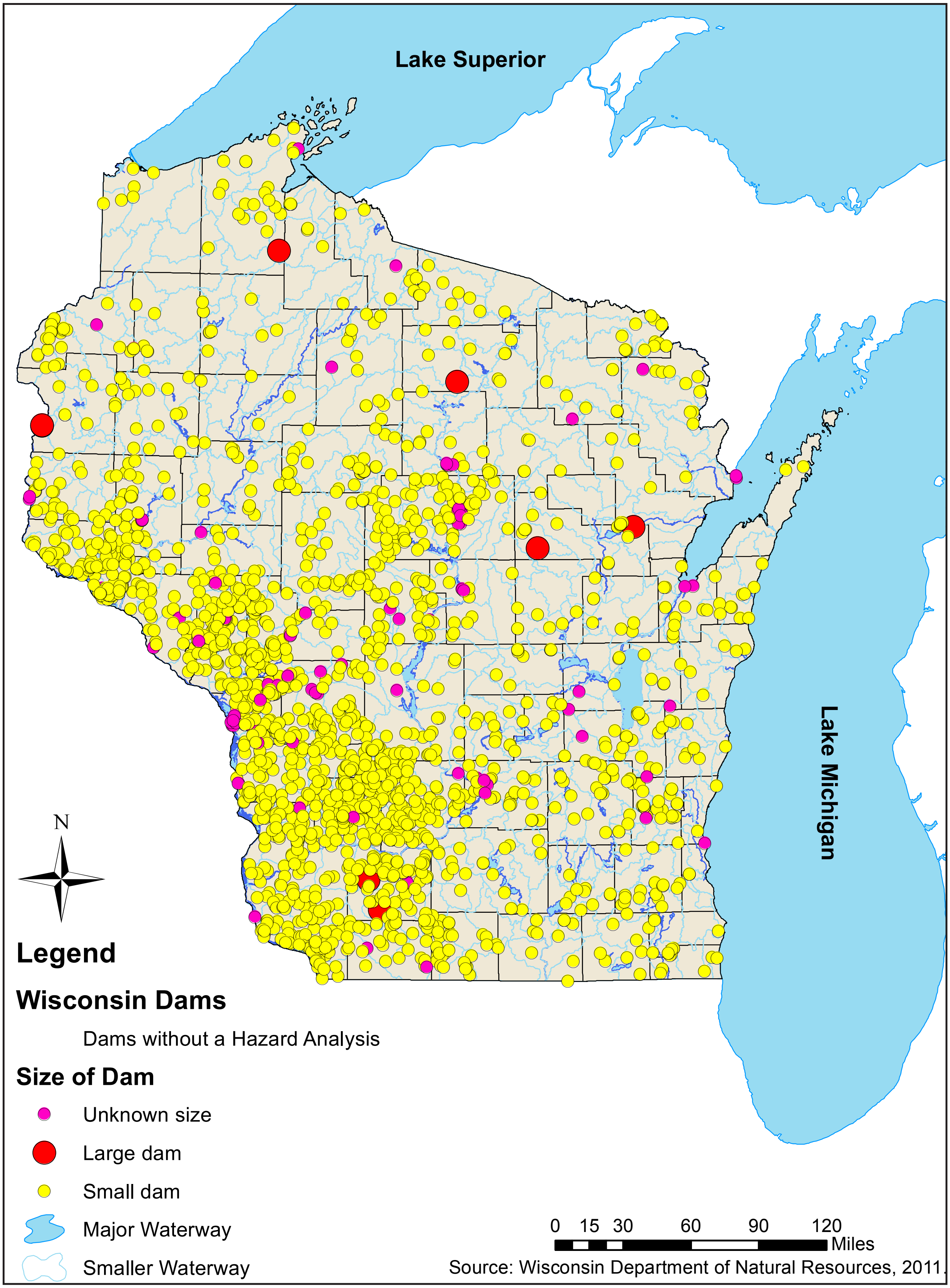


Figure 3.15.3-3 Dams without a Hazard Analysis in Wisconsin

3.15.5 Sources for Dam Failure

TABLE 3.15.5-1 SOURCES FOR DAM FAILURE	
Source Title	**Link to Resource**
FEMA's Multi-Hazard Identification and Risk Assessment, "Part 2: Technological Hazards"	http://www.fema.gov/library/viewRecord.do?id=2214
FEMA Dam Failure Information Site	http://www.fema.gov/hazard/damfailure/index.shtm
FEMA Dam Safety Publications and Resources	http://www.fema.gov/plan/prevent/damfailure/publications.shtm
US Department of the Interior, Bureau of Reclamation Dam Safety	http://www.usbr.gov/ssle/damsafety/
Wisconsin DNR Dam Safety Program	http://dnr.wi.gov/org/water/wm/dsfm/dams/
Wisconsin DNR Dam Inspection Database Search	http://dnr.wi.gov/damsafety/search.aspx
Association of State Dam Safety Officials	http://www.damsafety.org/
US Society on Dams	http://www.ussdams.org/
American Society of Civil Engineers Dam Report Card	http://www.infrastructurereportcard.org/fact-sheet/dams
American Society of Civil Engineers Levee Report Card	http://www.infrastructurereportcard.org/fact-sheet/levees
American Society of Civil Engineers Wisconsin Infrastructure Report Card	http://www.infrastructurereportcard.org/state-page/wisconsin

Other Sources:

Esposito, Katherine. 1999. "Dammed If You Do and Damned If You Don't," Wisconsin Natural Resources Magazine, April 1999. Wisconsin Department of Natural Resources. Accessed on the World Wide Web at http://dnr.wi.gov/wnrmag/html/stories/1999/apr99/dams.htm.

3.16 CLIMATE CHANGE

Weather is the short-term condition of the atmosphere. Climate is the long-term behavior of the atmosphere. Climate change indicates a significant, long-term change in weather patterns (NASA, 2011).

Global warming has been occurring over the past century. The average surface temperature of the earth has risen by about 0.8°C (= 1.4°F) (EPA, 2011). Most scientists agree that the dramatic increase is the result of human actions, but a few scientists think that it may be a coincidence or that other forces may be responsible. In addition, there is a debate over the potential effects of global warming. Some believe it will be very detrimental to the Earth's environment. Others believe the impacts will be small and humans and the environment will adapt easily. Because the potential for adverse or catastrophic situations resulting from global warming exists, this update of the Plan addresses the issue of climate change. This section will be expanded upon in future Plan updates as more information becomes available.

3.16.1 Nature of the Hazard

In the state, the Wisconsin Initiative on Climate Change Impacts (WICCI) has been researching specific effects of climate change in Wisconsin. WICCI is a partnership between the University of Wisconsin, Wisconsin Department of Natural Resources (DNR), and other state agencies and institutions. The group was formed in 2007 as a response to a bi-partisan State legislative committee wanting to better understand potential effects of this hazard in the state.

In much of its preliminary work, WICCI has found that Wisconsin's climate has changed in a pattern that is consistent with the well-documented historical global trend. This analysis was completed after examining daily weather data gathered from 176 weather stations from throughout the state from 1950 through 2006. Specifically, WICCI worked with the National Weather Service (NWS) to measure daily maximum and minimum temperatures, and used linear regression to configure the "best fit lines" for the entire time series (WICCI, 2009). (For more about the methodology used by WICCI, please visit: http://www.wicci.wisc.edu/climate-modeling-methods.php.)

Key findings from analyzing historical data:

- Figure 3.16.1-1, on the following page, shows the annual average temperature change throughout the state. Based on the data collected from 1950 through 2006, there was a statewide increase in annual average temperature of 1.1°F, with the peak warming in the northwest portion of Wisconsin (WICCI, 2009).
- The observed average temperature increase in the state has been highest for winter. Statewide, the temperatures have increased 2.5°F since 1950, with 3.5°F to 4.5°F increases in the northwest portion of the state, as seen in Figure 3.16.1-2.
- Wisconsin experiences fewer nights below 0°F than in 1950. Specifically, most of the state sees between two and six fewer nights, while the extreme northwest-

ern portion of the state experiences between 18 and 24 fewer nights below 0°F (WICCI, 2009).

- Statewide, the average growing season lasts 12 days longer than it did in the 1950 (WICCI, 2009). In other words, the "spring thaw" comes sooner, and the "fall freeze" comes later.
- Wisconsin has experienced a 10% increase in average annual precipitation over the 56 year period from 1950 to 2006. This is an annual average of about three more inches of precipitation than in the 1950s (WICCI, 2009). Figure 3.16.1-3 , on the following page, shows the statewide distribution. Noteworthy is the additional precipitation, as much as seven inches, in areas with high population density, such as near Madison (Dane County), Milwaukee (Milwaukee County), Eau Claire (Eau Claire County), and Hudson (Saint Croix County).

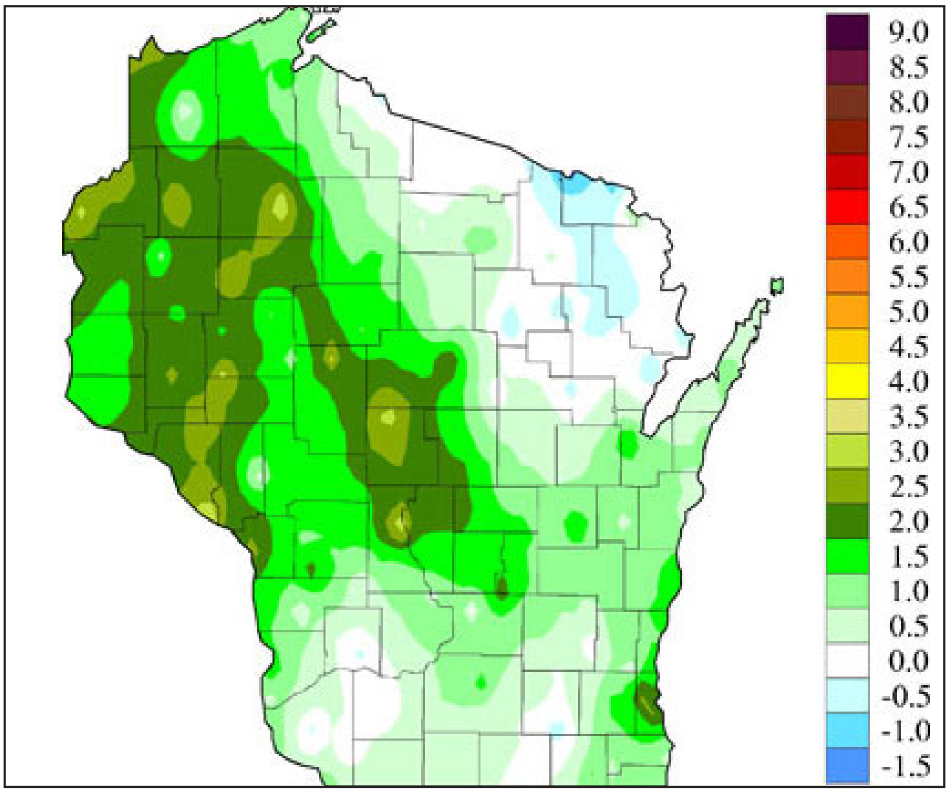


Figure 3.16.1-1 Change in Average Annual Temperature (°F), 1950-2006
Source: Wisconsin Initiative on Climate Change Impacts, "How is Wisconsin's Climate Changing?" 2009.

3.16.2 Probability of Occurrence

In relation to climate change, the future is uncertain, with varying models predicting a range of outcomes. It is unknown how much the climate will change and at what speed it will change. As further research is performed, better models can be created and understood. The 2014 State Hazard Mitigation Plan Update will have new data and modeling methods to draw from, in the hope that this hazard can be better understood.

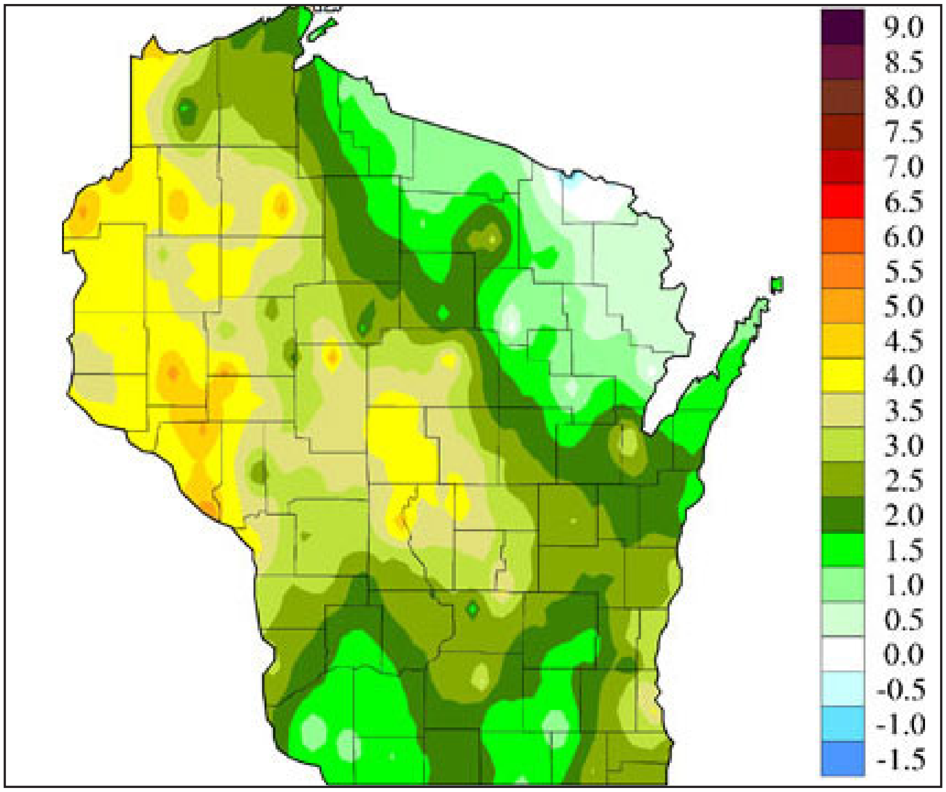


Figure 3.16.1-2 Change in Average Winter Temperature (°F), 1950-2006
Source: Wisconsin Initiative on Climate Change Impacts, "How is Wisconsin's Climate Changing?" 2009.

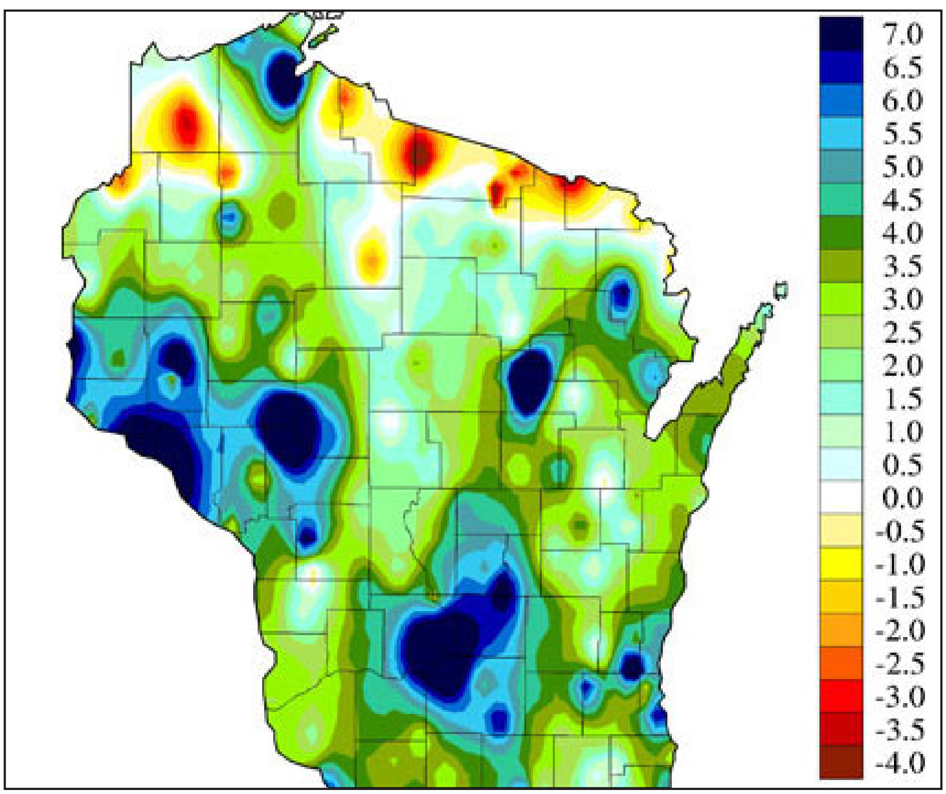


Figure 3.16.1-3 Change in Average Annual Precipitation (inches), 1950-2006
Source: Wisconsin Initiative on Climate Change Impacts, "How is Wisconsin's Climate Changing?" 2009.

3.16.3 Sources for Climate Change

TABLE 3.16.3-1 SOURCES FOR CLIMATE CHANGE	
Source Title	**Link to Resource**
Intergovernmental Panel on Climate Change	http://www.ipcc.ch/
NOAA Climate Services	http://www.wicci.wisc.edu/resources.php
United States Environmental Protection Agency Climate Change Site	http://www.epa.gov/climatechange/
NASA Global Climate Change Site	http://climate.nasa.gov/
WICCI Homepage	http://www.wicci.wisc.edu/
WICCI Climate Change Overview	http://www.wicci.wisc.edu/climate-change.php
WICCI Climate Change Modeling Methodology	http://www.wicci.wisc.edu/climate-modeling-methods.php
WICCI Resources	http://www.wicci.wisc.edu/resources.php
University of Wisconsin Nelson Institute for Environmental Studies	http://www.nelson.wisc.edu/
University of Wisconsin Sea Grant Institute Climate Change Site	http://www.seagrant.wisc.edu/home/Topics/ClimateChange.aspx

3.17 RISKS TO STATE-OWNED AND -OPERATED CRITICAL FACILITIES

This section of the Wisconsin risk assessment is intended to meet IFR requirements in subsection 201.4 (c) (2) (iii). The IFR states that the State Hazard Mitigation Plan:

> "[S]hall include…[a]n overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State shall estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas."

The 2008 plan included a flood, tornado, and straight-line wind risk assessment of State-owned and -operated critical facilities that used data at the facility level. Wisconsin Emergency Management (WEM) is currently in the process of completing a statewide, State-owned and -operated critical facility project. The completed project will allow WEM to do a more comprehensive risk assessment on State-owned and -operated critical facilities.

Critical infrastructure includes any system or asset that, if disabled or disrupted in any significant way, would result in catastrophic loss of life or catastrophic economic loss.

Critical facilities commonly include all public and private facilities that a community considers essential for the delivery of vital services and for the protection of the community. They usually include emergency response facilities, custodial facilities, schools, emergency shelters, utilities, communications facilities, and any other assets determined by the community to be of critical importance for the protection of the health, safety, and welfare of the population. The adverse effects of damaged critical facilities can extend far beyond direct physical damage. Disruption of health care, fire, and police services can impair search and rescue, emergency medical care, and even access to damaged areas. Furthermore, there exists the potential to cause serious bodily harm, extensive property damage, or disruption of vital socioeconomic activities if they are destroyed or damaged or if their functionality is impaired.

3.17.1 Flood Risk

Flood risk is highly site- and building-specific; truly accurate risk calculations can be accomplished only when there is detailed information about floodplain characteristics and the various aspects of an asset that could be damaged by floods. The flood risk assessment is done by two methods, discussed in more detail in the sections below. Note that unlike some other hazards (tornadoes for example), flood risk assessments must be conducted at the level of specific buildings, assets, or sites in order to be accurate. The methods used in this section provide a general idea of risk under pre-determined flood scenarios but do not use site-specific flood risk data, such as Flood Insurance Studies (FIS) or Flood Insurance Rate Maps (FIRMs). Because of this, there is no way to accurately determine the probability of floods occurring there. As discussed elsewhere in this report, probability is an essential feature of accurate risk assessment, so the results of this assessment should be considered only a general guide to risk under certain flood scenarios. The information should be used to prioritize those facilities that appear to have the most risk (i.e. the most significant potential future losses) and those facilities should be provided more detailed risk assessments in the future.

The 2005 plan included a flood risk assessment of State-owned and -operated critical facilities that used data at the facility level. Since 2005, Wisconsin Emergency Management (WEM) has been conducting a statewide, State-owned and -operated critical facility project. Currently, the only State agency with a completed building inventory is the Department of Corrections. The findings from the Department of Corrections are detailed in Section 3.17.4.

Data Management

Two kinds of data are required for risk assessments:

1. Probability and severity of the hazard
2. Physical and operational characteristics of vulnerable assets

Section 3.2 provides a general discussion of risk and vulnerability. The primary source of information about the State-owned and -operated facilities considered in this section was a database created by WEM in the form of a spreadsheet that included approximately 6,500 assets statewide. The accuracy and completeness of this database was not independently verified as part of this risk assessment.

The data provided by WEM include a wide range of State assets that were determined to be critical facilities. Based on the limited data available on State-owned buildings from an initial list provided by the Department of Administration, WEM reviewed the inventory and identified those buildings that could be considered critical facilities. In determining whether or not a building or structure was potentially a critical facility, WEM looked at its purpose and function(s), whether the facility's operation was critical to State operations, or critical in protecting the public health and safety of citizens and property during a disaster. Critical structures fell into the following categories:

1. A facility or structure related to communications – includes radio and television facilities for EAS, communications towers, etc.
2. A facility or structure that generated electrical power, provided heating, wastewater treatment, or water sources
3. Hospitals, homes, and other medical type facilities
4. Correctional facilities
5. Major state government facilities that house key state operations
6. Critical military facilities
7. Emergency response facilities related to law enforcement, security, fire, etc.

Based on this methodology, WEM identified an initial list of 460 critical facilities. The list was reduced to 452 for analyses because eight of the facilities did not have sufficient basic data to conduct the calculations. The following data were used in the calculation:

- **Asset Name Data**
  The Asset Name field in the database was fully populated in the initial version and required no adjustment.
- **Year Occupied Data**
  The Year Occupied field in the database was mostly populated, with only a few entries missing in the initial version. This is not a critical field for analysis except in cases where it is used in conjunction with the Use field to populate the construction type field by algorithm (see notes below).
- **Gross Square Footage Data**
  The Gross Square Footage (GSF) field in the database was partially populated in the initial version of the database. Several facilities did not list the GSF. In that case, the GSF for each facility was estimated based on similar facilities in the database. If there was no comparable facility, that particular facility was removed from the database, which was the case for eight facilities (two lightly engineered and six fully engineered buildings). The total number of structures considered in the risk assessment is 452. The GSF data was used to estimate the building occupancy which is included in the injury and mortality calculations.
- **Replacement Value Data**
  The Replacement Value field was populated in the initial version of the database. The data was used verbatim in the analysis. Table 3.17.1-1, below, shows the replacement values of the initial list of critical facilities provided by the Department of Administration and the final list of critical facilities selected by WEM for the risk assessment.

TABLE 3.17.1-1 STATE-OWNED AND -OPERATED CRITICAL FACILITIES SELECTED BY WEM

Category	Replacement Value Range	Initial List of Facilities	Facilities Selected by WEM
1	$100,000 - $599,999	1404	0
2	$600,000 - $1,000,000	238	52
3	$1,000,000 +	1223	408
4	Less than $100,000	3,595	0
Total		**6460**	**460**

Source: WEM, 2008.

Flood Probability

The basic assumption of the calculation is that the State-owned assets are subject to a two-foot flood. This is in turn based on an assumption that the facilities are within the boundaries of the 100-year floodplain. As discussed earlier, true flood risk assessments must be based on local conditions, i.e. flood probabilities in specific places. A single 1% annual probability is used for the present calculation. In fact, all floodprone sites are subject to a range of floods annually, and a comprehensive risk assessment would consider the annual probability of each flood event, and use an integrated calculation to determine the true risk. The figures generated by this method are best characterized as "potential flood exposure" rather than an absolute measure of risk.

Calculation Methodology

As noted, flood risk calculations are performed by assuming a two-foot flood in State-owned (and -operated) assets. The calculation uses a simple 1% probability flood (the 100-year flood) to determine damages. The damages from this event are then projected to a 30-year horizon using the OMB-mandated methodology.

TABLE 3.17.1-2 BUILDING TYPE AND NUMBER IN DATABASE

Asset Type	Number
Manufactured Housing	0
Non-Engineered Wood Frame	38
Lightly Engineered	290
Non-Engineered Masonry	0
Fully-Engineered	124
Total	**452**

Source: WEM, 2008.

The facilities were sorted into one of five building types, as shown in Table 3.17.1-2 (left). Many of the State-owned and -operated structures in the Wisconsin database provided by WEM included an "ISO Building Type," but this classification system could not be readily translated to flood (or wind, in later sections) damage functions, so it was necessary to assign more appropriate building types to the structures in the database. The assignment of building types to the structures was based on a combination of construction date, use (as determined by the name of the building which appeared representative of the use in most cases), and size.

The occupancy load of each facility was determined by estimating the number of people per square foot that would occupy the facility. Then this number was divided by the total GSF per facility. For example, in living quarters the square foot estimate per person may be 100, whereas the per person square foot estimate for a communications tower could be 5,000.

The database of State-owned and -operated facilities was organized by building class and presence or absence of a basement. Building flood damage functions are extracted from the FEMA Full-Data Benefit-Cost Analysis Module, and adjusted for the different building types in the state database. The functions are estimates. Since there are no standard damage functions for non-residential buildings, the analysis is based on adapting standard FEMA/NFIP damage functions to the facilities database provided by Wisconsin. Table 3.17.1-3, on the following page, shows the damage functions at a two-foot flood depth.

The nature of the contents in the assets in the State database is not known. Therefore, damages to contents are calculated by simply assuming their value is 30% of the value of the structure itself, and that the damage function is the same as the structure. The results of this method should be used only to get a general idea of flood risk, not as the basis for mitigation actions for individual facilities.

TABLE 3.17.1-3 ASSUMED DAMAGE PERCENT FOR TWO-FOOT FLOOD DEPTH

Building Type	Without Basement	With Basement
Manufactured Housing	40	N/A
Non-Engineered Wood Frame	20	30
Lightly Engineered	15	25
Non-Engineered Masonry	15	25
Fully-Engineered	15	25

Source: WEM, 2008.

<u>*Calculating Annual Damages*</u>

The calculation is performed as follows:

$$(P)(RV_b)(F_d)(1.3) = D$$

where:

P is the flood probability, assumed to be 1%
RV_b is the replacement value of the building in dollars
F_d is the flood damage function
1.3 accounts for the additional value of contents
D is the total expected damages

For example, consider a non-engineered, wood-frame building without a basement and replacement value of $1,000,000:

0.01 (Flood Probability) x $1,000,000 (Replacement Value) x 0.20 (Damage Function from Table 3.17.1-3) x 1.3 (Contents Value) = $2,600 (Total Expected Damages)

The calculation of future risk from this flood scenario is done as follows:

$$D*12.41 = D_{npv}$$

where:

D is the total expected damages in a two-foot flood
12.41 is the present value coefficient for a 30-year horizon with a 7% discount rate
D_{npv} is the net present value of damages for a 30-year horizon

For example, consider the previous damage calculation:

$2,600 (Total Expected Damages in a two-foot flood) x 12.41 (Present Value Coefficient) = $32,266 (Net Present Value of Damages for a 30-Year Horizon)

Results

TABLE 3.17.1-4 TWO-FOOT FLOOD AND FUTURE RISK			
Building Type	**Number**	**Damages in Two-Foot Flood**	**Future Risk**
Manufactured Housing	0	-	-
Non-Engineered Wood Frame	38	$182,919	$2,270,022
Lightly Engineered	290	$5,694,992	$70,674,847
Non-Engineered Masonry	0	-	-
Fully-Engineered	124	$3,102,789	$38,505,611
Total	452	$8,980,700	$111,450,480

Source: WEM, 2008.

3.17.2 Tornado Risk

Without evaluations of individual buildings by qualified structural engineers or architects, even qualified and general estimates of wind damage functions using the limited data available in the Wisconsin database is certain to include errors. The State will use the output of this analysis only to prioritize its mitigation actions in a relative sense, i.e. in comparisons among buildings, not to determine if it is worthwhile to perform mitigation actions on particular facilities. This will form the basis of an initial prioritization that will begin the process of identifying the most at-risk structures for further examination and potential mitigation efforts.

Calculation Methodology

Expected damages, injuries and deaths at each State-owned facility were calculated using the following steps, which are discussed in detail below:

1. Determine building type
2. Determine building occupancy load
3. Determine building size (footprint)
4. Determine annual probability of impact by range of tornadoes
5. Develop damage, injury, and mortality functions for building type classes
6. Calculate expected annual damages using damage functions and probabilities
7. Project future damages to 30-year horizon using the OMB-mandated method

Building Type

The facilities identified by WEM (452) were sorted into one of five building types identified in the FEMA Full-Data Benefit-Cost Analysis Module for floods. The criteria used to determine the building type were gross square footage, replacement value, and use. The sorting was conducted based on the available data. Table 3.17.1-2 in Section 3.17.1 shows the building type and the number that are included in the risk assessment database.

Occupancy Load

The occupancy load of each facility was determined by estimating the number of people per square foot that would occupy the facility. Then this number was divided by the total GSF of the facility. For example, in living quarters the square foot estimate per person may be 100, whereas the per person square foot estimate for a communications tower could be 5,000. The occupancy load will be used in the injury and mortality functions.

Building Size (GSF Data)

The GSF field was partially populated in the initial version of the database. Several facilities did not list the GSF. In those cases, the GSF for each facility was based on similar facilities in the database. If there was no comparable facility, that particular facility was removed from the database.

Annual Probability of Tornado

The meaning of the Fujita classes was discussed in the tornado hazard profile in Section 3.6 and will not be reviewed here. Tornado probability data was obtained from FEMA's Tornado Wind Benefit-Cost Analysis Module. The metadata used in the software was obtained from NOAA records, and is documented in the technical materials for the program. In this assessment, a proportional risk methodology was employed, as described below in steps. The purpose of these steps was to determine the annual probability of each F-class impacting the individual State-owned buildings in the data set.

1. Extract probability metadata from the FEMA software. This data indicates the area (in acres) that tornadoes of all the F-classes affect in Wisconsin every year. The data is expressed in acres of impact.
2. Determine the percentage of area in the state that is impacted by various tornado classes annually.
3. Determine the footprint area of buildings in the State-owned facilities database.
4. Determine the likelihood of buildings being impacted by the various F-classes each year by proportion.

TABLE 3.17.2-1 TORNADO AREAS OF IMPACT BY FUJITA CLASS

Data Parameter	Tornado Fujita Class					
	F0	F1	F2	F3	F4	F5
Number in Sample	130	315	255	57	13	2
Percentage of Sample (%)	16.84	40.80	33.03	7.38	1.68	0.26
Total Area of Impact (acres)	545	11710	45674	85193	42398	12611
Avg. Area of Impact per Event	4.19	37.17	179.11	1494.61	3261.38	6305.50
Avg. Annual Area of Impact	11.85	254.57	992.91	1852.02	921.70	274.15
Annual Probability (%)	0.0000283	0.000607	0.002368	0.004418	0.002199	0.000654

Source: WEM, 2008.

Injury and Mortality Functions

Injury and mortality functions are estimates of how many people will be injured and killed by tornadoes. There is no nationally-recognized method or proven source of data for these functions. The risk of tornado deaths and injuries (i.e. the dollar value of future risk) depends on several inter-related factors including those shown below. Given the number of State-owned facilities included in this assessment, it was not possible to determine items 4 and 5 in the list below with any certainty, so these were not taken into account.

1. Tornado probability by Fujita class
2. The number of people in a facility
3. The performance of the building that individuals are in during the tornado (if they are inside), i.e. the building damage function
4. The availability of advance warning about the event
5. The availability and accessibility of appropriate shelter

The figures used for valuation of deaths and injuries, shown below in Table 3.17.2-2, are approximations based on FEMA guidance used in benefit-cost analysis of hazard mitigation measures. Major and minor injuries are combined in the NOAA data, so it was necessary to use a blended number in the valuation.

TABLE 3.17.2-2 MONETARY CONVERSION VALUES FOR INJURIES AND DEATHS

Damage Category	Value for Monetary Conversion
Injury (blended major and minor)	$7,500
Death	$3,000,000

Source: WEM, 2008.

Table 3.17.2-3, on the following page, shows injury and mortality functions by building type. The functions are linked to the performance of the various building types during tornadoes. These figures are estimates and should not be used in any context other than the State Hazard Mtigation Plan. In order to accurately assess the expected mortality and injuries in specific buildings, it would be necessary to assess numerous aspects of those buildings, and to ascertain if occupants had adequate warning and shelter, as discussed previously. The figures in the table are used to calculate future risk for comparison among building types and uses in the Wisconsin database. The results of the calculations should be used only to gauge the relative risk as a part of the mitigation planning process.

TABLE 3.17.2-3 INJURY AND MORTALITY FUNCTIONS BY BUILDING TYPE (% OF OCCUPANTS INJURED OR KILLED)

Building Type	Fujita Tornado Class											
	F0		F1		F2		F3		F4		F5	
	I	M	I	M	I	M	I	M	I	M	I	M
Manufactured Housing	20	0	30	0	50	20	25	75	10	90	0	100
Non-Engineered Wood Frame	10	0	15	0	30	0.5	50	50	10	90	0	100
Lightly Engineered	5	0	5	0	25	0	40	40	65	80	10	100
Non-Engineered Masonry	0	0	5	0	25	0	40	40	65	80	10	100
Fully-Engineered	0	0	0	0	10	0	30	0	35	50	50	30

Source: WEM, 2008.

Building Tornado Damage Functions

Building damage functions were developed for each of the building types identified earlier. Damage functions describe the percentage to which buildings or other assets are damaged at various wind stress levels, in the case of tornadoes at various Fujita class wind speeds. The damage functions are expressed as percentages of damages, and are multiplied by building replacement value to determine expected damage under given wind loads. It is important to recognize that there exist no nationally-recognized wind damage functions based on building classification. The wind damage functions in this are estimated, referring to FEMA's Hurricane Wind Benefit-Cost Analysis Module as appropriate.

TABLE 3.17.2-4 WIND SPEED CLASSES: SAFFIR-SIMPSON HURRICANE VS FUJITA TORNADO

Classification	Saffir-Simpson	Fujita
0	60-73	40-72
1	74-95	73-112
2	96-110	113-157
3	111-130	158-206
4	131-155	207-260
5	>155	261-318

Source: WEM, 2008.

Table 3.17.2-5, on the following page, shows the wind damage function defaults in FEMA's Hurricane Wind Benefit-Cost Analysis Module. Because the Fujita classifications for tornado wind speeds are calibrated on a much higher scale, there is no reliable method for directly converting hurricane categories to the Fujita scale for tornadoes.

Table 3.17.2-6, on the following page, provides wind damage functions by Fujita class based on an estimated conversion from hurricane category functions. As noted above, the results of this analysis should be considered reliable only in relative terms, i.e. for comparisons in the State of Wisconsin.

TABLE 3.17.2-5 WIND DAMAGE FUNCTIONS FOR HURRICANE CLASS						
Building Type	Percent Damage by Saffir-Simpson Class					
	0	1	2	3	4	5
Manufactured Housing	10	25	50	80	100	100
Non-Engineered Wood Frame	0	7.5	20	50	90	100
Lightly Engineered	0	5	15	40	80	100
Non-Engineered Masonry	0	5	15	40	80	100
Fully-Engineered	0	2.5	5	20	40	60

Source: WEM, 2008.

TABLE 3.17.2-6 WIND DAMAGE FUNCTIONS FOR FUJITA CLASS						
Building Type	Percent Damage by Fujita Class					
	0	1	2	3	4	5
Manufactured Housing	10	35	75	100	100	100
Non-Engineered Wood Frame	5	30	50	100	100	100
Lightly Engineered	0	15	25	65	100	100
Non-Engineered Masonry	0	15	30	80	100	100
Fully-Engineered	0	10	25	60	100	100

Source: WEM, 2008.

Calculating Annual Damages

The basic damage calculation is accomplished by multiplying the values of buildings, injuries and deaths by the probabilities of various classes of tornadoes impacting the structure in question. Since the probabilities are calculated proportionally, they are not performed using an integration methodology, but are rather compiled as individual scenario events and added together.

The tornado risk calculation is performed as:

$$\mathbf{P_a[(RV)(DF_c)(1.3) + (O)(DF_i)(M_i) + (O)(DF_m)(M_m)] = D_a}$$

where:

P_a is the annual event probability
RV is the replacement value of the asset in dollars
DF_c is the damage function for the various building classes in the database
1.3 accounts for the additional value of the contents
O is the occupancy of the asset
DF_i is the injury function
M_i is the monetary value for a blended injury
DF_m is the mortality function
M_m is the monetary value for a mortality
D_a is the annual expected damage

The 1.3 multiplier on the replacement value reflects the value of contents. Given the size of the database there is no way to accurately assess the value or damage functions of the various contents. In these calculations the value figure is calculated by algorithm as 30% of the value of the structure, and the damage function is assumed to be the same as the structure.

For example, consider a non-engineered wood frame building with a replacement value of $1,000,000 and occupancy 10:

> 0.000000283 (Probability F0) * [$1,000,000 (Replacement Value) * 0.05 (Damage Function from Table 3.17.2-6) * 1.3 (Contents Value) + 10 (Occupancy) * 0.10 (Injury Function from Table 3.17.2-3) * $7,500 (Blended Injury Monetary Value from Table 3.17.2-2) +10 (Occupancy) * 0 (Mortality Function from Table 3.17.2-3) * $3,000,000 (Mortality Monetary Value from Table 3.17.2-2)] = $0.02 = Total Annual Expected Damages for an F0 tornado

This must be completed for all F classes and the results added together to calculate the total expected annual damage.

In accordance with Office of Management and Budget guidelines found in Circular No. A-94, future expected damages are expressed as net present value with a 7% discount rate. For this report, a 30-year time horizon is employed, although this figure can be adjusted using different present value coefficients. In the present calculations, the annual risk from tornadoes is multiplied by a present value coefficient of 12.41 to determine future risk at a 7% discount, as required. The calculation is done as follows:

$$D_a PVC=R$$

where:

> D_a is the annual expected damage
> PVC is the present value coefficient (7% discount rate, 30-year horizon)
> R is the risk (i.e. the cumulative losses over the 30-year horizon, discounted to present value)

<u>Results</u>

TABLE 3.17.2-7 TORNADO ANNUAL AND FUTURE RISK

Building Type	Number	Structural and Contents Damage	Injury and Mortality Damage	Annual Risk	Future Risk
Manufactured Housing	0	0	0	0	0
Non-Engineered Wood Frame	38	$6,282	$400,708	$406,990	$5,050,741
Lightly Engineered	290	$172,118	$10,310,741	$10,482,859	$130,092,280
Non-Engineered Masonry	0	0	0	0	0
Fully-Engineered	124	$87,480	$957,034	$1,044,514	$12,962,418
Total	452	$265,880	$11,668,483	$11,934,363	$148,105,439

Source: WEM, 2008.

3.17.3 High Wind Risk

As discussed in the high winds hazard profile in Section 3.6, high winds are winds unrelated to tornadoes. They are typically created by downbursts from thunderstorms or by strong weather fronts. Although Wisconsin has a history of these events, by nature they are very difficult to predict, particularly on a site-specific basis. In its ASCE 7-98 publication the American Society of Civil Engineers provides design guidelines for structures based on anticipated wind speeds in various parts of the US. For most of the country (including Wisconsin) the "design wind speed" is 90 mph. This figure is the 3-second peak gust at 33 feet above ground level. This wind speed is calculated as a 50-year event, i.e. one with a 2% annual recurrence probability.

Calculation methodology

The methodology used to calculate damages (including injuries and deaths) from high winds is identical to that used for tornadoes, except that there is only one probability function required. The calculation sequence is as follows:

1. Determine building type
2. Determine building occupancy load
3. Determine building size (footprint)
4. Determine annual probability of impact
5. Develop damage, injury, and mortality functions for building types
6. Calculate expected annual damages using damage functions and probabilities
7. Project future damages to 30-year horizon using OMB-mandated method

All these items are discussed in the tornado section above, and are not revisited here, except for a few brief comments below on probability and wind damage functions.

High Wind Probability
The probability calculation is done as a simple annual return frequency of 2%, or a 0.02 annual probability.

Building Wind Damage Functions
For this risk assessment, building wind damage functions are simply derived from the equivalent tornado wind damage functions by equating the baseline 90-mph wind to a Fujita Class 1 tornado. Table 3.17.3-1, at right, shows the percentage of building damage for the 90 mph peak gust.

TABLE 3.17.3-1 WIND DAMAGE FUNCTIONS FOR 90 MPH PEAK WIND GUST

Building Type	Building Damage (%)
Manufactured Housing	35
Non-Engineered Wood Frame	30
Lightly Engineered	15
Non-Engineered Masonry	15
Fully-Engineered	10

Source: WEM, 2008.

TABLE 3.17.3-2 INJURY AND MORTALITY FUNCTIONS BY BUILDING TYPE		
Building Type	**Injured (%)**	**Killed (%)**
Manufactured Housing	30	0
Non-Engineered Wood Frame	15	0
Lightly Engineered	5	0
Non-Engineered Masonry	5	0
Fully-Engineered	0	0

Source: WEM, 2008.

Table 3.17.3-2, at left, shows injury and mortality functions by building type. The functions are linked to the performance of the various building types during tornadoes. These figures are estimates and should not be used in any context other than the State Hazard Mitigation Plan. In order to accurately assess the expected mortality and injuries in specific buildings, it would be necessary to assess numerous aspects of those buildings, and to ascertain if occupants had adequate warning and shelter, as discussed previously. The figures in the table are used to calculate future risk for comparison among building types and uses in the Wisconsin database. The results of the calculations should be used only to gauge the relative risk as a part of the mitigation planning process.

The figures in this table match the injury and mortality functions for Fujita Class 1 tornadoes.

Calculating Annual Damages

The basic damage calculation is accomplished by multiplying the values of buildings, injuries, and deaths by the probability of a Fujita class 1 tornado impacting the structure in question.

The high wind risk calculation is performed as:

$$P_a[(RV)(DF_c)(1.3) + (O)(DF_i)(M_i) + (O)(DF_m)(M_m)] = D_a$$

where:

- P_a is the annual event probability
- RV is the replacement value of the asset in dollars
- DF_c is the damage function for the various building classes in the database
- 1.3 accounts for the additional value of the contents
- O is the occupancy of the asset
- DF_i is the injury function
- M_i is the monetary value for a blended injury
- DF_m is the mortality function
- M_m is the monetary value for a mortality
- D_a is the annual expected damage

The 1.3 multiplier on the replacement value reflects the value of contents. Given the size of the database there is no way to accurately assess the value or damage functions of the various contents. In these calculations the value figure is calculated by algorithm as

30% of the value of the structure, and the damage function is assumed to be the same as the structure.

For example, consider a non-engineered wood frame building with a replacement value of $1,000,000 and occupancy of 10:

> 0.02 (Probability) * [$1,000,000 (Replacement value) * 0.30 (Damage Function from Table 3.17.3-1) * 1.3 (Contents value) + 10 (Occupancy) * 0.15 (Injury Function from Table 3.17.3-2) * $7,500 (Blended Injury Monetary Value from Table 3.17.2-2) + 10 (Occupancy) * 0 (Mortality Function from Table 3.17.3-2) * $3,000,000 (Mortality Monetary Value from Table 3.17.2-2) = $8,025.00 = Total Annual Expected Damages

In accordance with Office of Management and Budget guidelines found in Circular No. A-94, future expected damages are expressed as net present value with a 7% discount rate. For this report, a 30-year time horizon is employed, although this figure can be adjusted using different present value coefficients. In the present calculations, the annual risk from tornadoes is multiplied by a present value coefficient of 12.41 to determine future risk at a 7% discount, as required. The calculation is done as follows:

$$\mathbf{D_a PVC=R}$$

where:

> D_a is the annual expected damage
> PVC is the present value coefficient (7% discount rate, 30-year horizon)
> R is the risk (i.e. the cumulative losses over the 30-year horizon, discounted to present value)

Results

TABLE 3.17.3-3 HIGH WINDS ANNUAL AND FUTURE RISK

Building Type	Number	Structural and Contents Damage	Injury and Mortality Damage	Annual Risk	Future Risk
Manufactured Housing	0	0	0	0	0
Non-Engineered Wood Frame	38	$436,328	$60,439	$496,767	$6,164,874
Lightly Engineered	290	$8,058,825	$615,248	$8,674,073	$107,645,247
Non-Engineered Masonry	0	0	0	0	0
Fully-Engineered	124	$2,842,064	0	$2,842,064	$35,270,017
Total	452	$11,337,217	$675,687	$12,012,904	$149,080,139

Source: WEM, 2008.

3.17.4 Critical Facility Risk Assessment by State Agency

There are approximately 6,500 state facilities not including infrastructure. In order to collect comprehensive data, it would take one person working full-time nearly 28 years to visit every facility. Therefore, the following strategy has been developed to obtain the necessary site-specific information on those facilities and infrastructure that are most critical and may be at most risk from future disasters. The information will be used for future updates to the State of Wisconsin Hazard Mitigation Plan.

1. Through the Wisconsin Hazard Mitigation Team and the Governor's Homeland Security Council's Interagency Working Group,
   a. conduct more in-depth analysis to determine the state facilities that are considered critical facilities;
   b. conduct more in-depth analysis to identify critical state infrastructure; and
   c. determine which state facilities are low priorities for further analysis or data collection. This would include such structures as outhouses and sheds, i.e., those facilities that are not critical or essential to state operations and would not be significantly affected by a disaster.
2. Prioritize facilities by county for further analysis and data collection. This would be based upon the following:
   - Number of state facilities
   - Number of state critical facilities
   - Number of federal disaster declarations that include the county
   - Total value of the state facilities
   - Total value of the state critical facilities
   - Whether there is Q3 floodplain data available
3. Work with state agencies to generate proper building contacts for the critical facilities.
4. Send out the finalized Wisconsin Risk Assessment Data Collection Worksheet to each contact at the critical facilities.
5. Work with Department of Administration Risk Management staff to create a secure database that can be easily accessed.
6. Hire staff to conduct site visits to collect additional data on facilities without a completed Data Collection Worksheet.
7. Develop a process to determine vulnerability and risk from natural and/or technological hazards based on probability. This may include utilizing HAZUS-MH if staff obtain adequate training and receive technical support.
8. Identify and prioritize potential mitigation measures for critical facilities and infrastructure in coordination with the Wisconsin Hazard Mitigation Team.
9. Incorporate identified potential mitigation measures into the Mitigation Strategy and Action Plan of the State of Wisconsin Hazard Mitigation Plan, as well as local hazard mitigation plans where appropriate.

10. Working with the Wisconsin Hazard Mitigation Team and other state agencies, apply for funding to implement mitigation measures for identified state facilities, critical facilities, and infrastructure.

Critical facilities include all State-owned facilities that are considered essential because of their function, size, service area, or uniqueness; because they deliver vital services; or because their purpose is the protection of the health and safety of citizens. They may include:

- Correctional facilities and other custodial facilities
    - Prisons
    - Jails
    - Facility heating plant
    - Food storage
- Certain University facilities
    - UW system
- Telecommunications
    - Radio and television facilities for EAS, communication towers, etc.
    - Repeaters
- Facilities that provide electrical power, heating, wastewater treatment, or water
- Hospitals, homes, and other medical facilities
    - Shelters
    - Nursing homes
    - Veterans Affairs nursing care
    - Mental health institutions
- Major state government facilities that house key state operations
- Critical military facilities
    - Headquarters
    - Air fields
- Emergency response facilities related to law enforcement, security, fire, etc.
    - Law enforcement
    - Fire rescue
    - Rescue facilities
- Agricultural/food supply

WEM, along with the Department of Administration, has created a Wisconsin Risk Assessment Data Collection Worksheet that will be used to collect information for each critical facility. The collection worksheet covers everything from general information, such as location, to more detailed facts regarding construction materials. All of this data is needed to create an accurate risk assessment on State-owned and -operated facilities. Based on the responses, the data is then assigned a number representing the relative risk associated with that attribute for each hazard. The questionnaire and scoring can be found in Appendix H.

Risk Assessment Scoring

TABLE 3.17.4-1 RISK ASSESSMENT SCORE RANGE		
Hazard	**Low Score**	**High Score**
Flood Risk Assessment	17	85
Wind Risk Assessment	21	87

Source: WEM, 2008.

The total score range was divided into five risk divisions. Each division was given a qualitative title as shown in Table 3.17.4-2 below.

TABLE 3.17.4-2 RISK LEVEL CATEGORIES		
Risk Level	**Low Score**	**High Score**
Low	0	16
Medium Low	17	34
Medium	35	52
Medium High	53	70
High	71	87

Source: WEM, 2008.

Table 3.17.4-3, attributed risk, shows the Data Collection Worksheet questions that have risk values associated with them. The "high" and "low" columns represent the highest score possible and the lowest score possible associated with each question. The empty cells in the table mean that the question does not pertain. Each column has the tabulated risk assessment score total that is possible.

TABLE 3.17.4-3 ATTRIBUTED RISK						
			Flood		**Wind**	
Question	**High**	**Low**	**High**	**Low**	**High**	**Low**
30	4	1	4	1	4	1
31	3	1	3	1	3	1
33	3	0	3	0		
34	3	1			3	1
35	5	1			5	1
36	3	1			3	1
37	3	1			3	1
38	2	0			2	0
39	2	1			2	1
40	3	1			3	1
41	3	1			3	1
42	5	1	5	1	5	1

TABLE 3.17.4-3 ATTRIBUTED RISK						
			Flood		Wind	
Question	High	Low	High	Low	High	Low
43	5	1	5	1	5	1
44	5	1	5	1	5	1
45	3	1	3	1	3	1
51	5	1	5	1	5	1
61	5	1	5	1		
65	5	1	5	1		
69	7	0	7	0		
70	5	1	5	1		
71	7	0	7	0		
72	3	1	3	1		
74	5	0	5	0		
76	5	0	5	0		
77	5	1			5	1
78	5	5	5	5		
79	3	1			3	1
80	7	1			7	1
81	4	1			4	1
82	3	1			3	1
83	3	0			3	0
84	3	1			3	1
85	5	1			5	1
86	5	1	5	1		
Total	**142**	**31**	**85**	**17**	**87**	**21**

Source: WEM, 2008.

3.17.5 Department of Corrections

The Department of Corrections (DOC) was used to pilot the questionnaire and data collection process that will be utilized to create a State critical facility inventory, giving more specific information to create a detailed risk assessment for the State of Wisconsin.

DOC critical facilities may include:

- Correctional facilities and other custodial facilities
    - Prisons
    - Jails
    - Facility Heating Plant
    - Food storage

WEM worked with the DOC on the collection of data for 471 DOC-owned buildings, within 25 different institutions, centers, and schools. DOC collected information on all buildings within their institutions, not only those considered critical facilities.

Flood Risk Assessment

Based on Data Collection Worksheets completed by DOC, the final range of scores saw a low of 5, and a high of 63. There were a wide range of totals, with most of the buildings falling within the Medium Low to Medium risk range. The following summarizes the final risk scores:

- 18 buildings were rated “Low,” with total scores between 0 and16.
- 166 buildings were rated “Medium Low,” with total scores between 17 and 34.
- 257 buildings were rated “Medium,” with total scores between 35 and 52.
- 30 buildings were rated “Medium High,” with total scores between 53 and 70.
- 0 buildings were rated “High,” with total scores between 71 and 87.

Out of the 471 buildings that DOC collected information on, 30 of those buildings were deemed to having a “Medium High” risk when looking at the buildings’ vulnerability to floods. The buildings were from a wide range of institutions and were not all deemed critical by DOC. Half of the buildings would be considered non-critical infrastructure, meaning they were storage, cellars, and garages. The other buildings would be considered critical infrastructure because of the services that they provide. Examples would be residence halls, barracks, and power plants.

3.17.6 Critical Facility Risk Assessment Summary and Recommendations

To have true accurate risk assessments for any of the hazards it requires site- and hazard-specific information. As such, WEM aims to continue to develop the comprehensive State-owned and -operated building inventory to better understand the State’s vulnerability to natural hazards.

Currently, WEM has a full inventory of the Department of Corrections. In upcoming updates, WEM plans to work with other State agencies to create a more complete inventory of State-owned and -operated buildings, so that additional critical facilities may be included.

As mentioned previously, there are over 6,500 state-owned and -operated facilities, critical facilities, and infrastructure components. The data collection process is very detailed and time-consuming to complete. Recognizing that it will take many years to complete the detailed structure inventory, for the purpose of future state hazard mitigation plan updates, the following strategy has been developed to address risk to state-owned critical facilities and infrastructure in the shorter-term:

1. WEM will obtain from the Department of Administration an updated spreadsheet of state-owned and -operated facilities.
2. Working through the Wisconsin Hazard Mitigation Team and the Governor's Homeland Security Council's Interagency Working Group, determine by Department the state facilities that fall within the definition of a critical facility.

   Critical facilities and infrastructure, as defined by the State of Wisconsin, consist of all state-owned facilities deemed essential due to their function, size, service area, uniqueness, delivery of vital services, and for the protection of the health and safety of citizens. This scope includes buildings and infrastructure that meet characteristics such as:

   - Communications facilities
   - Correctional facilities and other custodial facilities
   - Utility services, including: electrical power generation, heating, wastewater treatment, water treatment, etc.
   - Hospitals and other medical facilities, including: group homes, shelters, mental health facilities, etc.
   - Major state government facilities that house key state operations
   - Critical military facilities
   - Emergency response facilities, including: law enforcement, security, fire, etc.
3. Work with the individual departments to complete the detailed structure inventory of identified critical facilities in subsequent plan updates. Non-critical facilities will be low priority for further analyses and data collection.
4. Again, the State recognizes that the detailed structure inventory will be very time consuming and will take numerous plan updates to complete. Modeled after some of the best practices in other state hazard migration plans, the State of Wisconsin will create a database of state-owned or operated critical facilities and infrastructure that meets the following criteria:

   A. Replacement value of over $1,000,000: Using $1,000,000 as the cut-off focuses on buildings that are most difficult and costly to replace, as well as recognizes that most critical facilities within the State of Wisconsin have higher building replacement values.

B. Conveys the use characteristics of critical facilities, placing critical facilities and infrastructure in broad categories encompassed in the State definition of critical facility, such as:

   - agricultural/food supply
   - correctional
   - education
   - government
   - public health
   - public safety/emergency response
   - residential
   - utility

C. Highlights the location of facilities, indicating the county in which each facility or infrastructure is located.

   Based on this database, WEM can use a combination of means such as tables, charts or GIS maps in order to analyze which counties and State agencies have the highest concentration of critical facilities valued at $1,000,000 or above. Using this data can be analyzed to better understand where the locations of critical facilities intersect with areas of high population density, increased population change, and increased hazard-risk or historical occurrences. As a result, the focus can be narrowed to understand where efforts to mitigate the exposure of vulnerability to critical facilities could potentially have a greater amount of impact.

   In the long term, once this database is generated, WEM will be able to evaluate the vulnerability to specific hazards (high, medium, low), and whether or not the above criteria are sufficient for evaluating risk to State-owned and operated critical facilities and infrastructure.

3.18 LIFELINES

Lifelines are critical to the health and well-being of all Wisconsin residents. Lifelines, such as highways, railroads, power transmission lines, and water supply pipelines, tend to be linear in nature with key facilities, such as pumping stations, located at specific points. Due to the extensive geographic distances covered by lifelines, they tend to be exposed to a full range of natural hazards in the environment. By their nature, some lifelines are more hardened than others to specific hazards. For example, buried transmission lines have extremely low vulnerability to wind damage. On the other hand, all transmission lines have some level of vulnerability to earthquakes.

The purpose of this section is to provide a list of the general types of lifelines and their components and identify the major natural hazards to which the lifelines are most vulnerable. It is beyond the scope of this effort to attempt to provide a detailed vulnerability assessment and loss estimation for lifelines. Based upon American Lifelines Alliance's categorization, Table 3.18-1, below, provides a list of the major types of lifelines and their key components. An asterisk (*) indicates that a particular component has a high level of vulnerability to a given natural hazard. This assessment is intended to provide a relative indication of risk and is not intended to represent a quantitative valuation of risk. The focus of Table 3.18-1 is to highlight key vulnerabilities.

In an effort to more fully address risks to lifelines, WEM has developed a Rural Electric Cooperative Annex (see Appendix G) for the 2011 Plan Update. The Annex includes a risk assessment and profiles some of the hazards to which electrical facilities and lines are most vulnerable.

TABLE 3.18-1 WISCONSIN LIFELINES AND VULNERABILITY

Category	Description	Number/ Line Miles	Flood	Wind	Earthquake	Snow	Ice	Landslide
Communications Facility	Communication Lines, Control Vaults, Switching Stations, Radio/TV Stations, Weather Station	362	*	*	*	*	*	*
Waste Water Facility	Treatment Plants, Control Vaults, Stations	500	*	*	*	*	*	
Potable Water Facility	Pipelines, Treatment Plants, Control Vaults and Control Stations, Wells, Storage Tanks and Pumping Stations	5	*	*	*	*	*	
Oil Facility	Pipelines, Refineries, Control Vaults and Control Stations, and Tank Farms	6	*	*	*			
Electric Power Facility	Generating Plants, Substations, Distribution Circuits, and Transmission Towers	56	*	*	*	*	*	*

TABLE 3.18-1 CONTINUED								
Category	**Description**	**Number/ Line Miles**	**Flood**	**Wind**	**Earthquake**	**Snow**	**Ice**	**Landslide**
Electric Transmission Lines	Electric Transmission Lines	6,151 mi	*	*	*	*	*	*
Natural Gas Facility	Pipelines Control Vaults and Control Stations, and Compressor Stations	6	*	*	*			
Natural Gas Pipelines	Ductile and Brittle Pipe	85,737 mi	*	*	*			
Railroad Systems	Tracks, Bridges, Tunnels, Stations, Fuel, Dispatch and Maintenance Facilities	99 / 6,821 mi	*	*	*	*	*	*
Port Facility	Water Front Structures, Cranes/Cargo Handling Equipment, Warehouses and Fuel Facilities	142	*	*				
DOT Highways	Roadways, Bridges and Tunnels	11,753 state mi / 19,665 cty. trk. hwy. mi	*		*	*	*	*
Airports	Control Towers, Runways, Terminal Buildings, Parking Structures, Fuel Facilities, and Maintenance and Hanger Facilities	150	*	*	*	*	*	
Hospital	Medical Centers and Hospitals	230	*		*			

Source: WEM, 2008; based on the American Lifeline Alliance, 2003.

The natural hazards threat to lifelines has two components. The first is direct damage to the lifeline from a natural hazard that causes significant physical damage. The second is a denial of use or loss of function due to a natural hazard event. Snow and ice events on roadways are a significant and common example of this type of threat. Typically, such threats are temporary and do not result in a high level of physical damage to the lifeline. Figures 3.18-1 to 3.18-15, on the following pages, show the locations of at-risk Wisconsin lifelines.

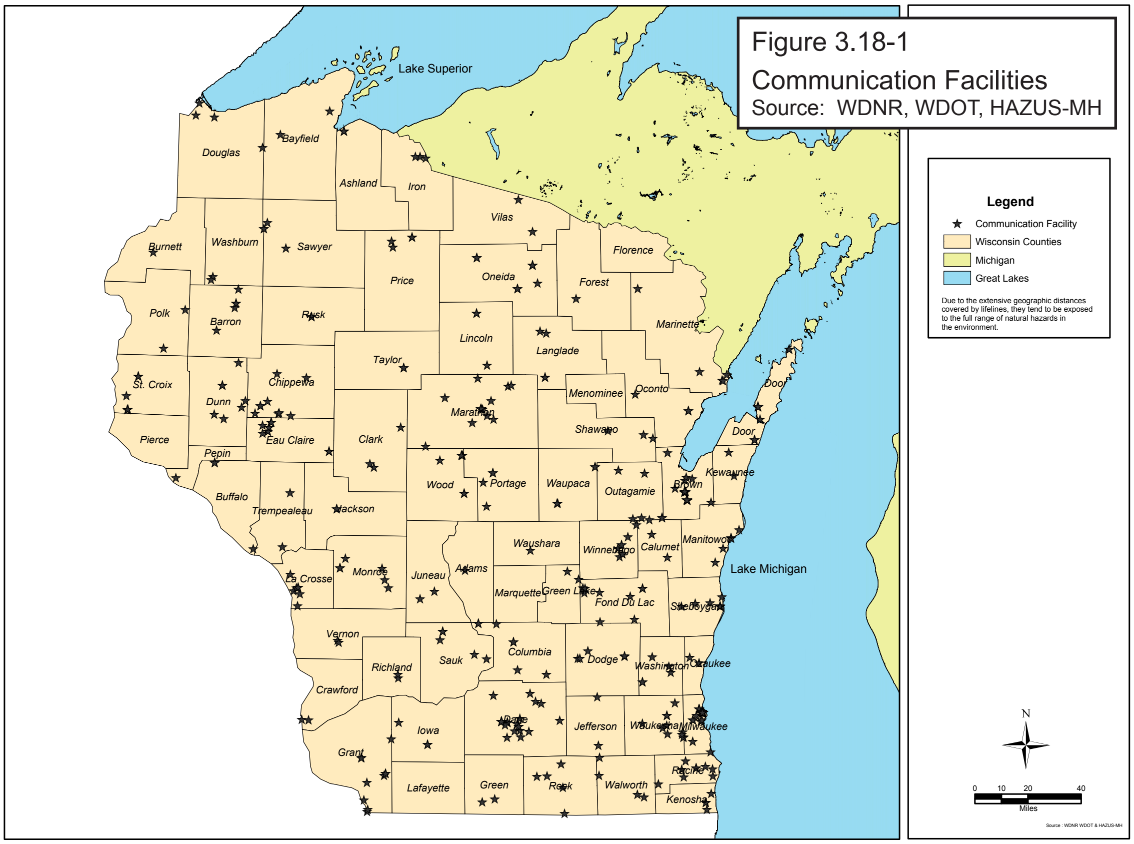


Figure 3.18-1
Communication Facilities
Source: WDNR, WDOT, HAZUS-MH
Legend
Communication Facility
Wisconsin Counties
Michigan
Great Lakes
Due to the extensive geographic distances covered by lifelines, they tend to be exposed to the full range of natural hazards in the environment.
Lake Superior
Lake Michigan
Douglas
Bayfield
Ashland
Iron
Vilas
Burnett
Washburn
Sawyer
Price
Oneida
Florence
Forest
Polk
Barron
Rusk
Lincoln
Marinette
Taylor
Langlade
Chippewa
St. Croix
Dunn
Menominee
Oconto
Door
Marathon
Eau Claire
Clark
Shawano
Pierce
Pepin
Kewaunee
Wood
Portage
Waupaca
Outagamie
Brown
Buffalo
Trempealeau
Jackson
Waushara
Winnebago
Calumet
Manitowoc
Monroe
Juneau
Adams
La Crosse
Marquette
Green Lake
Fond Du Lac
Sheboygan
Vernon
Richland
Sauk
Columbia
Dodge
Washington
Ozaukee
Crawford
Iowa
Dane
Jefferson
Waukesha
Milwaukee
Grant
Lafayette
Green
Rock
Walworth
Racine
Kenosha
N
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Miles

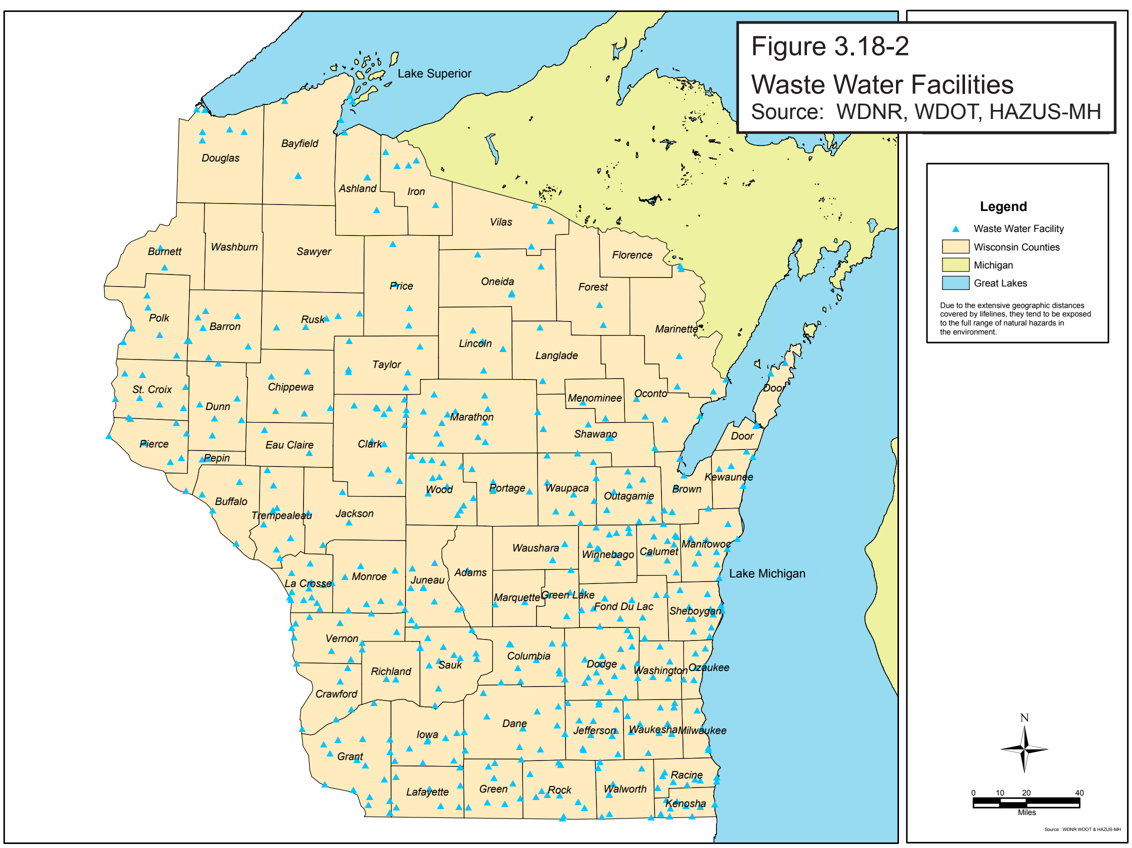
Figure 3.18-2
Waste Water Facilities
Source: WDNR, WDOT, HAZUS-MH
Legend
Waste Water Facility
Wisconsin Counties
Michigan
Great Lakes
Due to the extensive geographic distances covered by lifelines, they tend to be exposed to the full range of natural hazards in the environment.
Lake Superior
Lake Michigan
Douglas
Bayfield
Ashland
Iron
Vilas
Burnett
Washburn
Sawyer
Price
Oneida
Florence
Forest
Polk
Barron
Rusk
Lincoln
Marinette
Taylor
Langlade
Chippewa
St. Croix
Dunn
Menominee
Oconto
Door
Marathon
Eau Claire
Clark
Shawano
Pierce
Pepin
Kewaunee
Wood
Portage
Waupaca
Outagamie
Brown
Buffalo
Trempealeau
Jackson
Waushara
Winnebago
Calumet
Manitowoc
Monroe
Juneau
Adams
La Crosse
Marquette
Green Lake
Fond Du Lac
Sheboygan
Vernon
Richland
Sauk
Columbia
Dodge
Washington
Ozaukee
Crawford
Iowa
Dane
Jefferson
Waukesha
Milwaukee
Grant
Lafayette
Green
Rock
Walworth
Racine
Kenosha
N
0 10 20 40
Miles

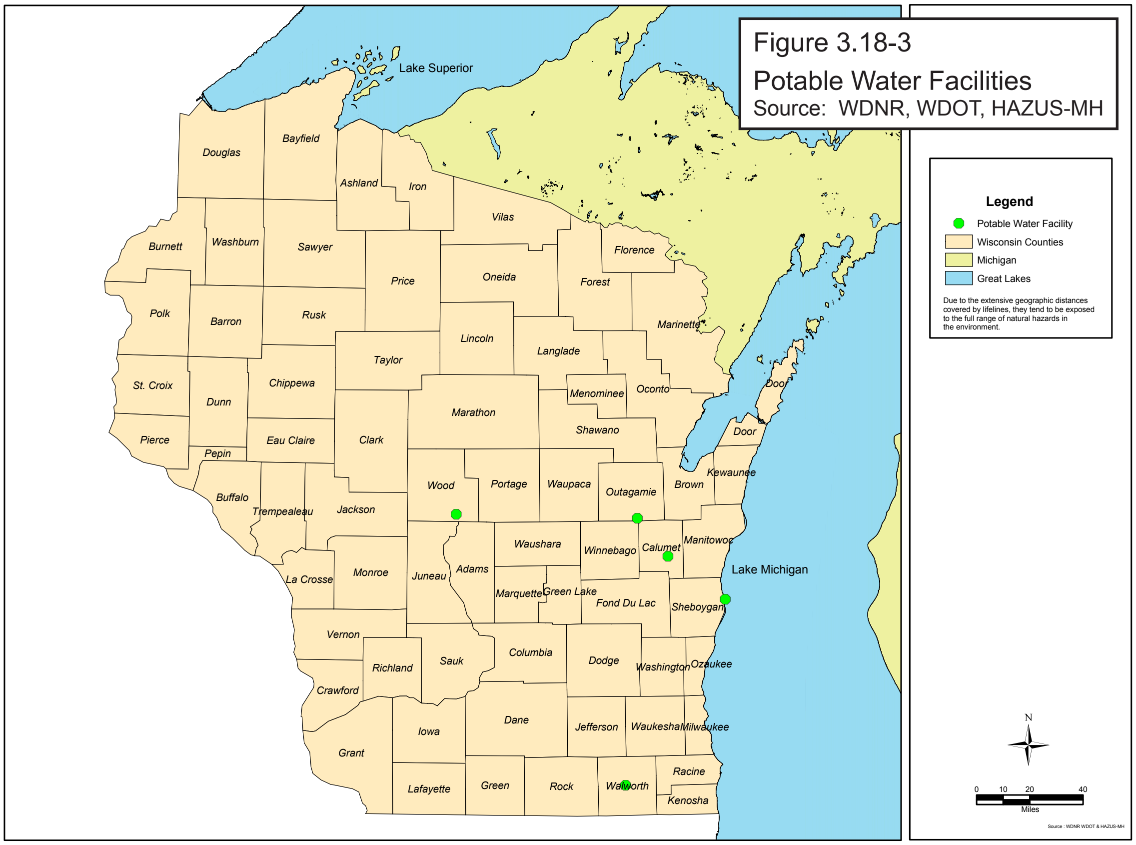

Figure 3.18-3
Potable Water Facilities
Source: WDNR, WDOT, HAZUS-MH

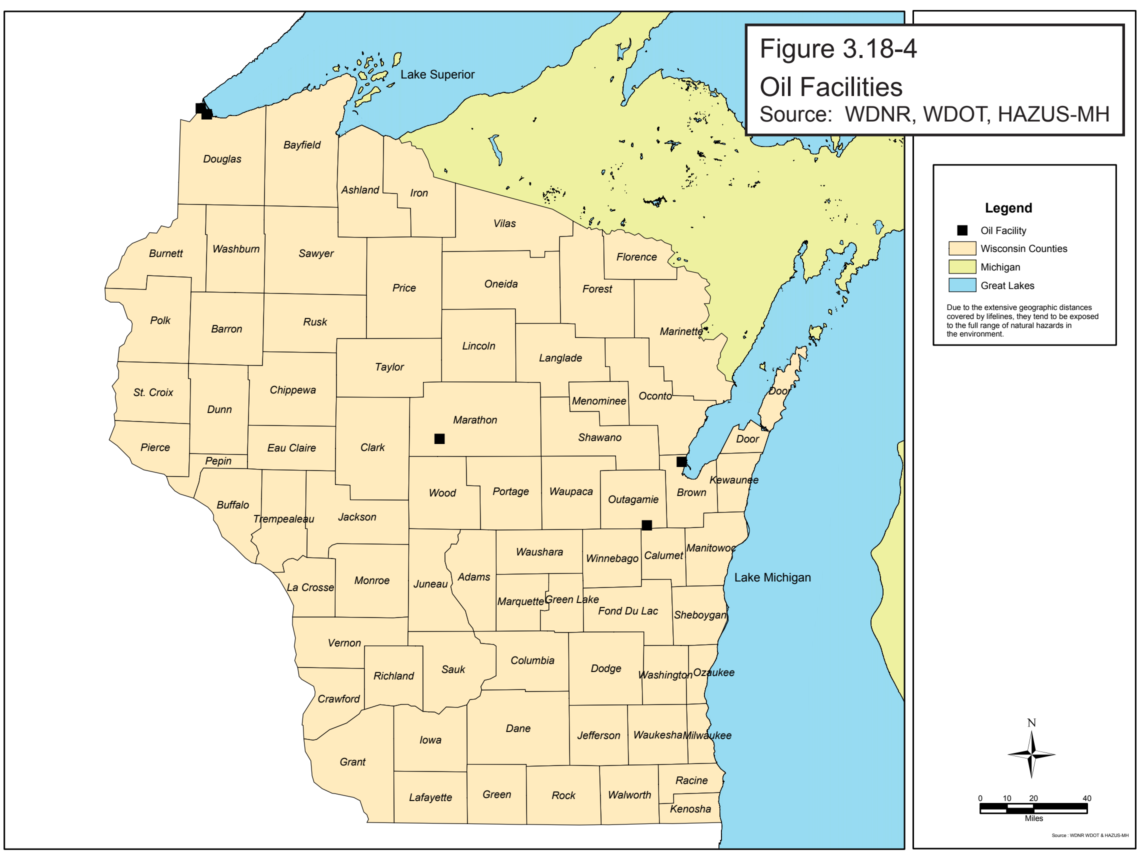

Figure 3.18-4
Oil Facilities
Source: WDNR, WDOT, HAZUS-MH

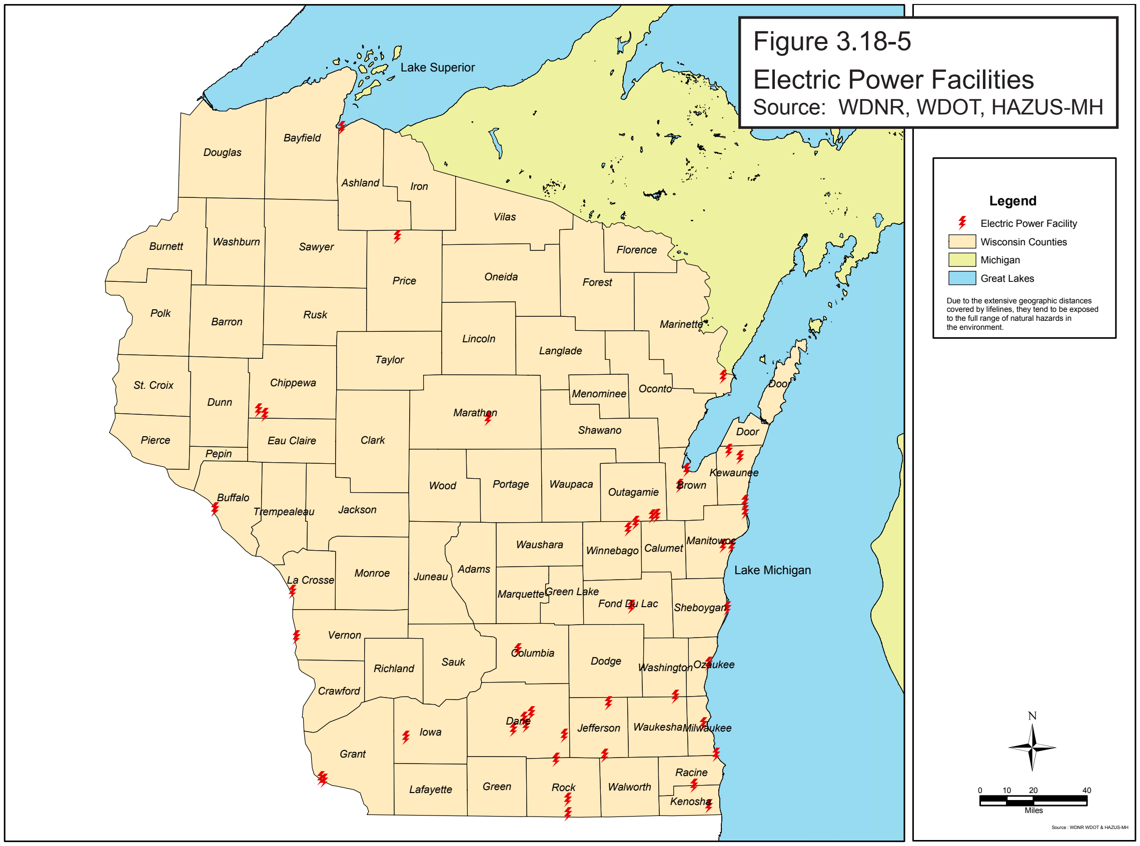

Figure 3.18-5
Electric Power Facilities
Source: WDNR, WDOT, HAZUS-MH

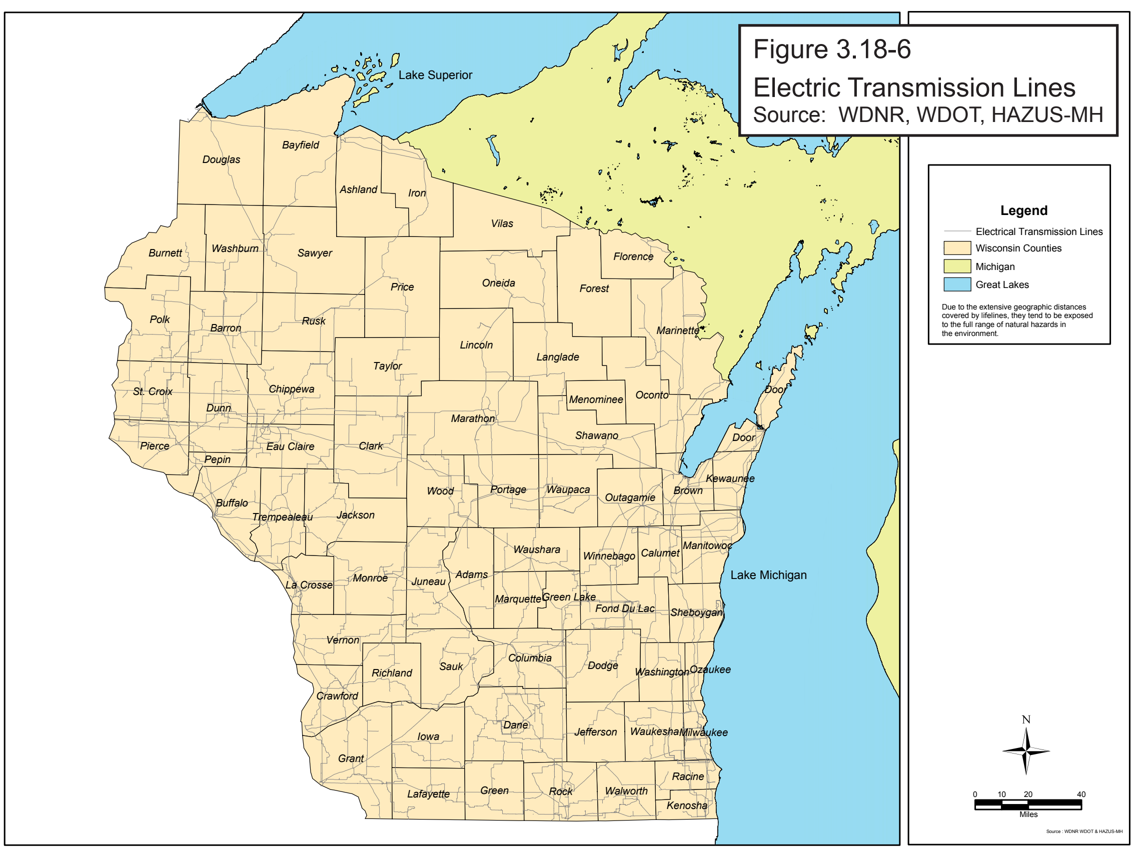

Figure 3.18-6
Electric Transmission Lines
Source: WDNR, WDOT, HAZUS-MH

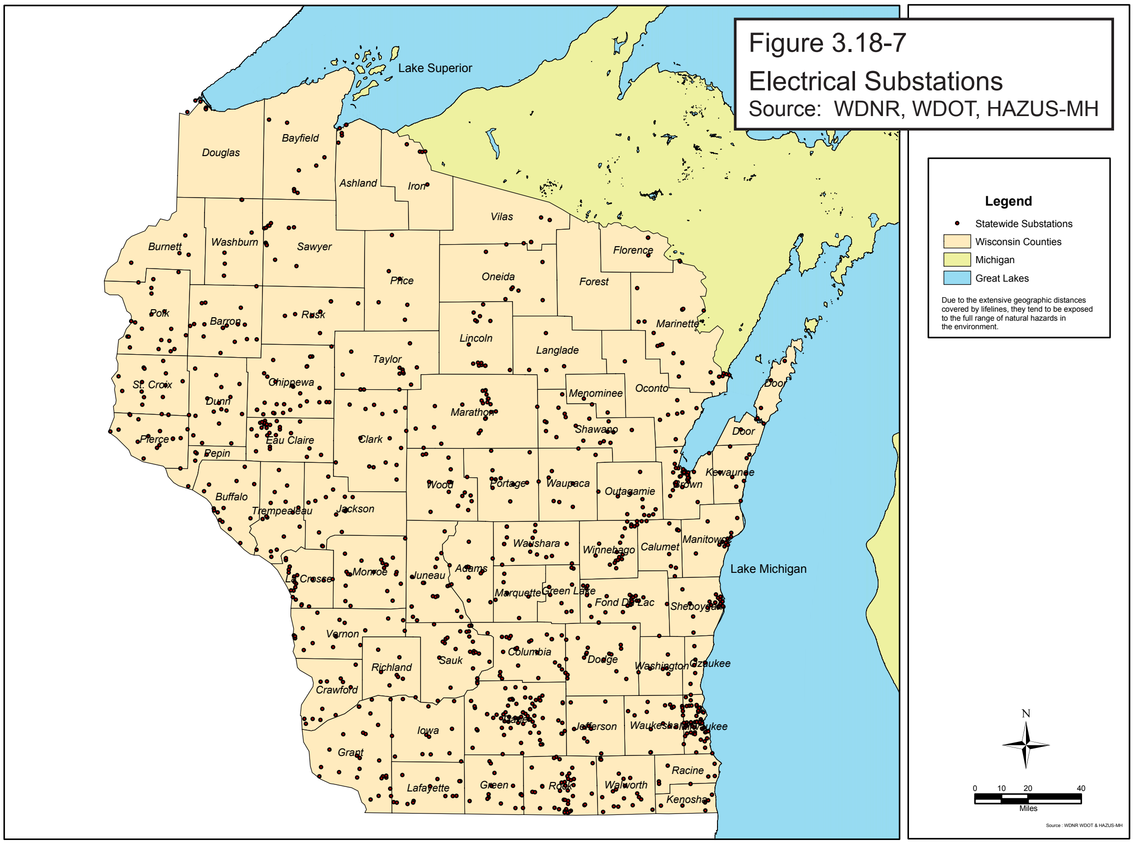

Figure 3.18-7
Electrical Substations
Source: WDNR, WDOT, HAZUS-MH

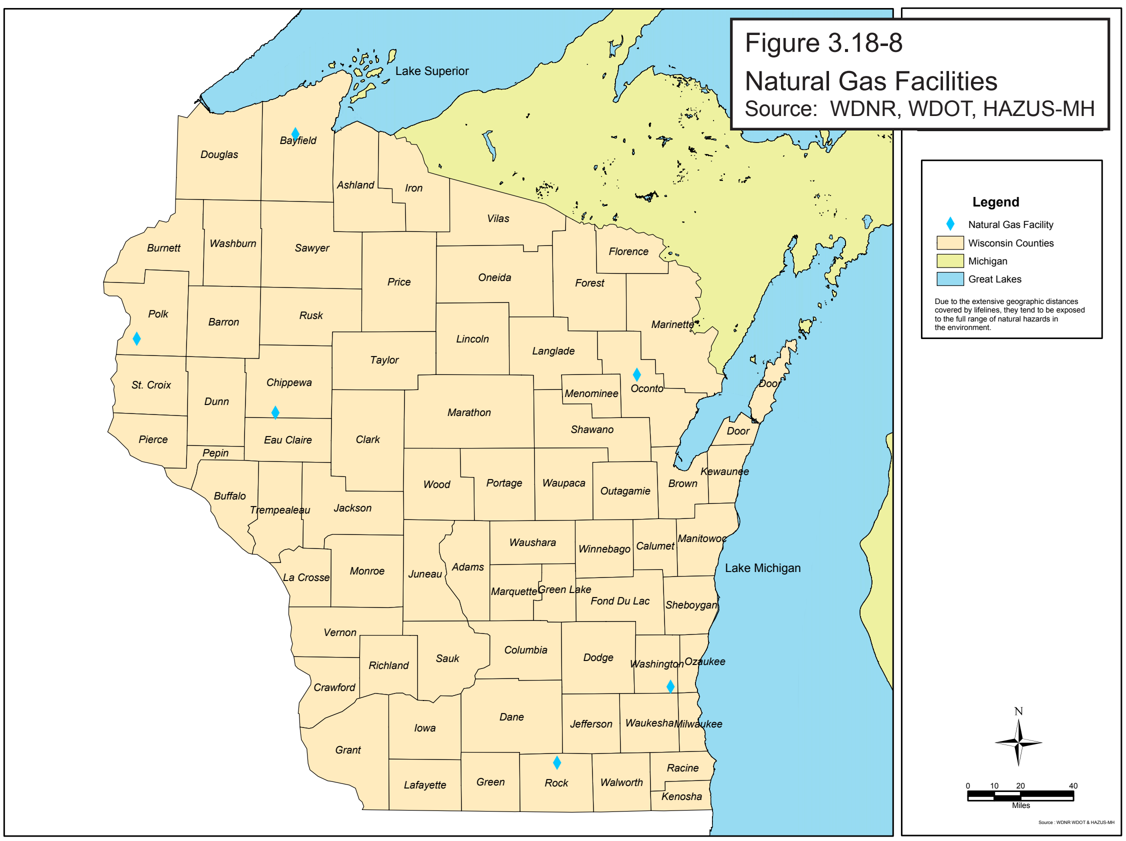

Figure 3.18-8
Natural Gas Facilities
Source: WDNR, WDOT, HAZUS-MH

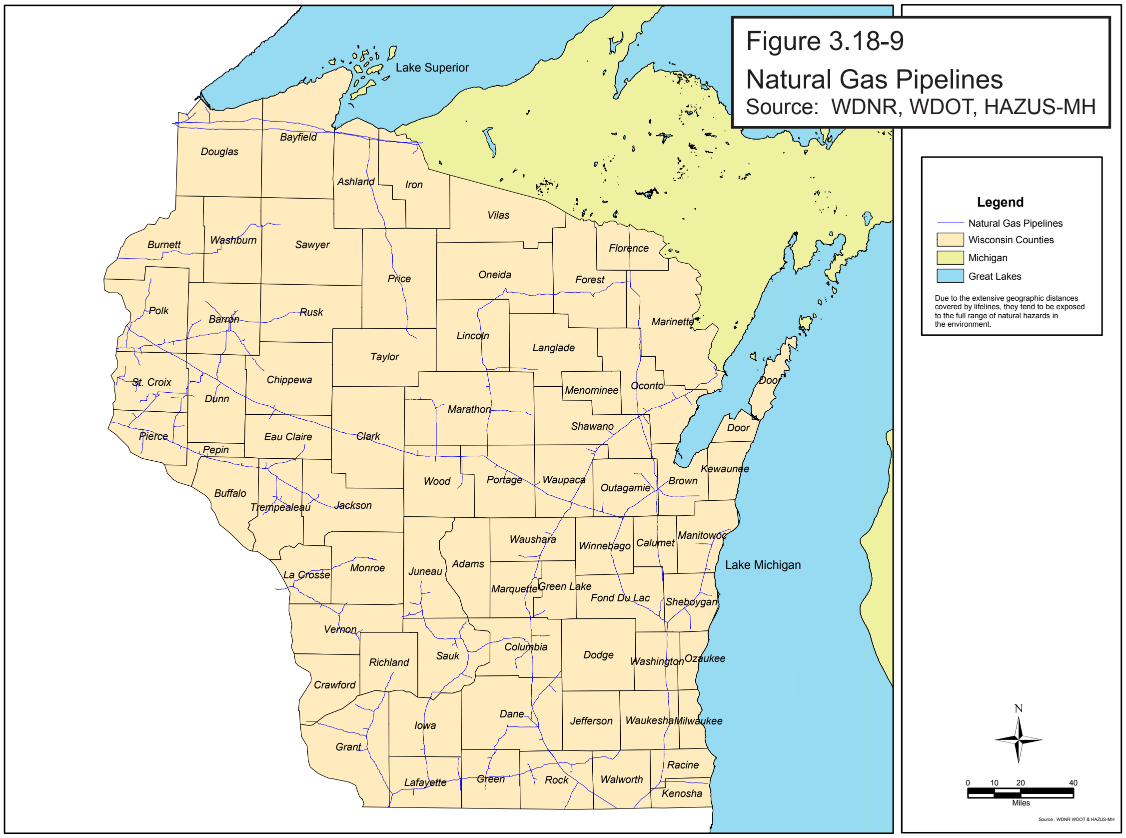

Figure 3.18-9
Natural Gas Pipelines
Source: WDNR, WDOT, HAZUS-MH

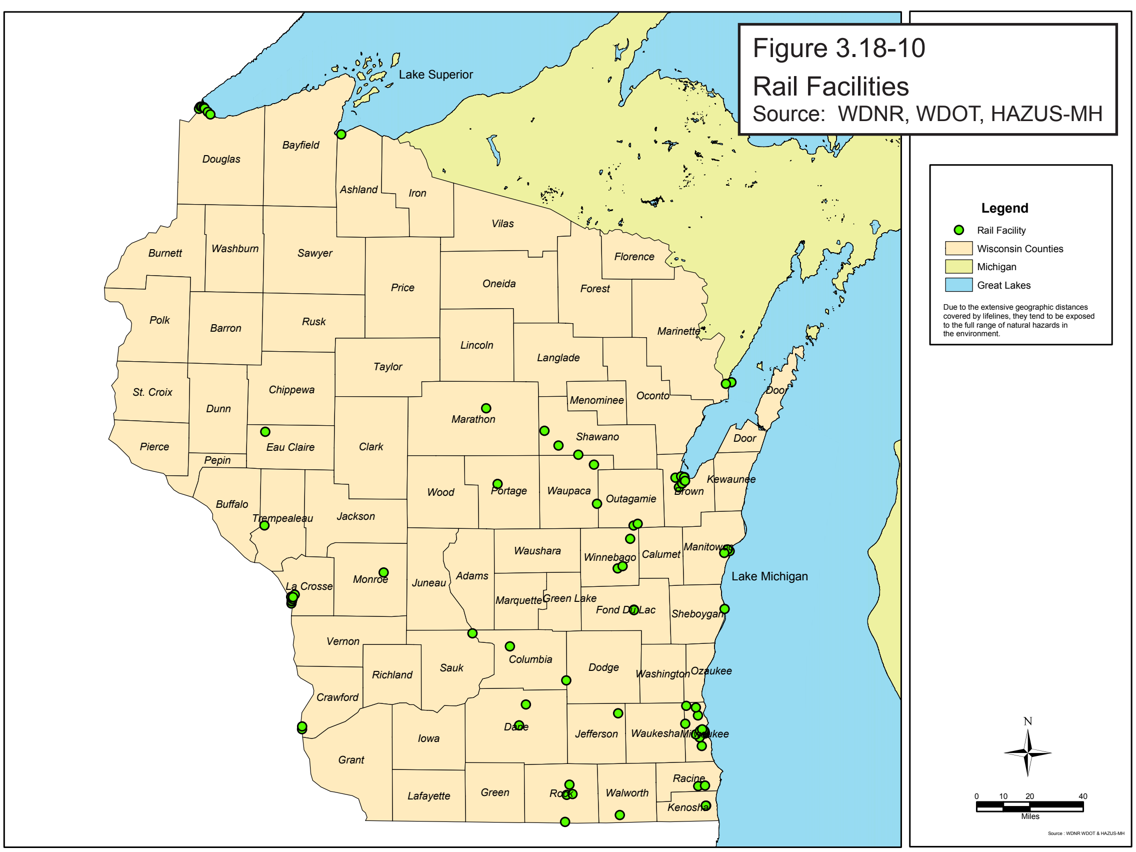

Figure 3.18-10
Rail Facilities
Source: WDNR, WDOT, HAZUS-MH

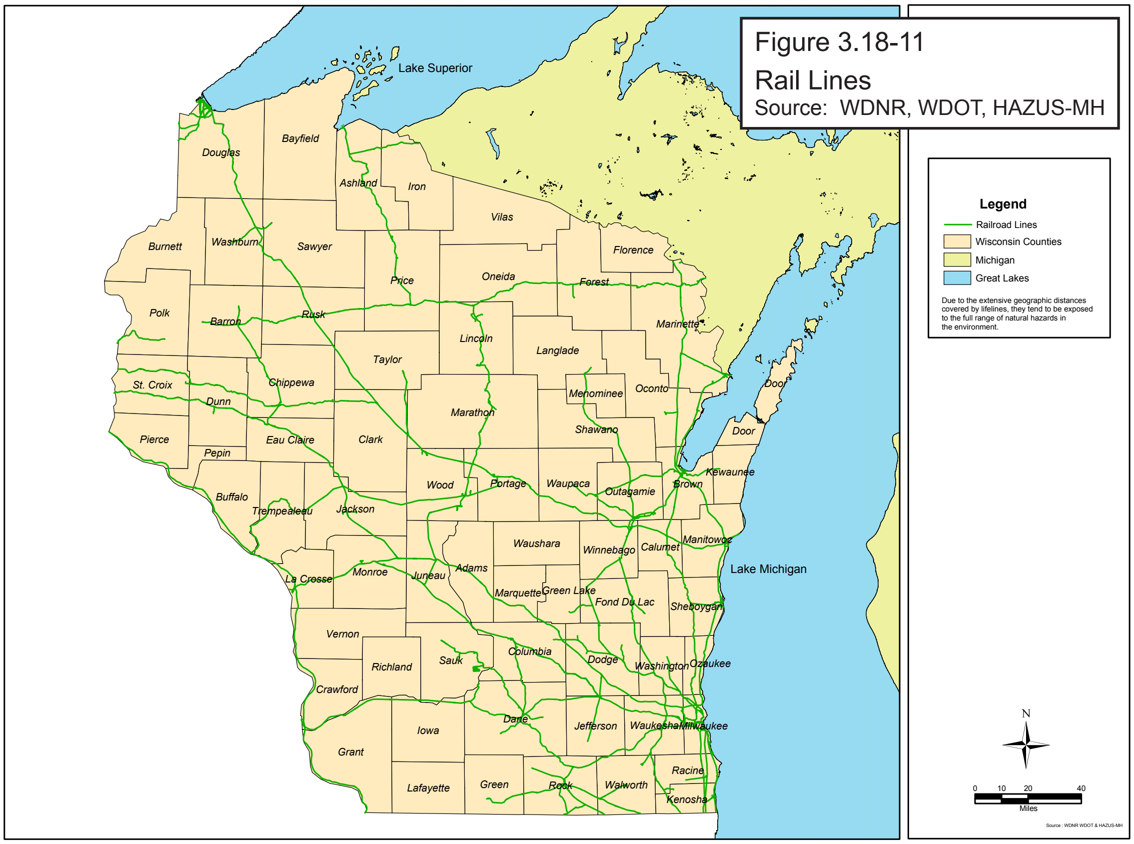

Figure 3.18-11
Rail Lines
Source: WDNR, WDOT, HAZUS-MH

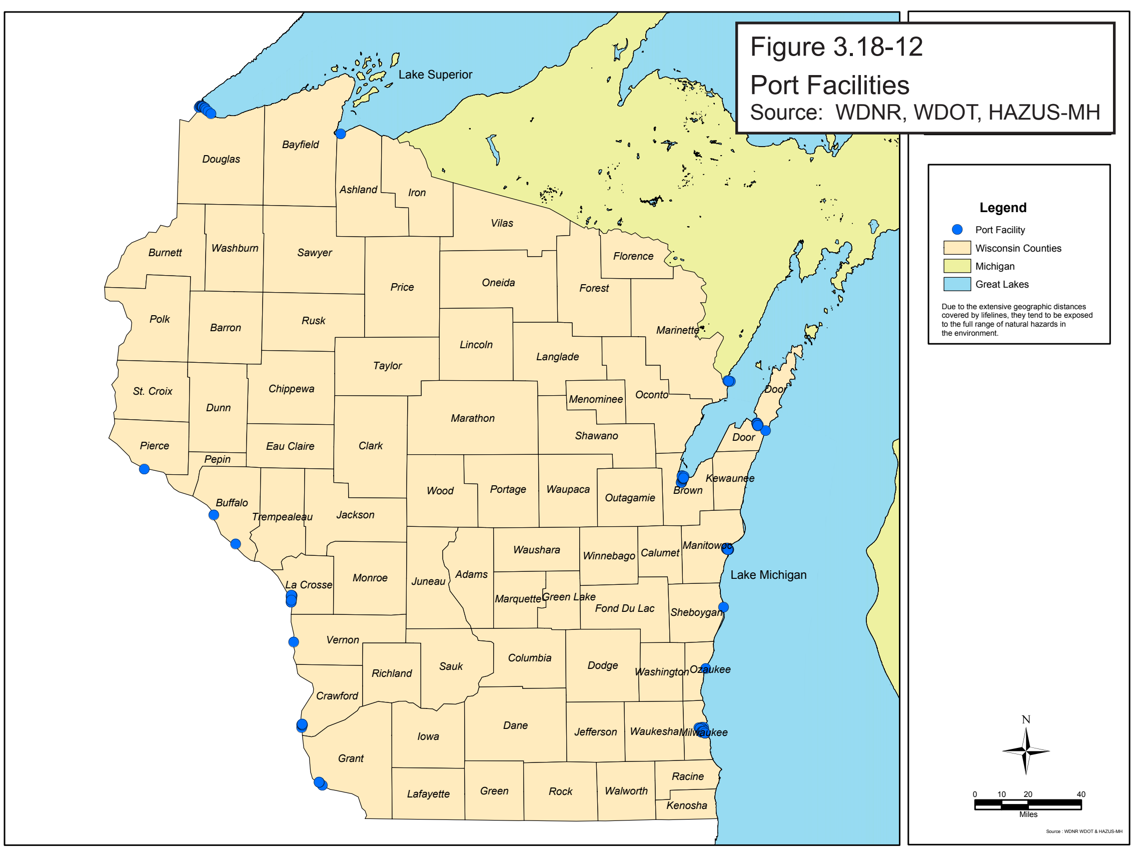

Figure 3.18-12
Port Facilities
Source: WDNR, WDOT, HAZUS-MH

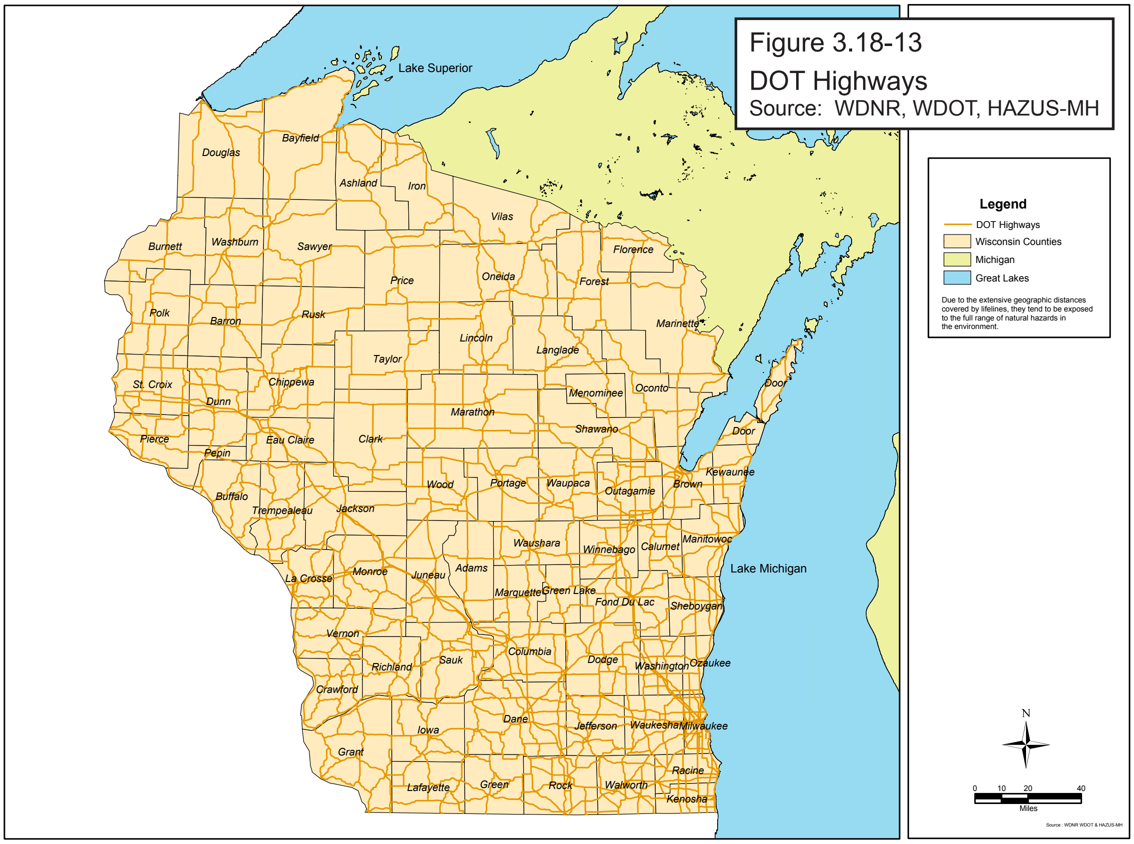

Figure 3.18-13
DOT Highways
Source: WDNR, WDOT, HAZUS-MH

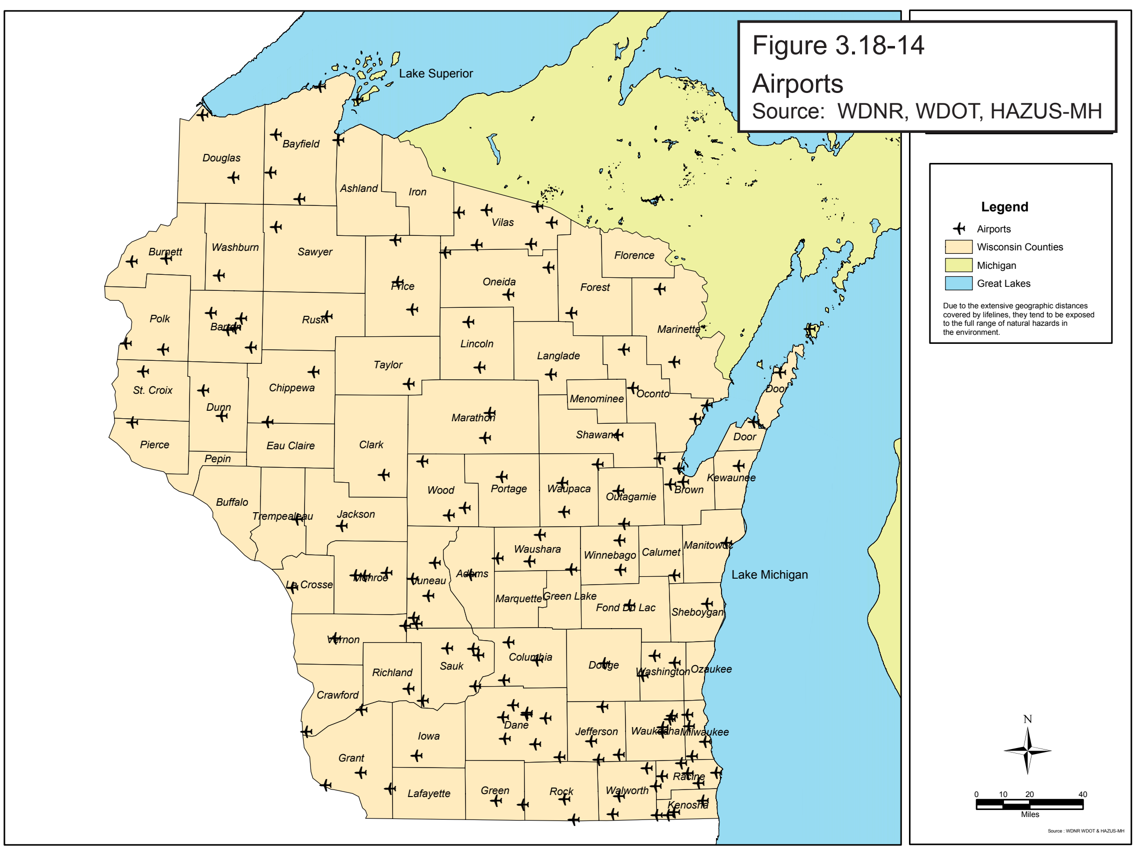

Figure 3.18-14
Airports
Source: WDNR, WDOT, HAZUS-MH

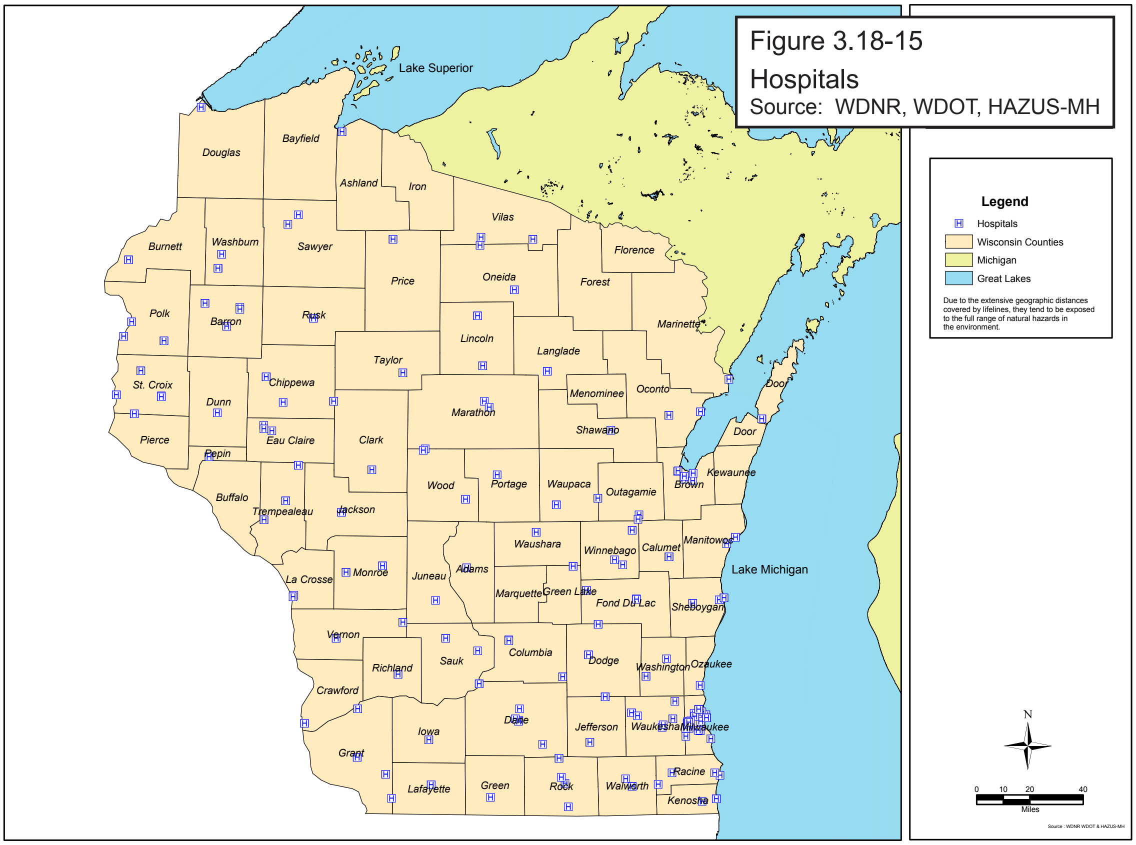

Figure 3.18-15
Hospitals
Source: WDNR, WDOT, HAZUS-MH

Data Limitations

As stated previously, this section provides a listing of the general types of lifelines and their components and identifies the major natural hazards to which the lifelines are most vulnerable. A detailed vulnerability assessment and loss estimation for lifelines is beyond the scope of this effort, with the exception of some of the electrical facilities addressed in the Rural Electric Cooperative Annex (Appendix G). At this time, the risk assessment for lifelines is included in Table 3.18-1, which provides a general indication of risk to lifelines based on the American Lifelines Alliance.

3.19 JURISDICTIONS MOST THREATENED AND VULNERABLE TO DAMAGE AND LOSS

This section of the plan addresses requirements of the Final Rule Section 201.4(c)(2)(ii).

The subsection 201.4 (c)(2)(ii) requires that the State Risk Assessment include an "overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments…The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events." Ultimately, the State shall describe which jurisdictions are most threatened and vulnerable to hazards and the process used to identify them. Identification of these jurisdictions shall be based on an analysis of available local risk assessments conducted throughout the state, and where not available, on the State Risk Assessment.

This section will examine the risk assessments from local hazard mitigation plans and integrate them into the State Plan. Next, the section will review and analyze the HAZUS Flood Hazard Analysis by county, the Tornado Risk Assessment by county, and the Wildfire and Coastal Hazard Analyses. Once complete, the results will be compared to the Natural Disaster Activity by County (see Appendix A). The comparison will determine whether the risk analysis substantiates the actual natural disaster events.

3.19.1 Local Risk Assessment Integration

In this three-year update of the State of Wisconsin Hazard Mitigation Plan, Wisconsin Emergency Management (WEM) chose to focus on integrating the local mitigation plans of those communities located along the Mississippi and Wisconsin rivers and the southeast counties of Kenosha, Milwaukee, and Racine that were higher risk and more vulnerable based on past events, number of repetitive loss properties, and the number of disaster declarations. Due to the number of completed and approved local mitigation plans within the State of Wisconsin, it would have been an overwhelming task to review and incorporate all approved local plans. In the next State Hazard Mitigation Plan update, more local jurisdiction plans will be included in the local risk assessment integration as they are approved.

Figure 3.19.1-1, on the following page, illustrates the focus counties used for the local risk assessment integration. Of the 21 counties in this area, two (Iowa and Pepin) are still in the initial planning process. Therefore, only the 19 counties with approved plans are included in the local risk assessment analysis.

In the local risk assessment integration analysis, potential losses and top hazards (as identified by the focus county) were reviewed. It was difficult to compare each of the counties' potential losses plan component because the State of Wisconsin does not require a standardized plan template. Therefore, each county had the liberty to create its own methodology for determining potential losses. However in some instances, multiple county plans were written by the same consultants or Regional Planning Commissions (RPCs) and do utilize the same potential loss methodology. Figure 3.19.1-2 illustrates the various methods of potential loss calculations used by the focus counties. (An important point to keep in mind is that estimating potential losses is not a required element in a plan but rather a recommended one so not all county plans include an estimate of losses.)

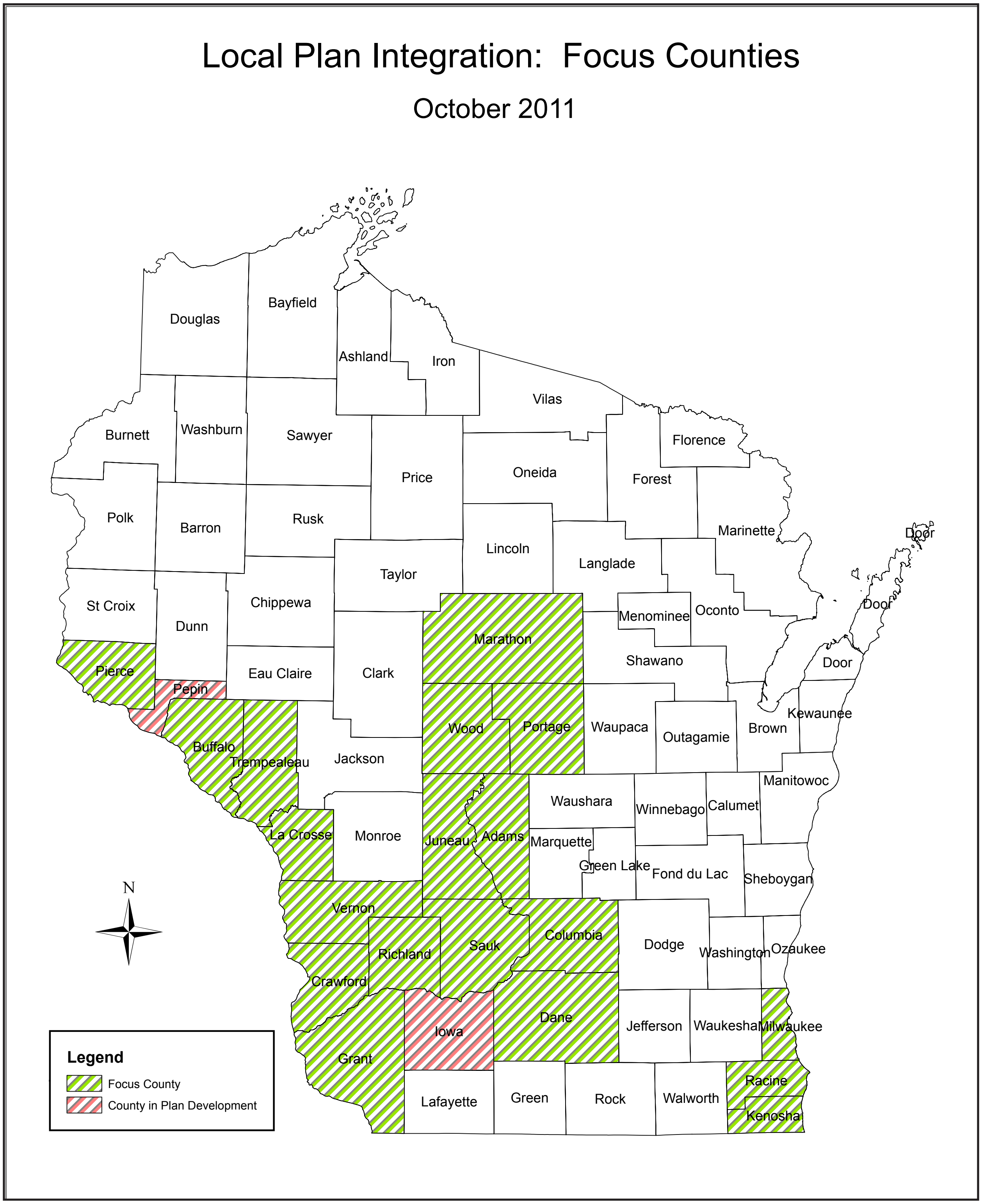

Figure 3.19.1-1 Local Plan Integration: Focus Counties
Source: WEM, 2011.

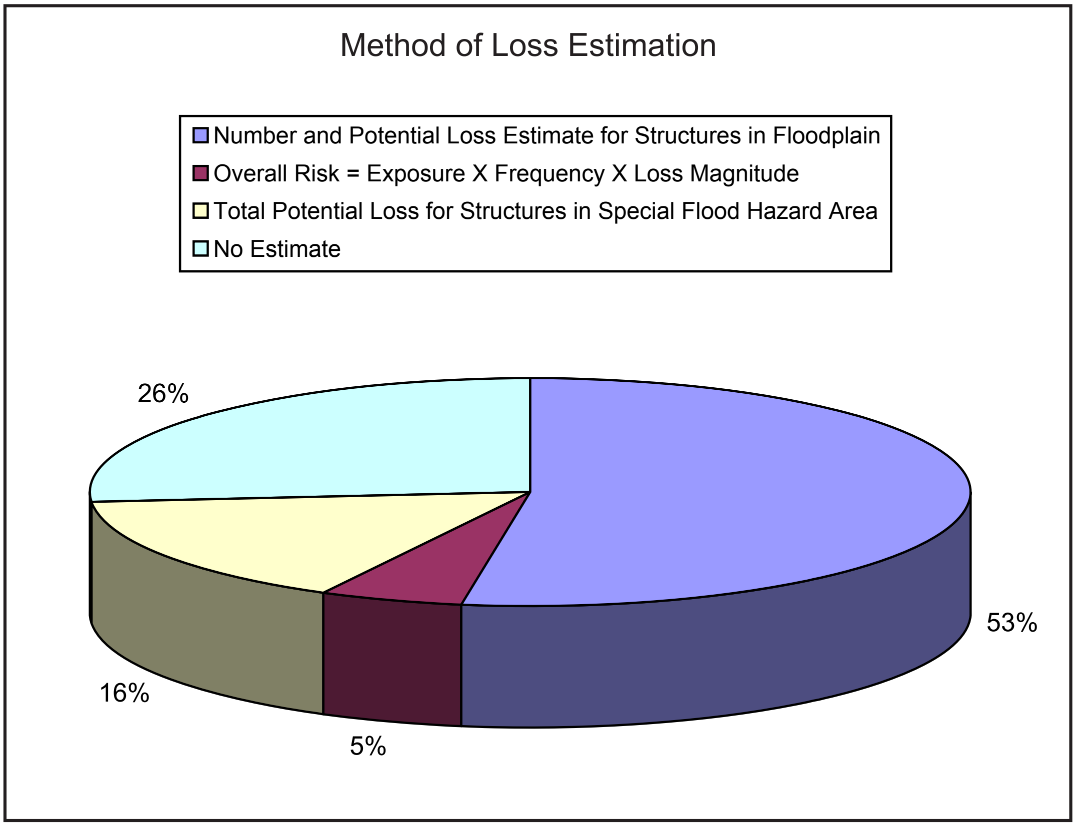

Figure 3.19.1-2 Methods of Loss Estimation by Focus Counties
Source: WEM, 2011.

Table 3.19.1-1, on the following page, lists the potential flooding losses for the focus counties by loss estimation methodology. According to the potential loss analysis, Milwaukee County (predictably because of the largest population and correspondingly highest property value) forecast the highest potential flooding loss of the 19 focus counties. Milwaukee County determined their potential flood losses by:

Overall Risk = Exposure x Frequency x Hazard Loss Magnitude (Building Risk)

In addition to determining the potential flood loss in this manner, Milwaukee County also determined losses from winter storms, tornadoes, and wind/hail storms.

The counties of Portage, Adams, Grant, Racine, Kenosha, Crawford, Dane, Vernon, Buffalo, and La Crosse determined potential losses by identifying the number of structures in the 100-year floodplain and subsequently estimating the potential losses of the structures. Marathon and Columbia counties included the number of structures in the 100-year floodplain, but did not do a loss estimate. Marathon County had a staggering 2,695 structures in the floodplain, which was more than any of the other counties that utilized this methodology.

Pierce, Wood, and Richland counties calculated potential losses by identifying the number of commercial and residential structures in the Special Flood Hazard Area (SFHA) and then determined the total potential loss for structures in the SFHA. Wood County

TABLE 3.19.1-1 FLOOD LOSS ESTIMATES BY METHODOLOGY

Methodology	Pierce	Trempealeau	Marathon	Wood	Portage	Juneau	Adams	Grant	Racine	Kenosha	Milwaukee	Crawford	Sauk	Dane	Vernon	Buffalo	La Crosse	Richland	Columbia
Overall Risk = Exposure x Frequency x Hazard Loss Magnitude ($1,000,000)											$17,530								
Flooding ($1,000,000)											$15,086								
Winter Storms ($1,000,000)											$2,053								
Tornadoes ($1,000,000)											$56.7								
Wind/Hail Storms ($1,000,000)											$91.8								
Loss Estimate of Structures in Floodplain ($1,000,000)					$52.8		$52	$13.9	$17.8	$6.3		$28.2		$105.4	$10.5	$4.5	$40.8		
Number of Structures in 100-Year Floodplain			2,695		537		824	221	793	359		632		1,645	292	290	1,570		1,880
Loss Estimate for Residential Structures in the SFHA (2-Foot Flood) ($1,000,000)	$20.7			$34.5														$8.1	
Number of Structures in SFHA	897			2,107														543	
Loss Estimate for Commercial Structures in the SFHA (2-Foot Flood) ($1,000,000)	$1.6			$12.8														$2.7	
Number of Structures in SFHA	4			24														3	
No Determination of Potential Losses		X	X			X							X	X					X

Source: WEM, 2011.

has 2,107 residential structures and 24 commercial structures in the SFHA. The potential losses for residential and commercial structures in Wood County are $34,500,000 and $12,800,000 respectively.

Another highlight of this table is Kenosha County: the loss estimate for structures in the 100-year floodplain in the 2008 Plan update was over $13 million. Since then, Kenosha County updated their local hazard mitigation plan to reflect numerous floodplain structures that were acquired and demolished through FEMA's Hazard Mitigation Assistance programs. For this Plan update, Kenosha County's loss estimate is only $6.3 million, less than half of what it was just a few years ago!

Of the 19 focus counties with approved local mitigation plans, five did not determine the potential loss in their communities, most likely because of insufficient data but also possibly because it is not a required element in the plan. It is expected that the county potential losses will be addressed in the five-year local plan updates. Dane County did complete a potential flood loss analysis as part of their FMA plan, however, that plan was not included in this analysis. In addition, Dane County only had 13 of 60 jurisdictions participate in the initial plan development. Dane County's plan update intends to include the rest of the jurisdictions.

In addition to examining the potential flood losses, the local risk assessment integration analysis identified the top hazards as determined by the focus counties.

Figure 3.19.1-3, below, highlights the top hazards as identified by the 18 of the 19 focus counties (Richland County did not specify which was the top hazard). Most of the counties noted that either flooding/dam failure or winter storms were the most precarious natural hazard they faced. However, thunderstorms and tornadoes also pose a significant threat to some counties.

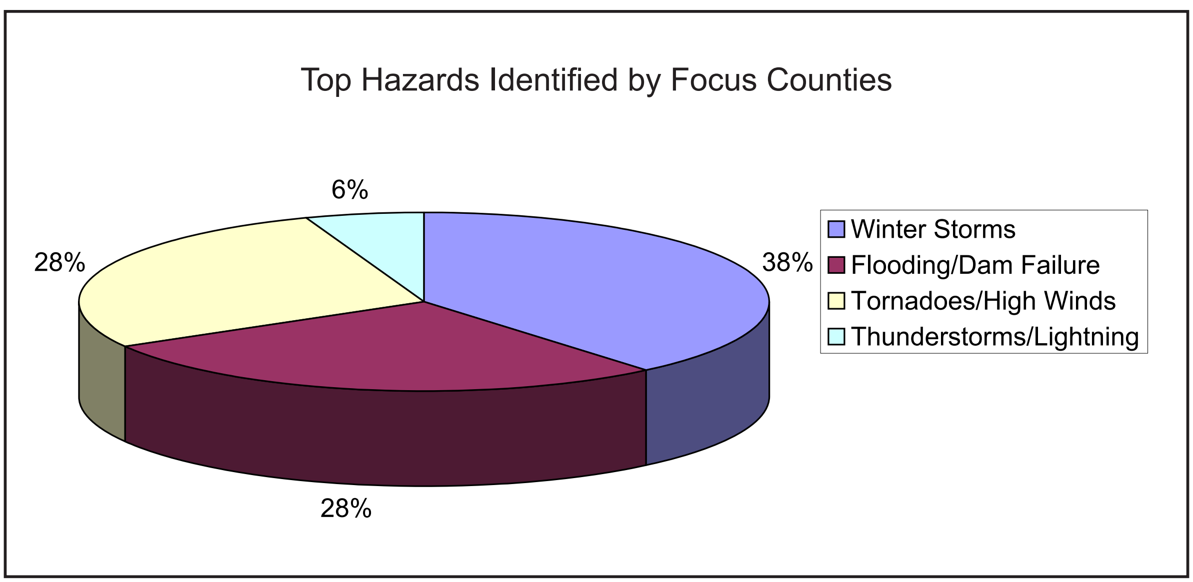

Figure 3.19.1-3 Top Hazards Identified by Counties
Source: WEM, 2011.

Table 3.19.1-2, below, shows all of the significant hazards identified by the focus counties. The "X" with the asterisk denotes the top hazard perceived by the community. As expected, all of the counties experience flooding to some degree. In addition, almost all of the counties identified winter storms and tornadoes as significant hazards. These two hazards are more likely to be identified as significant because they have a higher probability of occurrence. Winter storms have traditionally posed little risk for damage; however, tornadoes damages can be devastating. The remaining hazards are not as widespread. In fact, the hazards start to develop a regional pattern. For instance, forest and wild land fires were determined to be significant hazards in central and northern Wisconsin.

TABLE 3.19.1-2 TOP HAZARDS IDENTIFIED BY FOCUS COUNTIES

Hazard	Pierce	Trempealeau	Marathon	Wood	Portage	Juneau	Adams	Grant	Racine	Kenosha	Milwaukee	Crawford	Sauk	Dane	Vernon	Buffalo	La Crosse	Richland	Columbia
Flooding/Dam Failure	X*	X	X	X	X	X*	X*	X*	X*	X	X	X	X	X	X	X	X	X	X
Winter Storms		X*	X	X	X	X	X	X	X	X*	X*	X*	X	X	X*	X*	X*	X	X
Tornadoes/ High Winds	X	X	X*	X*	X*	X	X	X	X	X	X	X	X	X*	X	X	X	X	X*
Hail Storms	X	X			X				X	X		X		X	X	X	X	X	X
Extreme Temps		X	X	X	X	X		X	X	X	X			X		X	X	X	X
Forest Fires			X	X	X	X	X	X		X								X	X
Drought	X		X	X		X	X	X	X	X				X				X	X
Thunderstorms/ Lightning	X	X	X	X			X	X	X	X	X	X	X*	X	X	X	X	X	X
Coastal Erosion									X	X								X	
Landslides/ Subsidence			X					X											
Fog			X							X			X					X	

Source: WEM, 2011.

3.19.2 Jurisdictions Most Vulnerable to Loss from Floods

As described in Section 3.7, the loss estimation was performed using HAZUS-MH. The HAZUS-MH flood modeling was performed one county at a time. A stream network was delineated for every square mile within the county. The HAZUS-MH flood model performs an area weighted assessment of flood damage.

Tables 3.19.2-1 through 3.19.2-3 summarize the results of the HAZUS-MH flood analysis. It is not a surprise that Milwaukee County has with the highest total building exposure (Table3.19.2-1). The sheer volume of structures and number of rivers within Milwaukee

County account for almost $79 billion in building exposure. Dane County and Waukesha County also have high building exposure totals, but do not come close to Milwaukee County. When examining total economic loss from flooding (Table 3.19.2-2), Brown County had the highest total with $921,418. Once again, Waukesha County and Milwaukee County find themselves in the top three counties; however, Eau Claire County also had a significant economic loss total.

Brown County also had the highest risk of building loss (Table 3.19.2-3). However, Eau Claire rose to the second position in the building loss table. Waukesha and Milwaukee Counties were again in the top four. It is apparent from the Flood Risk Analysis that Brown County, Milwaukee County, Waukesha County, Eau Claire County, and Dane County face the greatest risk for losses in economics and structures due to flooding.

TABLE 3.19.2-1 TOTAL BUILDING EXPOSURE OVER $10 BILLION ($1,000)

Milwaukee County	$ 78,904,721
Dane County	$ 37,942,411
Waukesha County	$ 35,955,764
Brown County	$ 19,969,696
Racine County	$ 15,693,961
Rock County	$ 12,746,145
Winnebago County	$ 12,530,045
Kenosha County	$ 12,467,944
Outagamie County	$ 12,467,944
Washington County	$ 10,613383
Sheboygan County	$ 10,241,080
Marathon County	$ 10,032,014

Source: WEM, 2011.

TABLE 3.19.2-2 TOTAL ECONOMIC LOSS ESTIMATE OVER $250 MILLION ($1,000)

Brown County	$ 921,418
Waukesha County	$ 739,788
Milwaukee County	$ 732,195
Eau Claire County	$ 709,564
Dane County	$ 460,477
Marathon County	$ 365,012
Washington County	$ 351,573
Rock County	$ 316,841
Fond du Lac County	$ 300,969
La Crosse County	$ 294,438
Ozaukee County	$ 257,259
Kenosha County	$ 250,736

Source: WEM, 2011.

TABLE 3.19.2-3 BUILDING LOSS ESTIMATE OVER $100 MILLION ($1,000)	
Brown County	$ 430,304
Eau Claire County	$ 363,228
Waukesha County	$ 291,616
Milwaukee County	$ 286,370
Dane County	$ 180,345
Marathon County	$ 146,104
St. Croix County	$ 138,451
Washington County	$ 134,719
Columbia County	$ 130,669
Walworth County	$ 120,010
La Crosse County	$ 112,867
Racine County	$ 106,819

Source: WEM, 2011.

3.19.3 Jurisdictions Most Vulnerable to Loss from Tornadoes

Tables 3.19.3-1 and 3.19.3-2, on the following page, were complied using historic data from the National Climatic Data Center (NCDC). The tornado risk assessment reviewed the average damage amounts per tornado and the annual probability of tornadoes to determine the estimated future annual loss. In addition, injury and death were calculated using the 2008 figures from the Benefit-Cost Analysis Inflation Calculator. Ultimately, higher risks are associated with areas with increased populations as well as residential growth.

Table 3.19.3-1 shows Dane County as the county with the highest estimated future annual loss. Over the last 58 years, Dane County has had 44 tornadoes totaling approximately $69 million in damages. When considering the probability, Dane County can estimate that it may incur about $1.2 million a year in tornado losses. Fond du Lac and Dunn counties also have high estimated future annual losses because of the previous number of tornadoes and previous total damages, respectively.

Table 3.19.3-2 takes into account the loss of life and the number of injuries from tornadoes. Dunn County has had the most injuries (77) and deaths (21) due to tornadoes over the last 61 years. These factors contribute to its high estimate of total damages. Dane County had 66 injuries and 4 deaths while Oneida County has 36 injuries and 5 deaths. The final factor that contributes to the estimated annual loss number is the estimated annual loss for property damage. Both Dane and Dunn ranked in the top three counties because of the number of tornadoes.

It is interesting to note that Iowa County had a staggering 206 injuries and 9 deaths over the last 61 years, but because of its relatively low estimated annual loss for property damage, it ranked lower than Dane and Dunn Counties.

TABLE 3.19.3-1 TORNADO PROPERTY LOSS ESTIMATE BY COUNTY	
Dane County	$ 1,142,812
Fond du Lac County	$ 987,180
Dunn County	$ 955,689
Oneida County	$ 839,033
St. Croix County	$ 620,574
Chippewa County	$ 604,803
Waukesha County	$ 592,824
Washington County	$ 496,393
Waushara County	$ 472.623
Dodge County	$ 465,213
Wood County	$ 434,590
Vilas County	$ 433,607

Source: WEM, 2011.

TABLE 3.19.3-2 TORNADO TOTAL LOSS ESTIMATE BY COUNTY	
Dunn County	$ 3,016,787
Dane County	$ 1,578,320
Oneida County	$ 1,344,541
Fond du Lac County	$ 1,197,410
Chippewa County	$ 1,155,459
Iowa County	$ 1,064,000
Green Lake County	$ 1,015,831
St. Croix County	$ 840,000
Washington County	$ 829,295
Eau Claire County	$ 846,311
Waukesha County	$ 714,660
Waupaca County	$ 647,660

Source: WEM, 2011.

3.19.4 Jurisdictions Most Vulnerable to Loss from Wildfires

According to the Wildfire Risk Assessment found in Section 3.8, the approach used in the risk assessment model is based on the methodology developed in the NASF Field Guidance document. It recommends that assessment and mapping include four factors: 1) historic fire occurrences; 2) hazard; 3) values protected; and 4) protection capabilities. Modifications to the methodology were made to fit the data layers available for Wisconsin. The Wisconsin DNR used three factors to assess the Communities-at-Risk (CAR) to wildfire damage: 1) hazard (40%); 2) wildland-urban interface (30%); and 3) ignition risk (30%). Definitions of these three factors can be found in Section 3.8.

Unlike many hazard risk assessments (such as the tornado risk assessment) that rely solely on population, the Wildfire Risk Assessment primarily weighed the relative likelihood that an ignited wildfire will achieve sufficient intensity to threaten life or property based on land cover type and historic fire regime. More importantly, it also examined the vulnerability of each census block to wildfire damage based on housing density and spatial relationship with undeveloped vegetation based on density and proximity to vegetation, which is referred to as Wisconsin's Wildlife-Urban Interface.

Communities-at-Risk are reported at the municipal civil division (MCD) level. MCD was chosen due to its identifiable legal boundaries, ease in reporting, and use in the development of Community Wildfire Protection Plans (CWPPs). Each of Wisconsin's 1,864 towns, villages, and cities was defined as a community. Using the combination of natural breaks and filed verification, quantitative markers were assigned for five threat levels: very low, low, moderate, high, and very high. Ultimately, those communities determined to have a high or very high threat of wildfire were considered Communities-at-Risk. Three hundred and thirty-seven communities met the requirements for being at risk.

Using Figure 3.8.6-1, "Communities-at-Risk, Communities-of-Concern Map," Table 3.19.4-1 was derived. The red jurisdictions (Communities-at Risk, Very High) were counted for each county and the results were tabulated below. Adams and Burnett counties had the most Communities-at-Risk, Very High (12). Waushara, Washburn, and Juneau counties also had a number of CARs with 8, 7, and 7, respectively.

TABLE 3.19.4-1 NUMBER OF COMMUNITIES-AT-RISK BY COUNTY

Adams County	12
Burnett County	12
Waushara County	8
Washburn County	7
Juneau County	7
Jackson County	5
Oneida County	4
Douglas County	3
Monroe County	3
Sawyer County	3
Vilas County	3

Source: WEM, 2011.

3.19.5 Jurisdictions Most Vulnerable to Loss from Coastal Hazards

Table 3.19.5-1 and 3.19.5-2, on the following page, identify the counties with high and low coastal erosion risk. The data used for the coastal erosion analysis were derived from existing maps depicting rates of coastal erosion and the FEMA HAZUS-MH inventory of structures in the coastal zone.

High erosion risk is defined as the area within a one-quarter mile of the coast and low erosion risk is defined as the area within one-half mile. Tables 3.19.5-1 and 3.19.5-2 depict the total structures and loss estimation for residential, commercial, and governmental structures within the high and low erosion risk areas.

Milwaukee County's high population and the sheer number of structures make it the county ranked first in both the low and high erosion risk categories. Door County, a popular tourist destination located on the eastern peninsula of Wisconsin, has many primary and secondary residences, and commercial structures along the coast. Door County also has a great risk in both the low and high erosion risk categories.

TABLE 3.19.5-1 HIGH EROSION RISK LOSS ESTIMATION

County	Total Structures in Boundary	Loss Estimation
Milwaukee	6,513	$ 313,488,140
Door	7,956	$ 254,193,420
Ozaukee	2,225	$ 119,171,780
Racine	4,168	$ 97,102,480
Sheboygan	3,079	$ 64,475,440
Kenosha	2,295	$ 56,953,700

Source: WEM, 2008.

TABLE 3.19.5-2 LOW EROSION RISK LOSS ESTIMATION

County	Total Structures in Boundary	Loss Estimation
Milwaukee	15,977	$ 1,243,893,400
Door	9,747	$ 604,386,720
Ozaukee	3,867	$ 395,163,640
Racine	7,401	$ 396,492,600
Sheboygan	5,409	$ 211,743,360
Kenosha	4,556	$ 208,221,560

Source: WEM, 2008.

3.19.6 Summary

In Appendix A, the Natural Disaster Activity by County (1990-2011). Each of the events had a request for a Presidential Declaration; however, not all requests were approved. Most, if not all, of these events were due to a flood, severe storm, or tornado.

Table 3.19.6-1 shows the number of Presidential Disaster or Emergency Declarations issued for the highest ranking counties in the state. Dane County had 12 declarations over the last 22 years. Crawford, Green, and Milwaukee counties each had 10 events. All of the counties in 3.19.6-1 are located in the southern part of Wisconsin and were part of the 2008 flood declaration. The southern part of Wisconsin, compared to the rest of the state, receives strong storms and high rainfall amounts.

TABLE 3.19.6-1 NATURAL DISASTER ACTIVITY BY COUNTY (1990-2011)	
County	**Number of Declarations**
Dane County	12
Crawford County	10
Green County	10
Milwaukee County	10
Grant County	9
Sauk County	9
Vernon County	9
Waukesha County	9
Dodge County	8
Racine County	8
Richland County	8
Rock County	8
Columbia County	7
Juneau County	7
Kenosha County	7

Source: WEM, 2011.

The counties that consistently reappeared in the hazard risk assessments include Milwaukee, Dane, Waukesha, Racine, Kenosha, Brown, Eau Claire, and Marathon. These counties are among the most populous in the state and have substantial numbers of residential, commercial, industrial, and governmental structures. When determining risk in terms of loss of building structures and human life, the most populous counties typically will have the highest risk.

However, certain hazards' risks, such as the wildfire hazard, are dependent on the environment in the county. For instance, risk could be defined by examining the spatial relationship between housing density and with undeveloped vegetation. While population would play a part in the assessment, it would not be the deciding factor.

Regardless of the methodology used, it is important to complete risk assessments. Ultimately, the assessments need to be shared with local governments, state agencies, and most importantly, the citizens.