Climate Adaptation Plan for Marquette County, Michigan

Provided by the
Superior Watershed Partnership

Produced in Cooperation with the
Model Forest Policy Program and the
Cumberland River Compact

Foreword

In 2013, the Model Forest Policy Program (MFPP), the Cumberland River Compact, and the Superior Watershed Partnership (SWP) joined forces to create a climate adaptation plan for Marquette County, Michigan. Guided by the MFPP, all parties recognized the critical need for instituting local community resilience against the impacts of climate change, with particular emphasis on forest, water, and land resources. The result was the development of a climate adaptation plan for the County.

This plan captures the results of a community team effort, deep and broad information gathering, critical analysis, and insightful planning. The Superior Watershed Partnership took the local leadership role engaging with the Climate Solutions University (CSU) (Forest and Water Strategies Program), to lead the community toward climate resilience producing an adaptation plan that addresses local climate risks while integrating local conditions and culture. This achievement was made possible by the guidance and coaching of CSU, the Model Forest Policy Program, and the Cumberland River Compact. The goal of CSU is to empower rural, underserved communities to become leaders in climate resilience using a cost-effective distance-learning program.

The result of this collaborative effort is a powerful climate adaptation plan that a community can support and implement in coming years. The outcome will be a community that can better withstand impacts of climate change upon their natural resources, economy and social structure in the decades to come.

Acknowledgments

Climate Solutions University would not have been possible without the major funding of The Kresge Foundation and other funders, which allowed us to develop the in-depth curriculum and provide grants for local community participation.

The team that leads the CSU program includes: Nancy Gilliam, Gwen Griffith, Todd Crossett, Toby Thaler, Margaret Hall, Jeff Morris, Ray Rasker, Alyx Perry, Vanitha Sivarajan, Mike Johnson, and Josh Dye.

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Executive Summary

Throughout the last one hundred-plus years, weather in the Michigan's Upper Peninsula has been directly documented and archived. As modern technologies continue to advance, humans are better able to look back at earth's climate throughout past millennia using sources such as analysis of ice cores from ice caps and ancient pollen deposits. Analysis of multiple indicators show earth's climate to have always been one of continual change. Since the advent of the industrial age, however, evidence strongly points to a climate that is changing much more rapidly than natural cycles; these climate changes can be scientifically linked to human-induced changes of the atmosphere.

In the face of such present and emerging changes, humans need to consider the effects on their livelihoods, homes, health, and social structure and make necessary adaptations that minimize damage, disruption, and human suffering. It is in the interest of facilitating these adaptations in a timely manner that this climate adaptation plan was compiled.

Public meetings and input resulted in the identification of six themed issues that should be addressed in climate adaptation planning. These issues are: (1) land use, (2) water resources, (3) forest health (4) public health, (5) food security, and (6) tourism.

This climate adaptation plan is the culmination of a year of research, reporting, and outreach by the SWP and CSU team. It represents literature review, data collection, analysis, and forecasting and modeling by experts on the present and future vulnerability of the land, water, forests, and social and economic structure of Marquette County. Finally, and most crucially, the plan outlines goals and strategies to address climate change in this unique landscape.

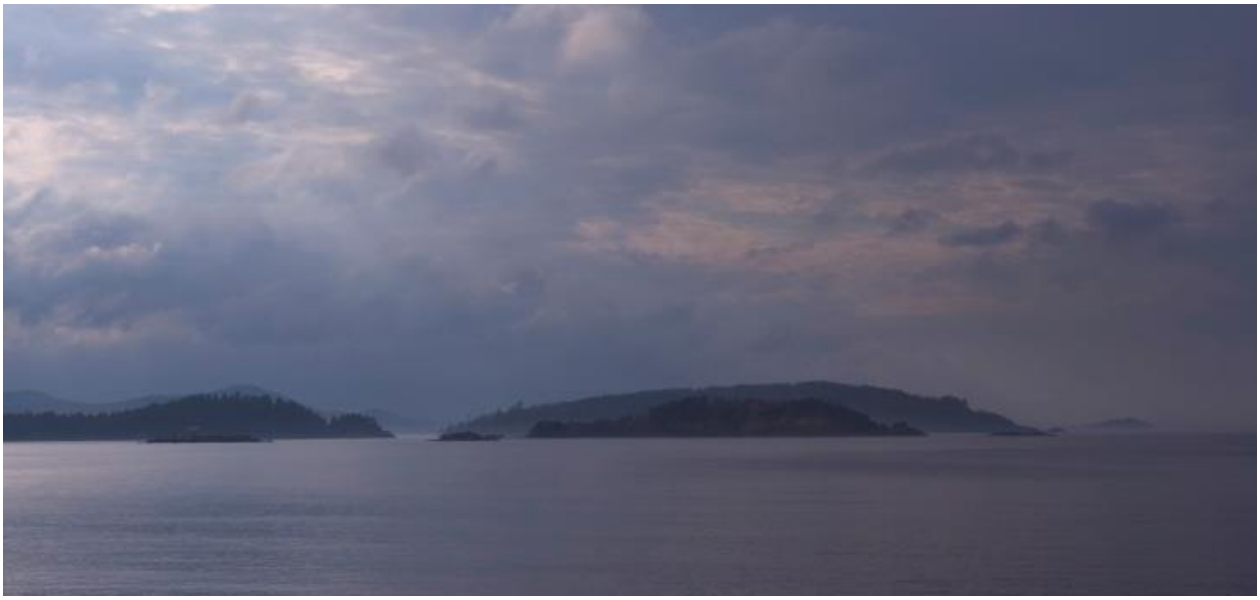


Figure 1: A Lake Superior View *(Source: Superior Watershed Partnership)*

Introduction

County and Project Introduction

In February 2013, the City of Marquette hosted a public meeting regarding climate change in the region. Over 70 members of the community and surrounding areas attended the public forum. From the many concerns attendees discussed, six themed issues emerged:

1. Land Use: Development, infrastructure maintenance, zoning regulations
2. Water Resources: Lake Superior water levels and ice cover, extreme precipitation events, impacts on the shipping industry, inland lakes and streams, groundwater
3. Forest Health: Increased risk of pest infestation, fire due to drought, decreased economic base
4. Public Health: Extreme temperatures, increase in pests and pathogens
5. Food Security: Food access and availability and local sources
6. Tourism: Changes in snowfall, extreme seasonal shifts

Marquette County

Marquette County is the fourth largest county in Michigan with a total area of 3,425 square miles. Home to roughly 67,000 people living on the south shore of Lake Superior and inland, county residents depend on a healthy, functioning lake ecosystem to sustain livelihoods and maintain a high quality of life.

As glaciers receded 8,000-10,000 years ago, scenic sharp cliffs and sandy beaches were left along its eighty miles of shoreline. Inland from the lakeshore, the glaciers deposited large tracts of sand plains and scoured out depressions that today form many lakes, wetlands and ponds. The result is a landscape that favors land and water-based forms of recreation, important components of the region's economy.

Roughly half of the County's watersheds drain north to Lake Superior, while the other half drain south to Lake Michigan. The climate and weather of Marquette County are heavily influenced by the forces of Lake Superior to its north. Warm moist winter air from open waters of Lake Superior can produce large amounts of lake-effect snow, as well as extend the winter season from November well into April. In the summer months, Lake Superior has the opposite effect, keeping most of the County cooler than areas farther inland. It is this cool climate that allows for the persistence of arctic disjuncts—northern plants found far from the main part of their range in northern Canada and Alaska.

Early European settlement of Marquette County stemmed first from missionaries and later from explorers searching for copper deposits in the nearby Keweenaw Peninsula. Instead of copper, iron ore was discovered near the city of Negaunee. Since that discovery, iron mining has been the key source of revenue for Marquette County. Nearly one third of the County's residents are

employed by one of the many facets of mining. This trend is projected to increase over time if more mines continue to open in the County in response to ongoing exploration and demand.

About the Lead Organization

The Superior Watershed Partnership and Land Trust (SWP) is a regional Great Lakes non-profit organization dedicated to the protection and restoration of Great Lake watersheds in Michigan's Upper Peninsula. The SWP provides creative leadership and promotes effective, community-based solutions to address emerging Great Lakes environmental issues. Based in Marquette, Michigan, the SWP serves three Great Lakes (Superior, Michigan, Huron), over 25 communities, 15 counties, and Native American tribes.

The Planning Process

The Superior Watershed Partnership took the local leadership role engaging with the Climate Solutions University (CSU) (Forest and Water Strategies Program), to lead the community toward climate resilience producing an adaptation plan that addresses local climate risks while integrating local conditions and culture. The goal of CSU is to empower rural, underserved communities to become leaders in climate resilience using a cost-effective distance-learning program.

This project builds on a similar effort in 2011 when the SWP collaborated with CSU to undertake climate adaptation planning for Alger County, Michigan. There are many similarities between Alger County (the next county eastward of Marquette County bordering on Lake Superior) and Marquette County. Through the planning process occurring in both counties, partnerships have been formed and strengthened; this further ensures the climate adaptation in these counties can serve as a model for other Great Lakes communities and counties.

Arctic Visitors under Stress

Climate change threatens the existence of delicate cold loving plants that are able to live in the Upper Peninsula because of Lake Superior's ability to keep summers cool. Known as **arctic disjuncts**, these are hardy plants have a range based far to the north in Canada; they have found an "arctic-like" home in the colder, sheltered pockets of UP forests. **Arctic Crowberry** and **Dwarf Raspberry** are two of just a handful of arctic disjuncts found in the Upper Peninsula. Listed as State Threatened on Michigan's Natural Features Inventory. They will likely disappear from the state if warming trends continue.

Arctic Crowberry (*Empetrum nigrum*)

Dwarf Raspberry (*Rubus acaulis*)

Climate Change

The Intergovernmental Panel on Climate Change (IPCC) scientists have examined a wide variety of changes associated with a warming planet and concluded that climate change due to the burning of fossil fuels is occurring and is increasingly well documented. The effects of climate change on human enterprises and quality of life and on ecosystems vary widely across the Earth, necessitating place-based adaptation planning.

Global Climate Change and Climate Change Adaptation

The underlying cause of climate change is a warming planet stemming from an increase in greenhouse gases (e.g., carbon dioxide, methane, water vapor) that trap reflected solar radiation on Earth. This increase in greenhouse gases has resulted in a 0.7 degrees Celsius rise in global average temperature in the last sixty years. This rise in temperature translates to higher ambient temperatures but also to complicated interactive effects such as increased storm frequency and intensity, droughts, melting of glaciers and ice caps, rise in sea levels, increases in plant pathogens and more (Herzog et al. 2005).

This build-up of greenhouse gases results primarily from human activities in the industrial age. According to a report from the World Research Institute (Herzog et al. 2005) a large contributor (17%) is electricity generation powered by fossil fuels followed by industry (14.7%) and industrial processes (4.3%). Transportation accounts for 14.3% of emissions followed by agriculture (13.6%), land use changes (particularly deforestation) (12.2%), miscellaneous fuel consumption (8.6%) and heating (5%). Clearly finding mitigation strategies to reduce input of greenhouse gases and slow global warming will necessitate a multifaceted approach.

Just as important is the development of place-based adaptation strategies that devise new ways for humans to live in and interact with their environments while taking into account inevitable effects of climate change.

Lake Superior Climate Change

Every year, it seems, there is more information available about the effects of climate change on Lake Superior communities and citizens. In 2012, extreme weather events in the form of intense rain and flooding caused severe impacts in Duluth in Minnesota as well as Thunder Bay and Wawa in Ontario, Canada. Increased intensity and frequency of rainstorms result in property damage, erosion, and impacts to infrastructure and water quality.

Lake Superior is indisputably showing a warming trend with record high surface temperatures documented in 2012. In that same year, the city of Marquette, Michigan was forced to close beaches due to high bacterial counts. Ice is forming later on the Great Lakes and is less extensive in coverage, with Superior experiencing an overall 70% decrease in ice cover in the past 40 years.

In a feedback loop, the warming lake results in ice going out earlier in the spring that, in turn, allows an earlier stratification of the lake and subsequent enhanced warming of the surface layer. The effects of this overall warming trend on the aquatic ecosystem are unknown and an object of ongoing research with great concern for cold-adapted aquatic species and the impacts on fisheries. Changes in timing, quality and quantities of snowfall directly affect winter-sport tourism (snowmobiling, skiing, etc.). Reduced precipitation in the entire Lake Superior basin combined with increased evaporation has resulted in falling lake levels with concomitant negative impacts on shipping and tourism.

Regional Climate Change Summary

Precipitation

Figure 2 from Great Lakes Integrated Science Assessments (GLISA) summarizes precipitation in the western Upper Peninsula, which includes Marquette County. The table on top summarizes data into two groups, 1951-1980 and 1980-2012. When these two groups are compared, one can see an annual decrease in precipitation of 1.5%. This decrease has been experienced in spring and summer, with increases noted in winter and fall for the same two periods. Perhaps because of this

Change in Mean Total Precipitation (%) from 1951-1980 to 1981-2010

Annual	-1.5
Winter, December-February	7.8
Spring, March-May	-5.6
Summer, June-August	-11.5
Fall, September-November	9.0

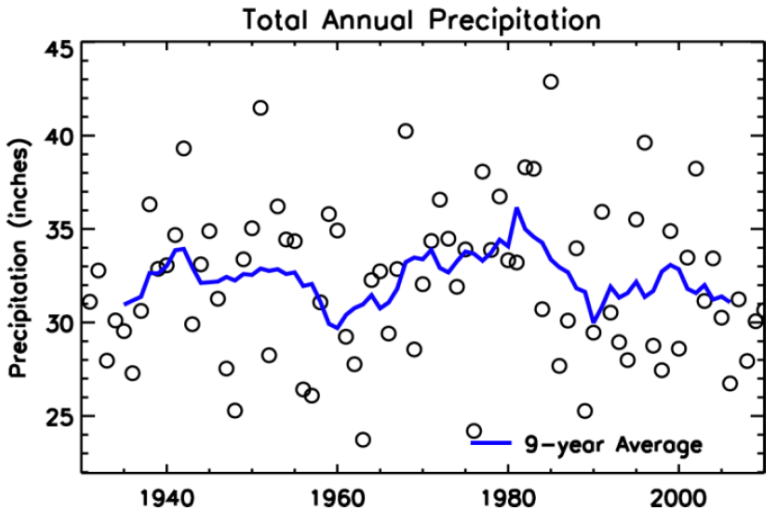


Figure 2: Precipitation Trends in the Western U.P. *(Source: GLISA)*

seasonal difference, the graphical representation of total annual precipitation and nine-year average rainfall from 1930 to 2012 does not show any conclusive trends. Effects can also vary within the region and County with some locations receiving greater lake-effect snowfall resulting from a warmer, ice-free lake, while other inland locations experience decreased snowfall.

If, as the tabular summary indicates, precipitation is decreasing overall, one can expect shifts in natural vegetative communities, impacts on agriculture, falling inland lake levels with negative effects on tourism and real estate, and falling Great Lake levels with profound impacts on shipping. All these effects have already been noted in the region and are potential targets for adaptation planning.

Temperature

Figure 3 from GLISA summarizes annual average temperature in the western Upper Peninsula, which includes Marquette County. The table on top summarizes data into two groups, 1951-1980 and 1980-2012. This comparison reveals an apparent annual increase in mean temperature between the two periods at all seasons with the greatest increase occurring in the winter (December-February).

Changes in Mean Temperature (°F) from 1951-1980 to 1981-2010

Annual	1.0
Winter, December-February	2.0
Spring, March-May	1.1
Summer, June-August	0.6
Fall, September-November	0.2

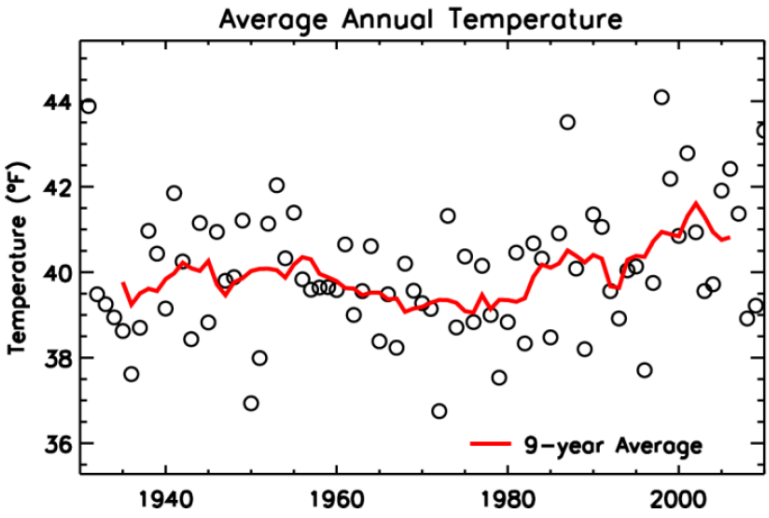


Figure 3: Annual Average Temperature in the Western Upper Peninsula
(Source: GLISA)

According to the graphical representation, the nine-year average temperature appears to be increasing although no statistical analysis is included. Based on global trends, these warming trends are expected to continue in the future.

Repercussions to humans from rising temperature will be experienced differently depending on a variety of factors such as season, economic and industrial drivers, and lifestyles.

Ranges of plants and animals are expected to gradually shift. Animal species with more southerly ranges will continue to expand northward (e.g., red-bellied woodpecker, turkey vulture, gray fox), sometimes displacing current residents. Species associated with more boreal habitats and a colder climate (e.g., moose, spruce grouse, boreal chickadee) may decrease in abundance and distribution. Plant species are expected to follow similar trends with the greatest attention to date having been paid to tree species. Ranges of herbaceous species will also be affected, perhaps even more rapidly.

Climate Change Predictions for the Upper Great Lakes

Although effects will vary throughout the region, climate scientists have made general predictions for the upper Great Lakes, including Michigan's Upper Peninsula. (Kling et al. 2003, 2005, Wuebbles et al. 2003, UCS 2009, NRPC 2010, Saunders 2011). Not all climate changes are "negative"—some may have positive effects, including increased economic opportunities.

A concise summary of documented Great Lakes climate changes from Kling et al. (2003, revised 2005) reads as follows:

- Winters are getting shorter.
- Annual average temperatures are growing warmer.
- Extreme heat events are occurring more frequently.
- The duration of lake ice cover is decreasing as air and water temperatures rise.
- Heavy precipitation events, both rain and snow, are becoming more common.

Figure 4 highlights and summarizes major direct and indirect general climate change impacts expected in the Upper Peninsula, including Marquette County. The impacts selected are those that are observable and measurable by the end of the 21st century with their magnitude depending on the scientific model scenario (high, mid-range, or low) of anticipated carbon emissions. For example, temperature rises at Pictured Rocks National Lakeshore in Alger County, immediately east of Marquette County, are projected to range from 5^0 F to 14^0 F by the end of the century (Saunders et al. 2011). Many effects are already being observed; the question then becomes one of severity and rate of change.

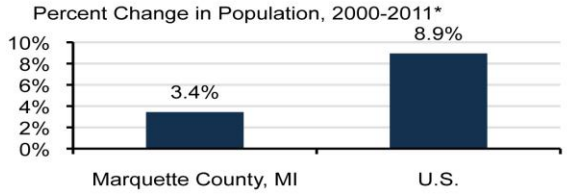
Current and Predicted Climate Changes	Predicted Direct Effects	Probable Indirect Physical and Biological Effects	Probable Indirect Effects on Human Experience
• Warmer summers • Increased droughts • Warmer winters, with more precipitation falling as rain rather than snow • Later freeze-up and earlier ice breakup and snow melt • Irregular, high intensity storm events	• Less winter ice • Increase in evaporation • Lower lake levels for Lake Superior and inland lakes • Ephemeral wetlands, hugely important biological areas, will dry up. • Some current open-water areas will become wetlands • Summer lake stratification lengthened • Changes to forest tree composition • Continued northward migration of native plants and animals	• Habitats will shrink or disappear for species at the edges of their ranges. • Increases in invasive insects and diseases • Changes in phenology, potentially disconnecting some critical ecological interactions • Cold water fish habitat will shrink, warm water habitat will increase • More algae • More lake turbidity • Certain tree species, such as Sugar Maple, Hemlock, Paper Birch and Jack Pine will decline • Rain-on-snow events will cause more winter and spring flooding • Increased danger of forest fires • Habitat for endangered species, such as Kirtland's Warbler and Pitcher's Thistle likely to be negatively impacted • Risk of degradation and damage to wetlands due to flooding, erosion and siltation.	• Longer summer recreation season • Shorter winter recreation season • Increased cost of living in summer; decline in winter • Possible heat-related health issues • Low lake levels will threaten shipping and infrastructure • Navigation hazards exposed • Recreational fishing quality will change • Degradation of cultural resources, such as shipwreck artifacts • Severe weather events i.e. flooding will affect built environments • Storms effects on public safety, disruption of services • Decline in winter tourism will affect local economy.

Figure 4: Overview of Projected Climate Change Effects in Marquette County

Economics and the Environment

Population

Marquette, the most populous county located within Michigan's Upper Peninsula (67,906 in 2012) averages roughly 37 persons per square mile. County households receive slightly less income than the state household average. In 2010, 67% of Marquette County's population ranged from 18-64 years old, with category ages 20-24 having the largest number of persons. Throughout the decade between 2000 and 2010, Marquette County experienced a 3.4% increase in population (Figures 5 and 6). As of April 2013, the unemployment rate of the County was 8.3%, one tenth percent below the state average.



Age & Gender Distribution, 2011*

	Michigan	Marquette County, MI	U.S.
Total Population	9,920,621	66,859	306,603,772
Under 5 years	603,820	3,360	20,170,377
5 to 9 years	644,069	3,014	20,207,046
10 to 14 years	686,008	3,817	20,631,572
15 to 19 years	748,083	5,314	22,083,463
20 to 24 years	671,777	7,223	21,463,191
25 to 29 years	597,326	4,085	20,940,180
30 to 34 years	579,109	3,595	19,728,641
35 to 39 years	631,109	3,423	20,367,911
40 to 44 years	685,616	3,949	21,315,317
45 to 49 years	753,161	4,725	22,654,947
50 to 54 years	758,261	5,277	21,924,721
55 to 59 years	671,029	5,267	19,215,139
60 to 64 years	549,731	4,075	16,292,447
65 to 69 years	401,287	2,806	11,984,083
70 to 74 years	304,975	2,246	9,168,648
75 to 79 years	248,379	1,831	7,365,437
80 to 84 years	202,619	1,484	5,753,990
85 years and over	184,262	1,368	5,336,662
Total Female	5,052,992	33,236	155,863,556
Total Male	4,867,629	33,623	150,740,216

Figures 5 and 6: Population Statistics for Marquette County, Michigan, *(Source: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000. Census Bureau, Systems Support Division, Washington, D.C.)*

Employment

Natural resources are a critical underlying component of predominately rural Marquette County's economic base (Figure 7). Impacts from climate change on this natural resource base can be expected to directly or indirectly affect employment in the future.

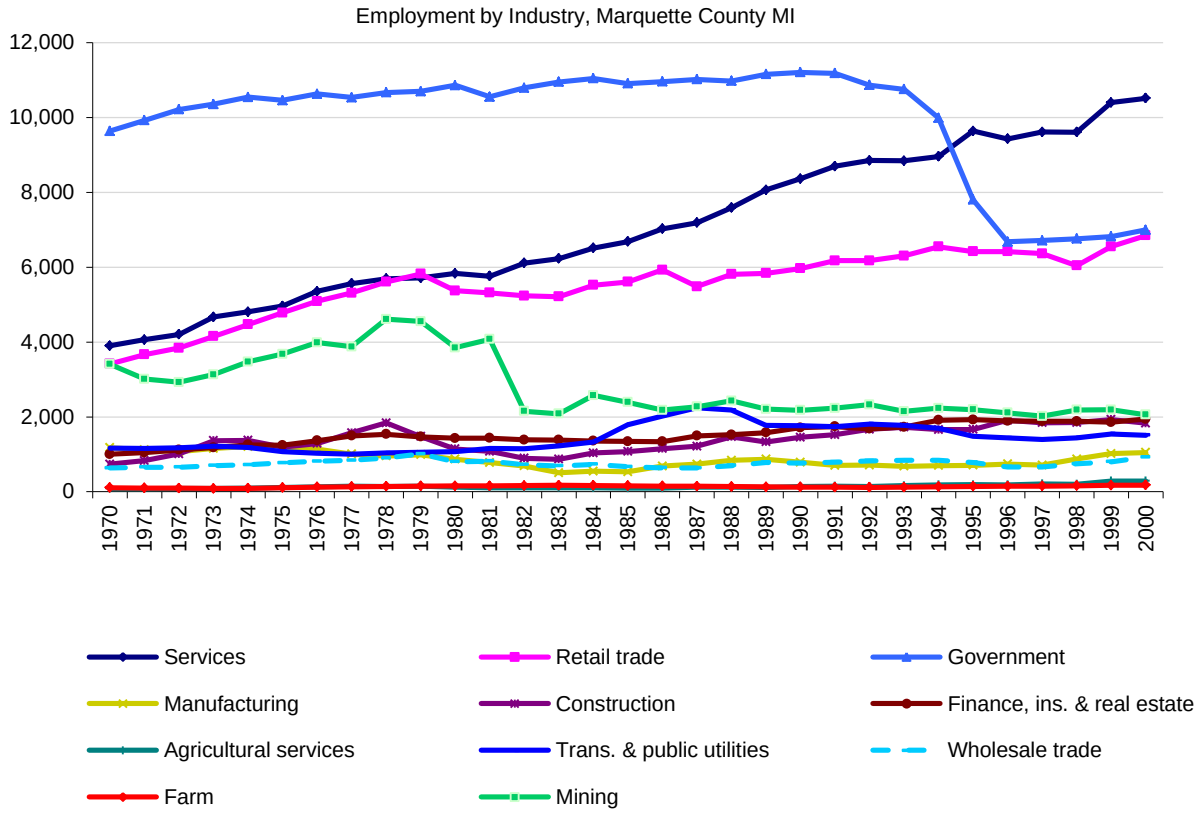


Figure 7: Employment Sectors for Marquette County, 2012 *(Source: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000. Census Bureau, Systems Support Division, Washington, D.C.)*

Services

The majority of employment in the County comes for service-related jobs, increasing 17% between 1970 and 2000, and nearly 11% since the beginning of 2001 (Figure 8). As of 2010, approximately 82% of Marquette was employed in service-related fields. Major contributors to the growth of this employment sector are the two hospitals located in the County. One of these, Marquette General Hospital, the Upper Peninsula's only level-two trauma center, was purchased by Duke Medical in September of 2012; the impacts of this new management remain unknown. Other occupations contributing to this field include retail trade, finance, and education. Northern Michigan University is located in the City of Marquette and employed 1,223 people as of 2012.

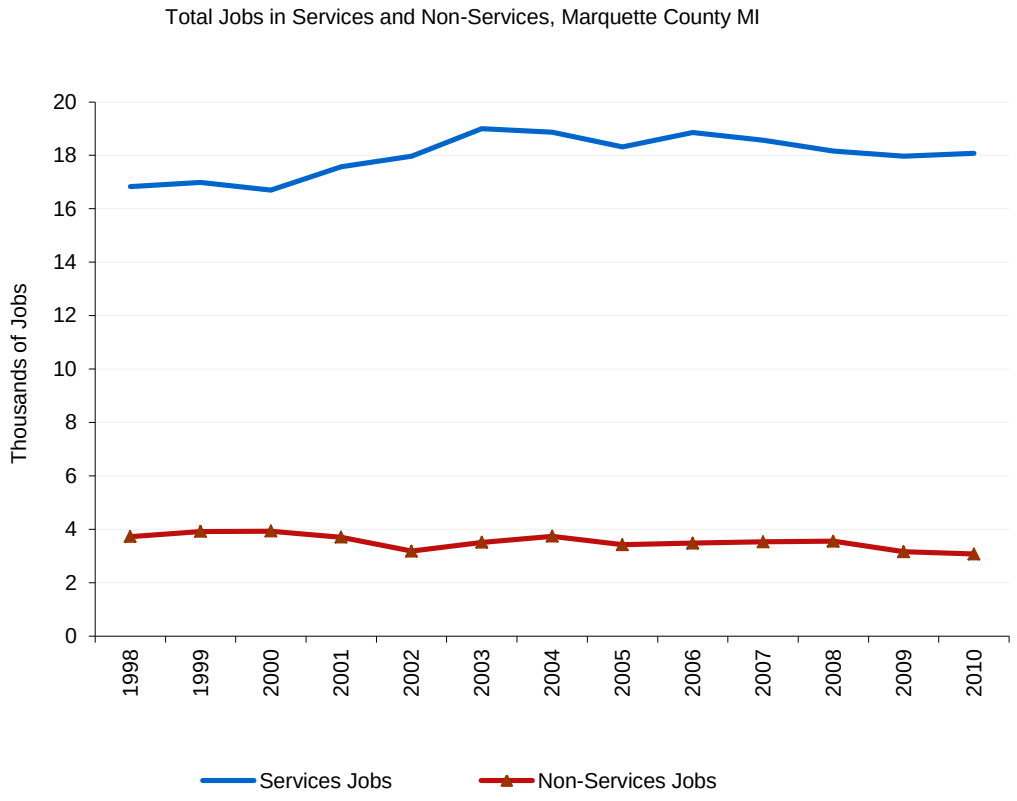


Figure 8: Services and Non-services Jobs, Marquette County, 1998-2010
(Source: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000.)

Government

The government employs 17% of Marquette County workers, a 12.6% decrease since 2001 (Figure 9). From 1970 to 2000, government jobs were reduced by over 4,200 people—a decrease of 37.6%. A major contributor to the loss of government jobs was the gradual shutdown of KI Sawyer Air Force Base in 1995. As a result of the shutdown, County officials estimate that Marquette lost 157 million dollars. Officials also stated that it took over 11 years for the jobs lost at Sawyer to be replaced in the County. The largest employer of government personnel currently is the Marquette Branch Prison with about 405 employees.

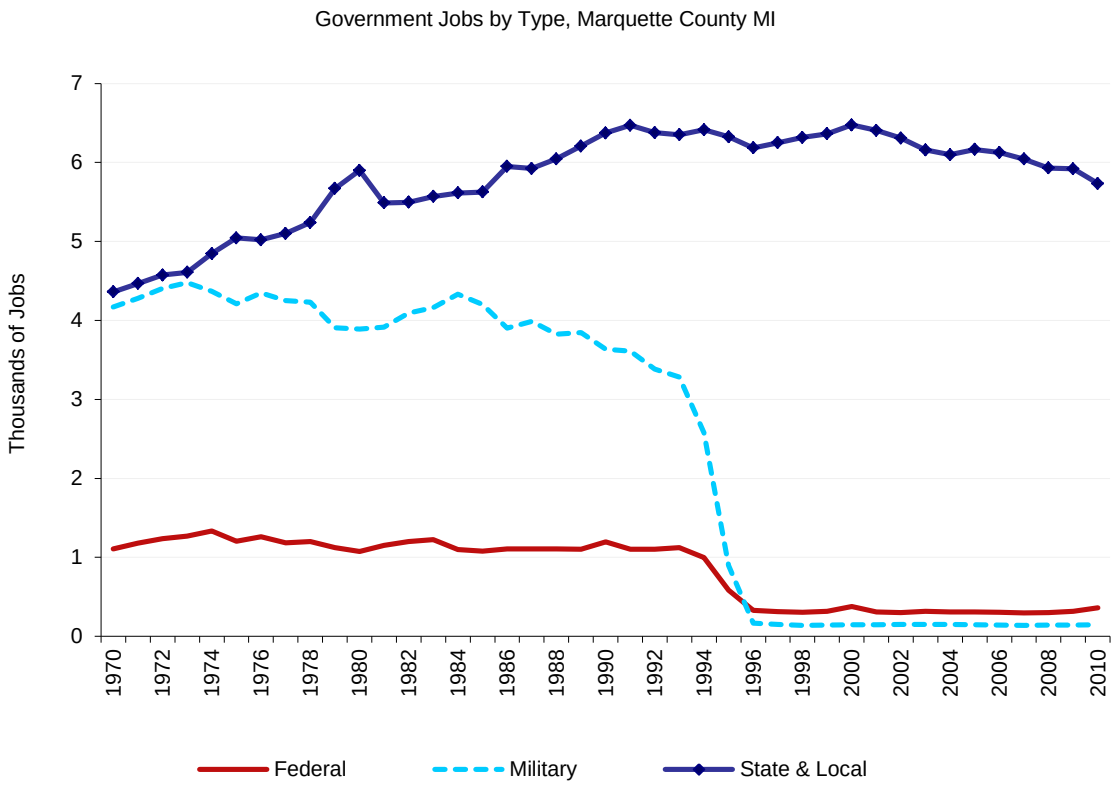


Figure 9: Government Jobs by Type, Marquette County, 1970-2010
(Source: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000.)

Tourism

Tourism has always had an important place within Marquette County's economy. Although it does not provide the steady "fuel" in the same sense provided by service and government jobs, the tourism industry is nevertheless a vital component of the County's economy (Figure 10). Almost 20% of private (non-federal) employment in the County is related to travel and tourism, which will certainly feel effects of climate change in both positive and negative directions.

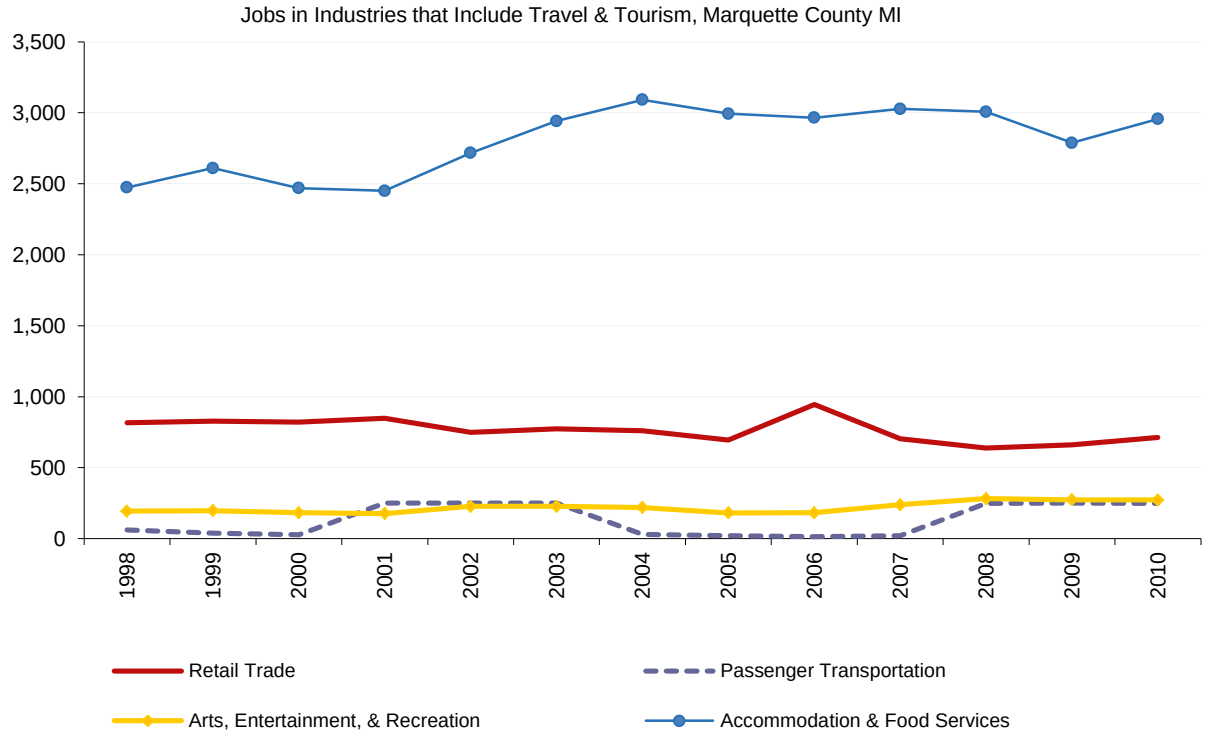


Figure 10: Travel and Tourism-related Jobs by Type, Marquette County, 1998-2010
(Source: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000.)

Mining

The historic existences of Marquette, Negaunee, Ishpeming, as well as numerous other smaller towns within the County, are based on mining. The County's rich mineral extraction legacy makes mining an industry valued by many citizens while others are concerned about the environmental impacts on the landscape. Mining has declined; only accounting in 2010 for roughly 6.5% of total County jobs (Figure 11). Recent exploration in the County as well as a new mine slated to begin operations in 2014 may change this picture.

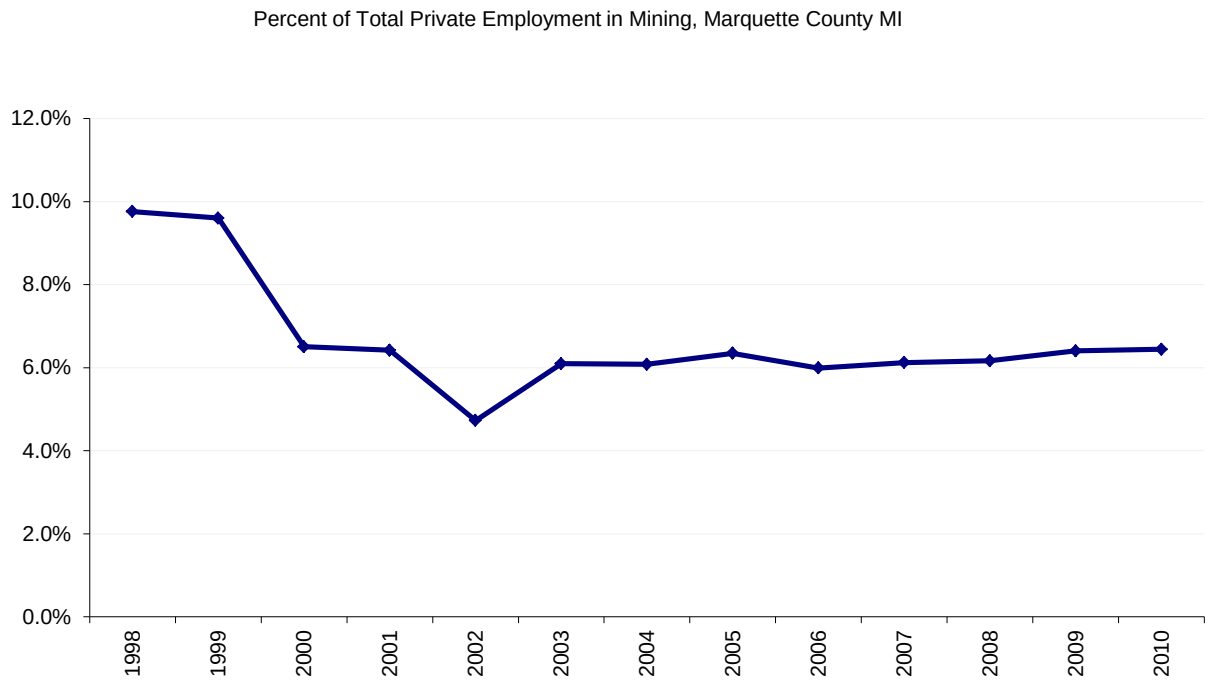


Figure 11: Mining Jobs, Marquette County, 1998-2010
(Source: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000.)

Timber and Wood Products

There is great lore regarding Upper Peninsula's lumberjacks, as they were some of the hardiest people in the United States at the time of the Great Lakes lumber booms. Timber camps became established cities boasting their own stock of woodsmen and support services. Unfortunately, due to lack of sustainable forest management in the mid-nineteenth century, today many of those cities are no more than a crossroads reflecting former boom-towns.

In present day (2010) Marquette County, the timber industry employs roughly 310 people representing 1.45 percent of the County's total employment (Figure 12). There are three sectors within the industry: growing/harvesting, saw/paper milling, and manufacturing. Though saw and paper mills have declined, manufacturing of wood products is trending upward and may be able to make up the difference.

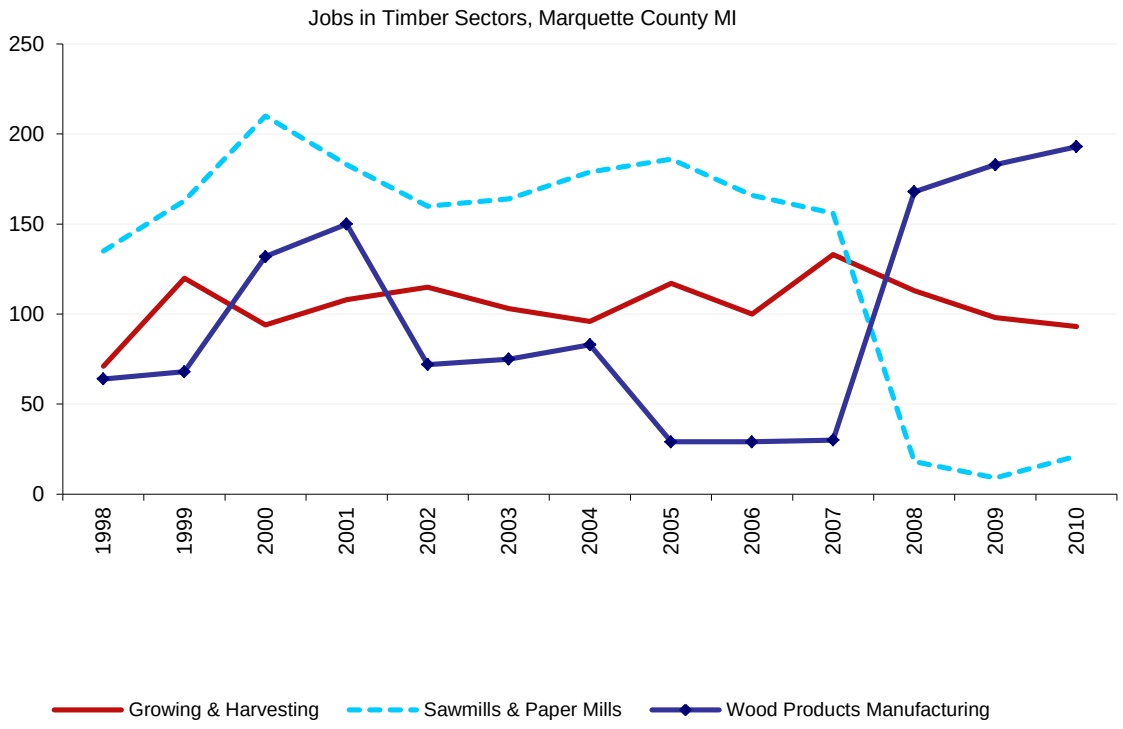


Figure 12: Timber and Wood Products Jobs, Marquette County, 1998-2010 *(Source: U.S. Department of Commerce. 2012. Census Bureau, American Community Survey Office, Washington, D.C.; U.S. Department of Commerce. 2000.)*

Agriculture

An awareness of the importance of local food production and food security has increased significantly in the County in the last couple decades. Organizations have been founded in the County with goals of facilitating localized food production and distribution, building on a nationwide trend. The local food co-op and local restaurants take advantage of local producers. In 2011, there were 1,166 farmers within the central Upper Peninsula (that includes Marquette County). These farmers have sold approximately $61.6 million dollars' worth of food products per year (1989-2011 average), while spending $62.2 million to raise them. This creates an annual loss of $633,000, or an average net loss of $540 per farm. This loss, however, is for agriculture as a whole in the County; there are those farms that operate in the black. The effects of climate change will likely be in both negative and positive directions. Any kinds of crop or technology changes may stress small operations.

Economic and Social Climate Change Vulnerabilities

The ever-changing demographics and fluctuating economic structure of Marquette County leave many residents vulnerable to negative impacts from climate change.

Vulnerable Populations

Typically the poor, elderly, and very young are most at risk for climate change-related impacts that affect health and safety (such as disruptions in power, water contamination resulting from weather events, and periods of extreme heat or cold). These groups may lack the means to proactively plan and prepare for weather events. They also have compromised immune systems, tolerances, and mobility. In addition, these residents may also depend more on government assistance that also is often hampered by some of the same events. In its adaptation planning, the County needs to consider the special challenges of its vulnerable populations.

Timber Industry

Though a very minimal percent (1.45) of County residents are employed in this industry, shifts in forest composition, increases in tree pathogens, decreases in soil and tree vigor (such as declines related to atmospheric acid deposition) will have cascading economic effects. Modern machinery and technology have greatly reduced the actual on-the-ground human labor force, but there are still manufacturing and service businesses that sell and keep high-tech equipment functional. Effects may be felt in wood products sectors as well if the availability of needed raw material comes at a higher cost and milling and manufacturing entities move elsewhere. More detail on this topic is found under the section on Forest Assessment.

Tourism

Tourism has increasingly become a major player in Marquette County's economy. Based on seasons and natural resources, tourism will inevitably be affected by climate change. Longer and

warmer summer and fall seasons will likely result in increased tourism in these seasons as visitors come to enjoy features such as lakes, streams, and trails (hiking, ATV, bike) in extended good weather. Fishing, boating, camping, biking, and hiking are expected to flourish. The coastal areas of Marquette County, in particular, enjoy cooler temperatures during the hottest days of summer, giving Lake Superior beaches particular drawing power.

The warming of Lake Superior, however, has already come at a cost to recreation. In August 2012, surface temperature readings of Superior were in the record-breaking 70s (° F), 10 to 20 degrees above normal. In that same period the City of Marquette has its first ever beach closure due to high levels of *E. coli* bacteria, an indicator of potential problems with human pathogens.

The winter tourism season is expected to experience the most dramatic effects of climate change with impacts on activities such as skiing, snowshoeing, snowboarding, and snowmobiling. Within the lake-effect snow belt of the County, there actually may be more snow for winter sports. Nevertheless, the timing, frequency, quality and duration of snow cover are likely to change. And in inland portions of the County, the amount and duration of snow cover actually may decrease. Rain on snow events are predicted to increase with warmer temperatures, degrading snow for winter activities. Variability in freeze-up and ice-out on water bodies may negatively affect winter activities such as ice fishing. In short, winter-based recreation is likely to experience a drop in revenue due to unpredictability and overall reduced time with good conditions for snow and ice-based activities.

Agriculture and Food Production

Marquette County contains two plant hardiness zones with each further divided into two sub-zones. Areas closest to Lake Superior Lakeshore (Zone 5b) have an average annual extreme low temperatures ranging from -10° to -15° F, while areas farther in the interior (Zone 4a) have low temperatures ranging from -25° to -30° F. Because of these extreme temperatures and relatively short growing season, food production is generally of low diversity, with hardy greens, cabbage family vegetables, root vegetables, potatoes, multiple berry types and some orchard fruits (apples) comprising the majority of crops.

As hardiness zones shift northward, favored crops may also change. With such shifts, farmers may be able to grow a greater diversity of crops. They may, however, also have to adjust cultivation, irrigation and fertilization regimens to accommodate new water and nutrient needs dictated by new crops and other climate change effects. Farmers may need to invest in new technologies and machinery for cultivation, sowing, and harvest. There likely will be additional agricultural pests favored by warmer temperatures, necessitating new control measures. Extreme storm events and periods of drought, particularly in the growing season, will add to stresses on crops and expenses. In short, small-scale food producers, while experiencing new growing opportunities, will likely face new expenses, making it more difficult to turn a profit for small producers.

Forest Assessment

Introduction

Marquette County has a long history that is entwined with logging and forests. From early lumberjacks to present day tourists, forests define much of the land area of the County and influence uses and activities on it. Change in these forests is nothing new but the scope and rate of transitions associated with current climate change will tax society's ability to predict and adapt. From impacts on the timber industry and tourism to cascading effects of invasive species, forests are in the forefront when it comes to crafting thoughtful climate adaptation strategies.

Forest History

The retreat of the last continental glaciers 8,000 to 9,000 years ago left varied topography and soils that eventually developed into a landscape dominated by a northern hardwood-hemlock forest in the uplands and conifers such as black spruce and tamarack in the lowlands. Boreal forest (dominated by white cedar, paper birch, white spruce, and balsam fir) was found near areas of cooler microclimate also influenced by enhanced disturbance patterns of Lake Superior. Outwash plains and rocky outcrops tended to be dominated by pines (white pine, red pine, and jack pine). This basic pattern persists today.

Throughout the centuries the massive expanse of timber went unnoticed by Europeans until the first surveyors reached the Upper Peninsula. As soon iron ore was discovered in the northern ranges of Marquette County in the mid-1800s, trees soon began disappearing through harvest, used for mine timbers and buildings. The first to be harvested were white and red pines whose buoyancy allowed them to be rafted down rivers to mills. Hardwoods followed in later years as transportation improved. Within less than 30 years, the timber boom had passed in the County.

Around 1900, many people in Michigan began to understand that forest resources were not going to last forever given the past rate of logging. A shortage of wood and the loss of other forest values were seen as distinct possibilities. During the Conservation Period, which lasted about 40 years roughly from 1900 to 1940, many groups and agencies were formed. The U.S. Forest Service was organized in 1905 and our National Forests were created between 1909 and 1938. The Michigan Forestry Commission was established in 1899 and the Michigan Department of Conservation (now the Department of Natural Resources) was formed in 1921. The first State tree nursery was established at Higgins Lake in 1904. The first corporation to hire a forester was Cleveland Cliffs, who hired S.M. Higgins in 1903. In 1903, the Forestry Commission established the first state forest in Crawford and Roscommon Counties in the Lower Peninsula. Over the next 100 years the state forest system grew from 34,000 acres to nearly 4 million acres.

As forests regenerated, the vegetation changed dramatically as well, transforming from cutover and burned-over abandoned land to vibrant, healthy, growing forests. In general, the forest that has resulted after over 150 years of harvest and modification is diverse, scenic, and an important part of the economy and quality of life of the County.

Climate Change and Upper Peninsula Forests

As already mentioned, climate change shifts for Marquette County will likely include temperature increases of 2.4° to 3.0°C per century in summer and 3.6° to 4.2°C per century in the winter (Bartlein 1992) and changes in moisture regimes. This is predicted to produce heat or drought stress, increased winter damage due to diminished dormancy, and increased pest activity that may cause a dieback of tree species with a more northerly range before more southerly species can migrate northward (Brown, undated report). This will, in turn, result in significant changes to entire terrestrial ecosystems, which also will result in impacts to the timber industry.

Adaptation planning on a landscape scale requires increasingly accurate and predictive modeling of responses of terrestrial ecosystems to the effects of climate change. This type of work is already underway by many scientists, taking into account parameters such as soil types, topography, and geographic location as well as patterns interpreted using historic and prehistoric data.

In Marquette County, the varied and dramatic physiography of sandy outwash plains, exposed bedrock, and steep moraines results in steep moisture and temperature gradients. The result is a landscape where relatively small changes in temperature and moisture are predicted to translate to fairly profound effects on the landscape. For example, given enough time, some forested areas may change to savannas, as was the case in the hypsithermal period (a warming after the last glacial retreat) (King 1981).

In most of Marquette County, Lake Superior moderates the normal continental climate of the region, creating conditions that support northern plant species growing at the southern edges of their ranges. This moderating effect of Lake Superior may decrease the magnitude of effects of a warming climate for a time. On the other hand, northern species at the edges of their ranges may be more vulnerable to even slight increases in temperature. Rate of change will likely dictate outcomes.

Prehistoric Pollen Data

Prehistoric data, such as can be acquired through obtaining pollen cores, has proved an invaluable component for predictive climate change models as such data cumulate information on climate change over thousands of years. Such a study has been conducted in Marquette County.

Three lakes were selected in order to represent three types of post-glaciated soil conditions. Camp 11 Lake represented silt loam soils, Lost Lake was chosen to represent the sand loam depositional class and the Yellow Dog Pond represented sand. Temporal changes in pollen stratigraphy were tallied at all three sites.

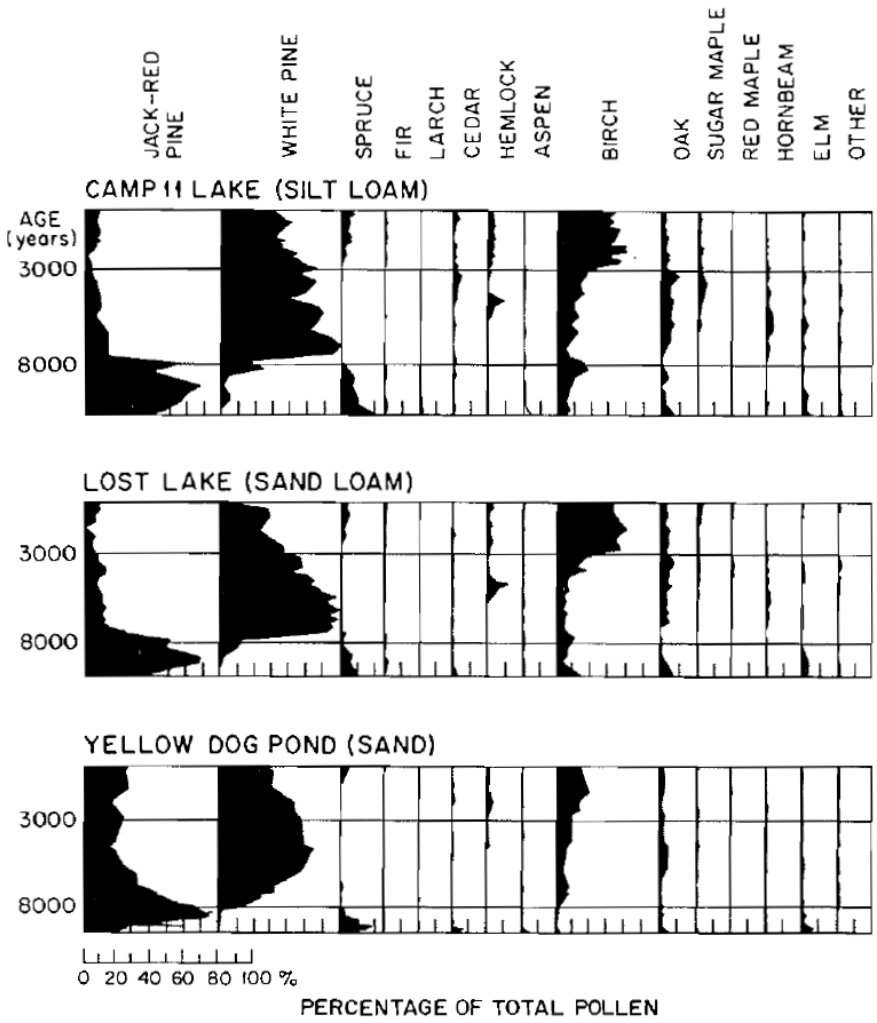


Figure 13: Pollen from three lakes in Marquette County of Michigan (Brubaker 1975). Time of accumulation ranges from 9,100 years (Yellow Dog Pond) to 10,350 years (Camp 11 Lake)
(Source: Solomon et al.1992)

At 8,000 years ago, red pine and jack pine (indistinguishable by pollen analysis), dominated each depositional class.

Approximately 2,000 years later, a massive spike in white pine pollen was noticed at each site, while a decrease in red/jack pine was witnessed as well. 3,000 to 8,000 years ago was dominated by the mighty white pine in each represented area with a slight decline experienced over time.

At approximately 3,000 years ago, deciduous trees (birch and sugar maple) became more evident in the pollen collections indicating increases in abundance for these species (Figure 13).

Because pines are anemophilous (the wind as the sole pollinator), red, jack, and white pines produce much more pollen than other types of tree species and are likely to be over-represented

in pollen samples compared to species with multiple pollination vectors (including insects). Anemophilous species simply produce much more prodigious quantities of pollen compared to species pollinated by organisms. This skewed abundance of pine pollen makes it impossible to accurately construct prehistoric forest compositions directly from pollen samples.

To account for these discrepancies, Solomon of Michigan Technological University and colleagues have created a model that calculates historic total biomass using these same pollen samples correcting for the different abundances of pollen. The model predicts that, by biomass, sugar maple dominated the Marquette County forestlands 9,000 years ago even though the majority of pollen in the sample was from pines (Figure 14).

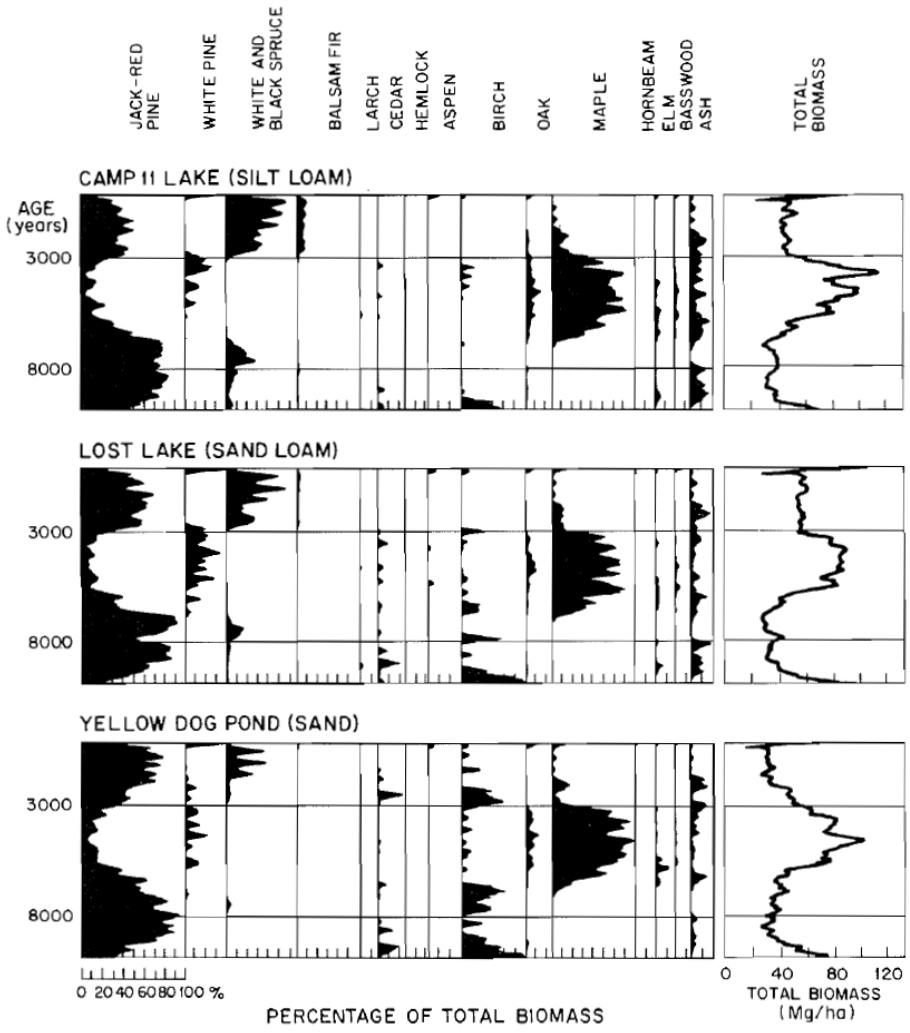


Figure 14: Simulated biomass chronology generated by a gap model. Scale represents percentages of simulated biomass. Note that total stand biomass values in megagrams per hectare are diagrammed at right. *(Source: Solomon et al.1992)*

Past and Current Forests

After the pine boom resulting in the removal of many of the old growth conifers, deciduous forests dominated the region. Maples (red, sugar), ashes (white, black, green), aspens (quaking bigtooth), and birches (paper, yellow) are the primary species of deciduous trees, comprising about 57% of the County's land base. Nearly 26% of the County is composed of coniferous forests including white cedar, white spruce, black spruce, and red, jack, and white pines. The remaining land covers include mining, agriculture (crop, orchards, and pasture), industrial, lakes and reservoirs. Figure 15 shows County land use as of 1983.

Forest communities today on silt loam are dominated by sugar maple, with scattered yellow birch, eastern hemlock, white ash, white spruce, and white pine. White pine and red oak are abundant on exposed bedrock while black spruce, balsam fir, white cedar, and tamarack comprise forested wetlands. Sandy soils tend to support pines, although not at the abundances that existed in pre-settlement forests. Outwash sandy soils in the southern part of the County are still dominated by jack, red, and white pine with scattered hardwoods. Areas adjacent to sandy loam outwash soils, in northeast Marquette County, are dominated (75%) by sugar maple. In the northwest part of the County white spruce and balsam fir are more abundant.

Pollen core analysis has revealed gradual changes in forest composition and overall density during the last 10,000 years. Initially, after glacial retreat, boreal forests of spruces, jack pine, and balsam fir dominated the cool and relatively dry landscape for approximately 2000 years with white spruce woodlands on sandy outwash plains. As the climate warmed further about 8,000 years ago, white pine and sugar maple replaced the more boreal forest. On drought-prone outwash sands, closed canopy jack pine forest was replaced by a more open jack pine woodland, with a reduction in its white spruce component. On moister silt loam soils, sugar maple, oaks, elms, and white pine assumed dominance.

With the advent of a cooler, moister climate 3,000 to 4,000 years ago, sugar maple decreased in dominance as white spruce and balsam fir increased. Yellow birch and eastern hemlock increased in abundance especially on mesic silt loam soils. White pine increased to its maximum abundance about 7,000 years ago. There has been a decline in abundance of white pine (hastened by the blister rust pathogen and by humans through logging) extending to the present time.

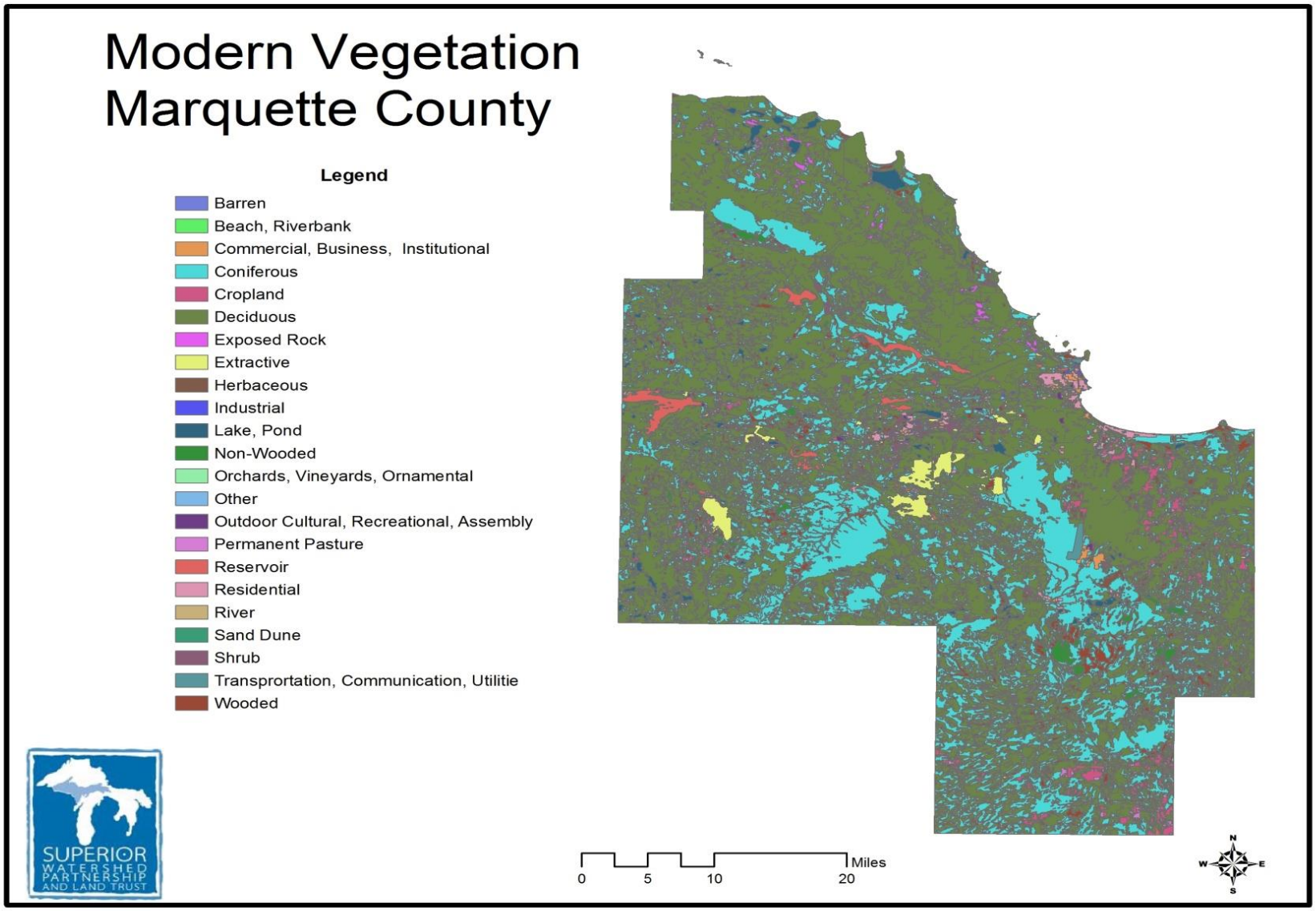


Figure 15: Land uses in Marquette County (ca. 1983)

Predicted Future Forests

Predictive modeling that includes parameters of increasing CO_2 concentrations and increasing temperatures forecasts a forest that may not change greatly in composition for at least 30 years, although structure is predicted to change as biomass, as measured by leaf area, stem numbers, etc., begins to decrease right away (Figure 16). More than 30 years of warming and CO_2 increase may be required before certain boreal tree species show declines in abundances. With an additional 20 years of warming, the prediction is for elimination of these species from the landscape, perhaps occurring fairly rapidly. Other predicted changes within 50 years of the present include decline of jack and red pine, perhaps with elimination within 80 years. A reduced canopy cover will also favor different ground cover as well as regeneration of shade intolerant species. White pine and sugar maple may cease to be dominant species within 200 years. Modeling and prehistoric data lead to predictions of northward migration of southerly species. Whether the rate of migration of southern species will keep up with the rate of extirpation of northern species is currently unknown, as is the rate of change in climate-mediated effects like temperature and rainfall.

Forest and Economics

As of 2009, Marquette County possessed a land base composed of 85% forest and agricultural cover types under a variety of ownerships and management regimes (Figure 17). As already detailed, forest types are coniferous, deciduous, and mixed. Agriculture includes crop, orchard, pasture and range lands. These rural cover types directly support income streams coming from forestry and recreation. Marquette County contributes over 200,000 jobs and 12 billion dollars to the state economy in forest production and forest-related tourism and recreation. In addition, Marquette County experienced a 13.7% increase in timber-related jobs between 1998 and 2010 even though most of the country has seen a decrease in the timber industry.

Like much of the Upper Peninsula, forest resources are an important part of the County's economy. With a growing population, however, contiguous blocks of forest are increasingly subjected to fragmentation by development and sales, and remote management by owners in other countries. About 400 acres of land in the County are converted to a more urban landscape every year, making urban sprawl a distinct threat to the forest economy.

The effects of increased access and harvest to forest lands through private ownership development and resulting fragmentation of forests combined with the effects of climate change are likely to result in decreases in forest health. Added roads make it easier for invasive species to enter ecosystems. Additional human encroachment increases fire risk that already may be enhanced by drought and warmer temperatures. Tree pathogens may also increase in abundance and be more readily transported by humans. On the other hand, increased recreational use of forests will also contribute to the economic bottom line. The challenge is to structure a balance of uses, in the light of climate change stressors.

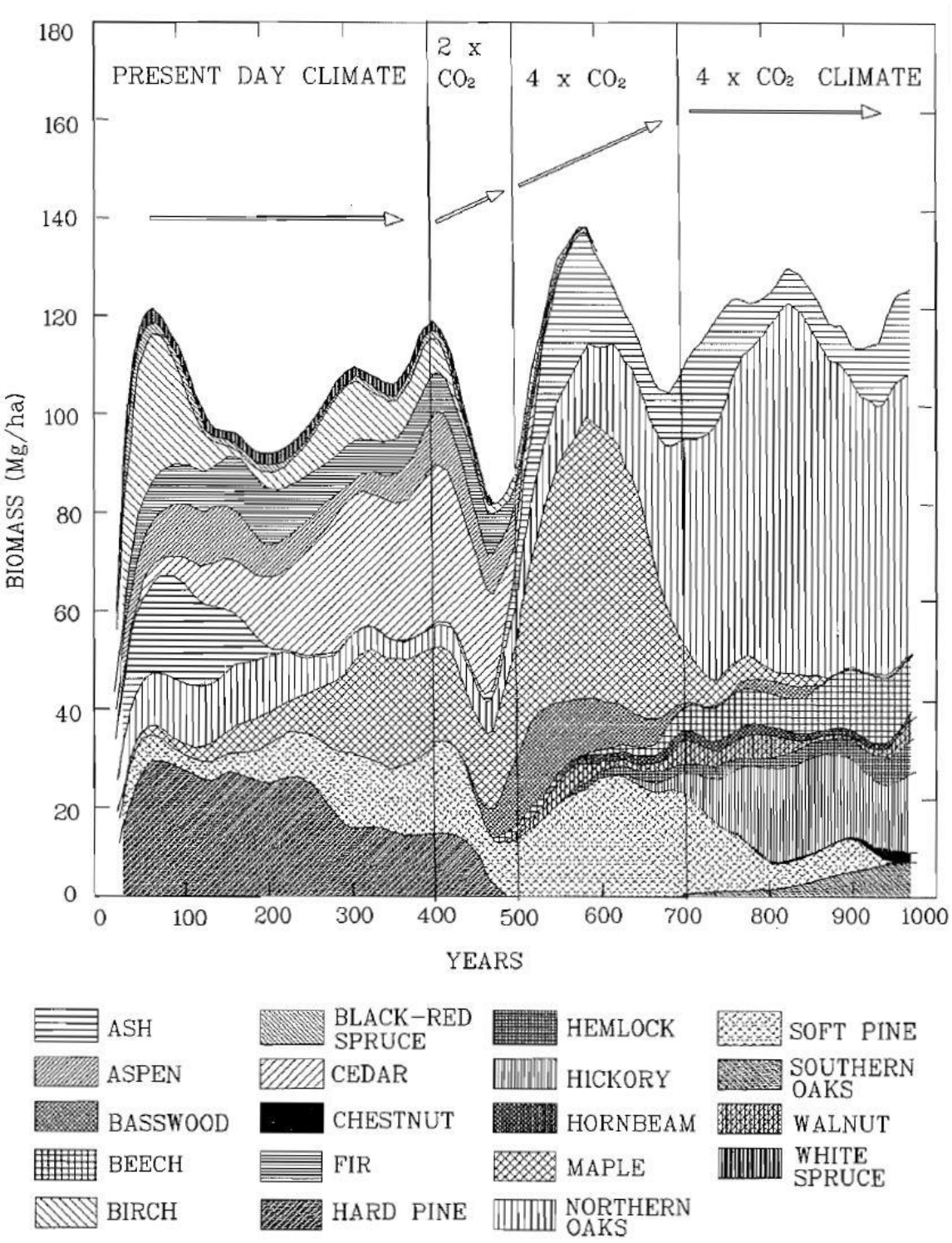


Figure 16: Project forest biomass and composition changes modeled for warmer temperatures and increased CO2 *(Source: Barlein 1992.)*

Type of Owner	Specific Owner	Management	Potential Significance in Community
Land Owners			
	Marquette County	Owns approx 9300 acres in the county, has a land use plan for the holding	Lands available for recreation use
	Plum Creek	Largest corporate owner in the county, has riparian and other management plans	Largest corporate land owner in the county, treats as public land, builds trail networks, land management plans available
	The Forestland Group	Corporate owner in the county, has riparian and other management plans	Holds conservation easements for land holdings
	State of Michigan	Manages large tracts of forested lands in the county,	270,692 acres held in the county, high use recreation areas
	US Forest Service	18,147 acres held in the county, much of which is wilderness area, and very protected	Does not manage large tracts of land, though the land USFS does hold is pristine and is well managed
	Private Land Holders	Unknown forest practices	May have devastating impacts to resources as impractical forestry practices take place such as clear cutting
Land Management Agencies			
	State of Michigan DNR Forest and fire management div., State Parks Div.	Manages parks and open space. Can lease mineral and/or grazing rights.	Lands available for recreational use, conducts forest and fire management
	Michigan Dept of AG	Implements invasive species control such as Emerald Ash borer, Oversees pesticide applicators certifications	Major significance in terms of controlling invasives pests and plants
	County of Marquette	Manages county road right of ways as well as land holdings.	Corridor for invasives, as well as manages high use rec area
	The forestland group		
	Plum creek	Large land ownership in the county, has management plan regarding land use	Major significance in the fact they provide vast lands for public use. Major player in forest health
Regulatory Agencies			
	Michigan DEQ	Regulates impacts to wetlands, water quality, and inland lakes and streams under clean water act. Regulates mining activities.	Ensures new development does not impact resources
	Michigan DNR	Regulates burning permits, mineral and grazing rights	
	EPA	Regulates impacts to wetlands, water quality, and inland lakes and streams under clean water act	Ensures new development does not impact resources
	Marquette County	Regulates new development through zoning ordinances	Ensures new development does not impact resources

Figure 17: Forest Ownership and Management in Marquette County

Land Ownership

The major portion of Marquette County forested lands is in corporate holdings. Corporations own 358,462 acres, with the majority of those held by Plum Creek. Plum Creek has active management plans for their property with climate-related issues included. For example, a brief summary of their riparian zone policy is as follows: "Our company policy is to retain streamside management zones on all streams with a defined bed and bank and all lakes/ponds (not including beaver ponds). The width of these zones varies based on a variety of factors including slope, soils, existing vegetation, etc. Some harvesting is allowed within streamside buffers, but a minimum residual basal area of 60 sq. ft. is required and soil disturbance must be minimized. In many instances, the forester foregoes harvest of timber within a riparian buffer." In terms of other direct responses to climate change, Pat Riley of Plum Creek wrote: "Our approach to dealing with potential changes in forest composition over the long term is to maintain a healthy well-managed forest today and address forest health issues such as Emerald Ash Borer or Beech Bark disease as they arise. Healthy, well-managed forests are believed to be most resilient to future perturbations. Trying to predict what will happen to the resource as a result of perceived long term future disturbances or climate patterns is difficult."

The State of Michigan owns 270,692 acres in Marquette County. Much of this land is used by both recreationists and timber harvesters. Research is going on within these forests to address dieback in various tree species caused by pathogens and invasive species. In addition, a large study is currently under way on the Upper Peninsula addressing the decline and die-off of sugar maple. In 2012, the population of nearly 500 acres of high quality maple stands experienced a decline of 12.4%; current suspected factors are correlated with the effects of climate change.

Only 18,147 acres in the County are federally owned. Though much of this federal land in Marquette County is considered wilderness or protected areas, this protection is not complete. Non-wilderness lands have even less protection. In Marquette County, many of these underlying lands are very mineral rich. Under the 1872 mining law, these lands are left vulnerable to exploitation and extraction combined with degradation and destruction of their forest cover.

The County of Marquette itself owns slightly more than 9,000 acres with much of their holding in jack pine-dominated sand plains. These lands are mainly used for recreation and wildlife management.

Most of these holdings are all publically accessible (corporate holdings under the Commercial Forest Act) and are used by residents and visitors for hunting, camping, and other outdoor recreation.

Forest Stressors

The forests of Marquette County have been fluctuating in composition throughout millennia with these changes attributed for the most part to changes in global climate. As humans become a greater altering force on global climate, changes in forest health and composition are likely to

occur at a much faster rate than in the past. Stressors induced or accentuated by human activities include species shift, invasive insects and plants, fire, and forest conversion and habitat fragmentation.

Ecosystem Shifts

As the climate warms, longer summers are forecast for Marquette County. Precipitation is expected to occur in heavier concentrated storms with the intervals between precipitation events expected to lengthen. The result will be droughty periods when the soil is unable to retain adequate moisture. Models predict that forests in Marquette County will undergo transformations in species compositions as more southerly species better suited to warmer, drier climates come to dominate.

As has already been addressed in this report, changes in forest composition will likely affect the timber industry and its associated support services. New markets may have to be developed for new dominant species, or manufacturing processes modified. Representing only 1.37% of Marquette County's economy, such changes are unlikely to have profound effects on the overall economic bottom line, but societal effects will be felt.

To date, most modeling efforts have focused on changes in tree species. An altered climate, however, will affect entire ecosystems. Ground flora also will be altered, favoring species that can tolerate droughty, warmer conditions; grasses and sedges may come to dominate ground cover of many stands rather than ferns and fern allies. As was mentioned earlier, arctic disjunct species, with main ranges far to the north of Lake Superior, will likely be extirpated in the County.

Generalist species such as white-tailed deer and coyote will be favored over species relying on cold winters and snow such as moose and fisher. Most changes will be hidden to the casual observer such as those involving the myriad invertebrates, bacteria, and fungi that form the complex soil community that is particularly responsive to temperature and moisture changes as well as changes in symbiotic relationships with trees.

Invasive Species

Non-native invasive species (migrated or introduced by humans from other regions) pose an ongoing threat to aquatic and terrestrial ecosystems. In some cases, the invasives are from more southerly regions with warmer conditions in the north directly favoring their increase at the expense of natives. In forest ecosystems already destabilized by the effects of climate change (drought, intense storms, etc.) as well as human disturbance (logging, development, road-building) the effects of invasive species often can be accentuated. Invasive species have potential to disrupt healthy forests by removing key species, such as is in areas under attack by the emerald ash borer or beech bark disease. In the case of an invasive such as gypsy moth, the insect pathogen becomes one more stressor on an already stressed forest ecosystem rather than a direct source of species-specific mortality.

Fire

Increased tree mortality resulting from drought stress and increased pathogen activity (both predicted to result from climate change) will bring with it another heightened threat—that of wildfire. Fires have resulted in the past from a build-up of fuel, most notably when large amounts of slash were left after the pine day logging boom. Hotter drier temperatures and earlier loss of snow cover will also result in desiccated ground cover and duff of grasses, sedges, and leaves, leaving forests particularly vulnerable to fires in the spring. Two of the largest wildfires on record in the Upper Peninsula happened in the spring of 2012. Vegetation on droughty soils, such as sandy soils supporting jack pine, are particularly susceptible to fire. The results of wildfires are not all negative. Jack pines in particular have evolved to thrive after disturbance by fire as they release seeds from otherwise tightly closed serotinous cones, resulting in robust regeneration.

Many species benefit from cool fires, particularly leaf fires in the spring. Nutrients are released from burned vegetation. Competition is reduced for some of the less competitively growing species. In short, forest diversity is fostered. Management of fire risk does not mean eliminating all fire. Rather, it will incorporate techniques such as prescribed burning to reduce the magnitude of future fires, and clearing around structures to minimize property, health and safety risks to humans. A major goal is to avoid catastrophically hot fires that scorch and sterilize the soil, greatly delaying recovery and regeneration. Climate change will likely make techniques now considered standard in the western states a necessary part of land management in Marquette County as well.

Forest Conversion and Fragmentation

Conversion of forested lands almost always follows increases in population. Marquette County has experienced increases in population in two age groups, 45 years or older and 18-34. Because so much of remaining undeveloped land is forested, the search for new home sites will affect forest integrity through conversion and fragmentation. Some forest ecosystems are especially vulnerable to such disturbance and smaller fragments of forests are certainly more susceptible to all the stressors discussed above. Climate change stressors exacerbate all the impacts brought to a forest by development.

Water Resource Assessment

Introduction

Marquette County is a water-rich portion of Michigan's Upper Peninsula. Lake Superior dominates its northern shoreline, drawing residents and tourists alike. Abundant coldwater trout streams, fed by groundwater, entice fly fishermen, canoeists, and kayakers. In the west, the Michigamme Reservoir is well known to recreationists, while also serving as part of a greater hydroelectric system. The Dead River Storage Basin likewise serves multiple functions of recreation and energy generation. River water is used for agriculture as well, such as irrigation water drawn from the southward flowing Escanaba River for potato fields in southern Marquette County. In short, Marquette County's water resources are of paramount concern with respect to climate change.

The Water Resource Assessment section of this draft has been accomplished collaboratively with the help of top practitioners in the field. Geri Grant and Carl Lindquist of the Superior Watershed Partnership provided a vast majority of information regarding planning and policy for the County's water resources. Curt Goodman, the Water and Wastewater Superintendent for the City of Marquette also provided excellent knowledge and literature needed for the completion of this section. Figure 18 displays a summary of the diverse ways that climate change may impact the water resources of Marquette County.

Current and Predicted Climate Change	Predicted Direct Effects	Probable Indirect Physical and Biological Effects	Probable Indirect Effects on the Human Experience
• Warmer winters, with more precipitation falling as rain rather than snow • Warmer summers with increased temperatures and periods of drought. • Later freeze-up and earlier ice breakup and snow melt	• Increased water temperatures • Increase in evaporation • Less winter ice • Lower or fluctuating lake levels • Ephemeral wetlands, hugely important biologically, will dry up. Some current lake areas will become shallow wetlands • Warmer water extending lower in the water column will affect lake turnover and nutrient cycling, and potentially lead to permanent lake stratification	• Diminished diatom population • More turbidity/algae • Increase in irregular, high intensity winter storm events • Increased wave action on Lake Superior, leading to shoreline erosion. • Possible decline of whitefish eggs in Lake Superior due to greater turbulence. • Increases in invasive aquatic pests and diseases • Decrease in cold water fishery, increase in warm water fishery	• Decreased commercial/sport opportunities as cold water fish populations are diminished • Increased summer aquatic sport recreation and tourism • Reduced ice fishing tourism as lake ice decreases • Impacts to docks, harbors, shoreline infrastructure as water levels fluctuate. • Impacts on commercial shipping

Figure 18: Potential effects of climate change on water resources of Marquette County

Taking a Landscape Perspective on Water Resources

Marquette County encompasses 22 sub-watersheds with the majority of those flowing northward into Lake Superior; some rivers and streams flow south into Lake Michigan. Altogether there are approximately 4,000 miles of streams and more than 1,900 inland lakes in the County, most lying within a forested landscape. In addition, Lake Superior constitutes 70 miles of the northern border of the County.

Watersheds and Riparian Areas

Watersheds are extremely complex systems possessing multiple indicators of ecological health, stability and well-being. In such complex systems, the removal of one component has potential to cause cascading damage throughout the ecosystem. In any landscape, but perhaps more dramatically in a forested landscape, vegetated areas adjacent to a stream or lake (riparian zones) are particularly vital for maintaining a variety of ecosystem functions. These include, for example, flood control, groundwater recharge, filtration of runoff to protect water quality, wildlife habitat, a source of large woody material for aquatic habitat in streams, and connective habitat corridors.

Climate change makes it all the more imperative that a landscape perspective is adopted when designing adaptive strategies to protect water resources of the County from the effects of climate change. Forest cover in Marquette County watersheds is neither uniformly distributed nor of equally functional quality. Adaptations need to rectify shortcomings currently present on the landscape that fail to protect water bodies from pollution as well as proactively "climate-proof" existing riparian zones against possible impacts of climate change (such as the previously discussed shifts in vegetation composition, effects of drought, fire, etc.). In general, the more robust and diverse a riparian ecosystem, the better it can adapt to the changes brought about by a warming climate.

Changes to vegetation, already discussed under the section on forest resources, will come to riparian zones as well. For example, increased mortality of trees and shrubs in a riparian zone may put the adjacent stream at risk for increased warming and deposition of sediment through erosion. Sedimentation in the stream, in turn, eliminates many of the microhabitats needed to sustain a diverse stream fauna. Degradation of other forest resources may put riparian zones under additional harvest pressures as harvest operations target less productive lands (from a timber stocking point of view). Removal of biomass from riparian zones depletes large woody material in streams, a crucial component of aquatic habitat. In short, in the face of the many unpredictable changes wrought by a changing climate, maintaining healthy transitional riparian ecosystems by water bodies is perhaps one of the very best strategies for protecting water resources.

Inland Surface Waters

Reservoirs comprise a major component of surface water in the County with the larger reservoirs being Lake Michigamme (4,212 acres), Dead River Storage Basin (2,704 acres), and Silver Lake

Basin (1,214 acres at its restored state). The Greenwood Reservoir/Escanaba River (1,400 acres) and Switzer's Reservoir (650 acres) are used by the mining industry as a source of water for iron-ore beneficiation.

In areas of the County largely underlain by Precambrian bedrock, and other portions of the landscape with steep topography, stream networks are highly developed, providing rapid and efficient drainage. These streams exhibit a "flashy" stream behavior, wherein streams rise quickly after precipitation (and especially snow melt), with high peak flows and subside equally quickly. Flatter portions of the County have a poorly developed drainage system containing numerous ponds, lakes and a variety of wetlands. In such areas, streams exhibit relatively uniform flows. They are supplied by groundwater during dry periods and store water in ground strata and wetlands during periods of high flow.

The surface waters of Marquette County face multiple pressures and demands, all of which may be exacerbated by the effects of climate change. The surface waters of Marquette County are used for recreation (boating, fishing, swimming), agriculture, hydroelectric power generation, wastewater treatment, and industrial uses such as processing of ore. Shoreline development (primarily dwellings) is more apparent near urban areas although not unknown on isolated lakes and streams and often contributes to degradation of riparian zone functions.

The flow of streams throughout the year depends in large part on the storage capacity of the watershed. This, in turn, relies on a watershed dominated by natural vegetation, rather than impervious surfaces. Impervious surfaces serve to quickly shunt water off the land and into receiving waters, complete with pollution loads from rooftops, streets, lawns, and farms. A stream whose watershed has a large percentage of hard surfaces is more vulnerable to larger fluctuations in flow that, in turn, result in terrestrial patterns of floods, drying and warming. Precipitation that would normally soak into the soil is thus lost out of the hydrological cycle. Successful climate change adaptation demands thoughtful restoration and conservation of the entire hydrology of a watershed, to better conserve increasingly scarce precipitation.

Subsurface Water

County subsurface or groundwater resources are evenly divided between bedrock aquifers and aquifers in glacial deposits. Much of the development in Marquette County, which utilizes groundwater as a source for municipal or industrial use, is located on the Precambrian bedrock formations and uses glacial drift is the main source of sub surface water.

The static water table is near ground surface (0-50 feet) in most of the County. Most wells in the northern and extreme southern part of the County are completed in bedrock at depths less than 100 feet with yields between 3 and 40 gallons per minute. Deeper wells are found in the central part of the County in glacial deposits up to 250 feet thick, and yield up to 200 gallons per minute.

Climate Change Impacts on Water Resources

Precipitation

Figure 19 depicts average annual rainfall from 1930 to 2012 expressed as percent compared to the average amount of rain between 1951 and 1980 (dashed line set at zero). A nine-year running average from 1935 to 2008 is shown as a solid blue line. It appears from the graphical representation that the average annual rainfall has decreased relative to historic averages. If this trend holds, drought will become an even greater concern. It will affect riparian vegetation in the ways previously detailed under the section on forest resources through drought stress, species shifts, fire, etc. A drier climate also will affect the recharge of groundwater, which in turn will reduce input to coldwater streams, hastening their warming and subsequent shifts in fish species and other aquatic species. Reduced precipitation will also result in lower lake levels and warmer waters and modified dynamics such as stratification. More projected impacts on surface waters are discussed in the next subsections.

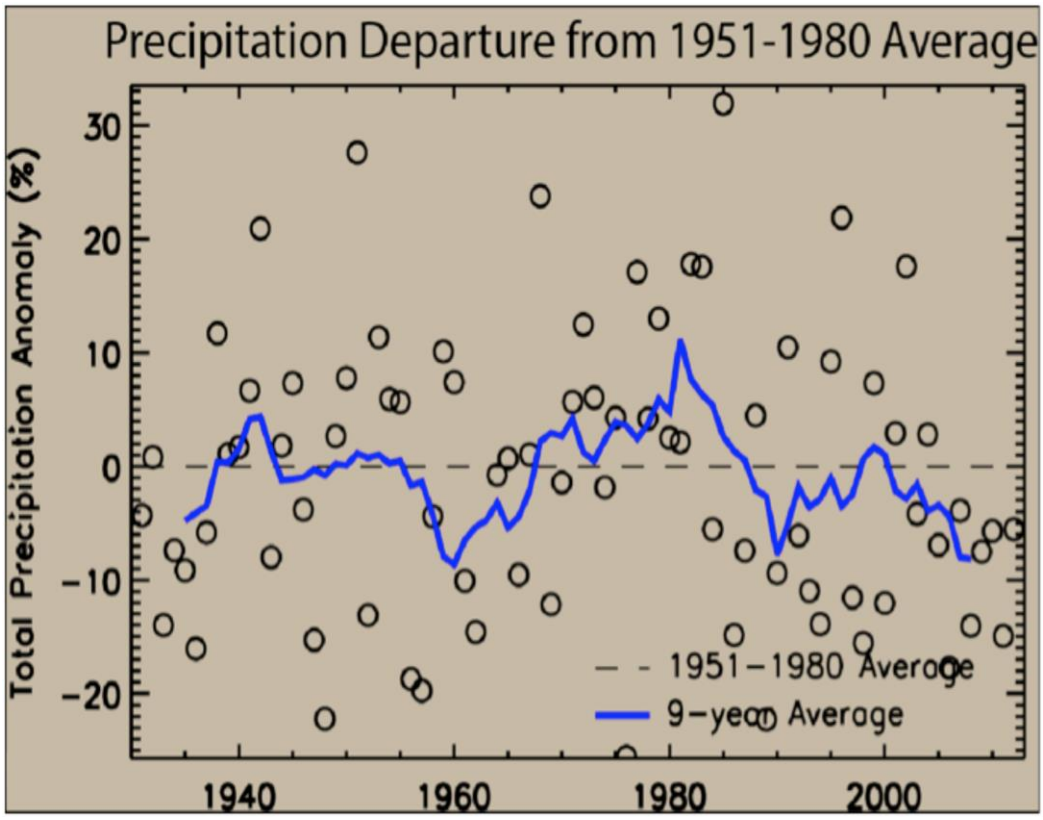


Figure 19: Average annual rainfall as a percent of a 1951-1980 baseline average *(Source: GLISA)*

Lake Superior Levels

The level of Lake Superior appears to be on a long-term decline with over a decade of below average recorded water levels (Figure 20). The sheer size of Lake Superior means that it wields huge influences on its own riparian lands as well as modifying the weather considerable distance inland. (It is the world's largest freshwater lake as calculated by a surface area of 31,700 square miles; it is 350 miles long by 160 miles wide; its deepest point is 1,333 ft.) Declines in the lake level will affect coastal wetlands, estuaries, and exposed shorelands, in some cases increasing their vulnerability to invasive plant species.

Declining Superior lake levels will have major impacts on shipping economics. According to Minnesota's SeaGrant/NOAA, a loss of an inch of water in Lake Superior translates to a 270 ton loss of cargo for large cargo vessels. With the projected decrease in lake levels, the shipping of iron ore will face particular constraints. The LS&I Ore Dock in the City of Marquette's Presque Isle Harbor is an important shipping point in the County.

Water supplies, particularly for the City of Marquette which relies on Lake Superior, will be negatively affected by declining lake levels combined with effects of warming. Roughly 22,000 residents access 3 million gallons of water daily directly from Lake Superior through intake piping and a treatment facility with capacity to treat 7 million gallons daily. As water levels decline, intake infrastructure may have to be modified. Water quality is also at risk due to higher bacterial levels and greater sediment loads in shallower, warmer, and more disturbed waters.

Some climate change models show that lake levels will continue to decrease, mainly due to increased evaporation stemming from increased winds engendered by a warming lake. Other models suggest lake levels will remain the same, or may even rise due to greater quantities of precipitation from intense storm events. This speaks to the complexity of climate change predictions and the enormous challenges for human communities making climate adaptation decisions. Nevertheless, waiting until "all the answers are in" is not a viable plan.

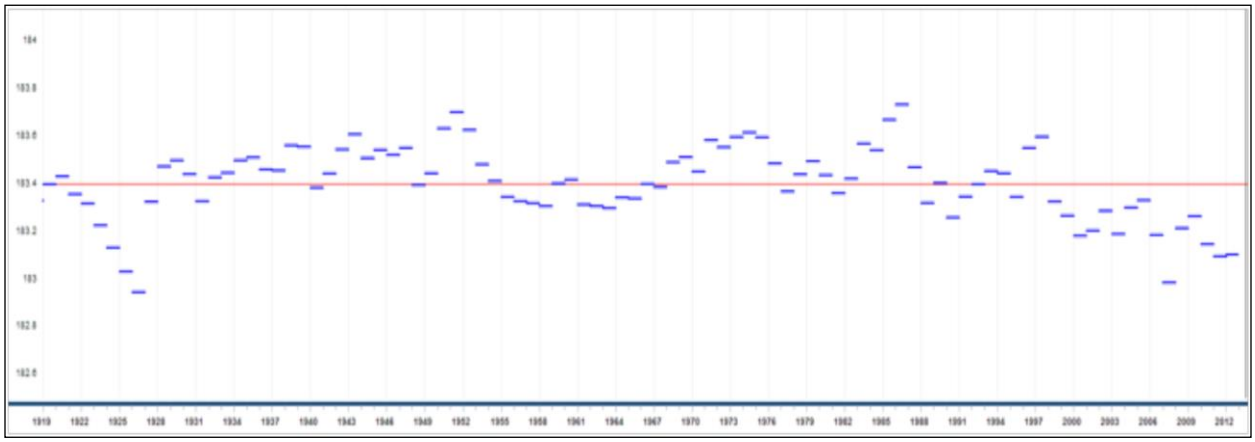


Figure 20: Lake level changes in Lake Superior, 1919-2012 *(Source: GLISA)*

Inland Lake Levels

Many inland lake levels, particularly seepage lakes that are fed by precipitation and groundwater, have experienced declining levels as well in the past few decades. These declines potentially have similar ecological effects on riparian areas as those that may happen in Lake Superior riparian zones. In addition, declining lake levels on inland lakes can have profound economic effects—reducing real estate values as the amount of shoreline decreases and/or degrades. Declining inland lake levels have already resulted in closed boat launches that have been left without sufficient water, or even stranded on dry land, in some cases cutting off public access to a lake. Declining lake levels also result in loss of riparian habitats including shallow water spawning habitat for game fishes.

Warming-related Effects

In 2007, studies by Dr. Jay Austin and colleagues at the University of Duluth revealed surprisingly, that frigidly cold Lake Superior has been warming quicker than expected (about 4.5^0 F total) since 1980. This was almost twice as fast as air temperatures rose in the region over that same time period. Much of the lake warming is due to reduced ice cover, which has also been declining in duration and extent during the past 30 years. The warmest surface Lake Superior temperatures ever recorded (since records were started at Sault Ste. Marie in 1906) occurred in August 2012, with temperatures ranging in the low to mid 70's (° F). As already noted, there is a predicted interaction between Lake Superior temperature and higher winds producing increased evaporation and declining lake levels. Waters of inland lakes and streams are warming as well with numerous ecological consequences described further in the final sections on risk.

Warmer lake waters lead to later freeze-ups, and less extensive coverage and reduced thickness of ice. Loss of ice allows a lake to absorb more sun energy in winter as sunlight hits open dark water instead of reflective ice. Warming water transmits heat to nearby ice, which melts and creates more open water, amplifying the effect. Some models predict that Lake Superior will be typically ice-free in winter by 2040. For Lake Superior, the trend appears to be toward more ice-free or nearly ice-free winters; Superior may still freeze over, just less frequently (Figure 21). On some inland lakes, less ice cover may actually decrease problems with winter-kill of fish due to oxygen depletion. Other ecological effects are mentioned below.

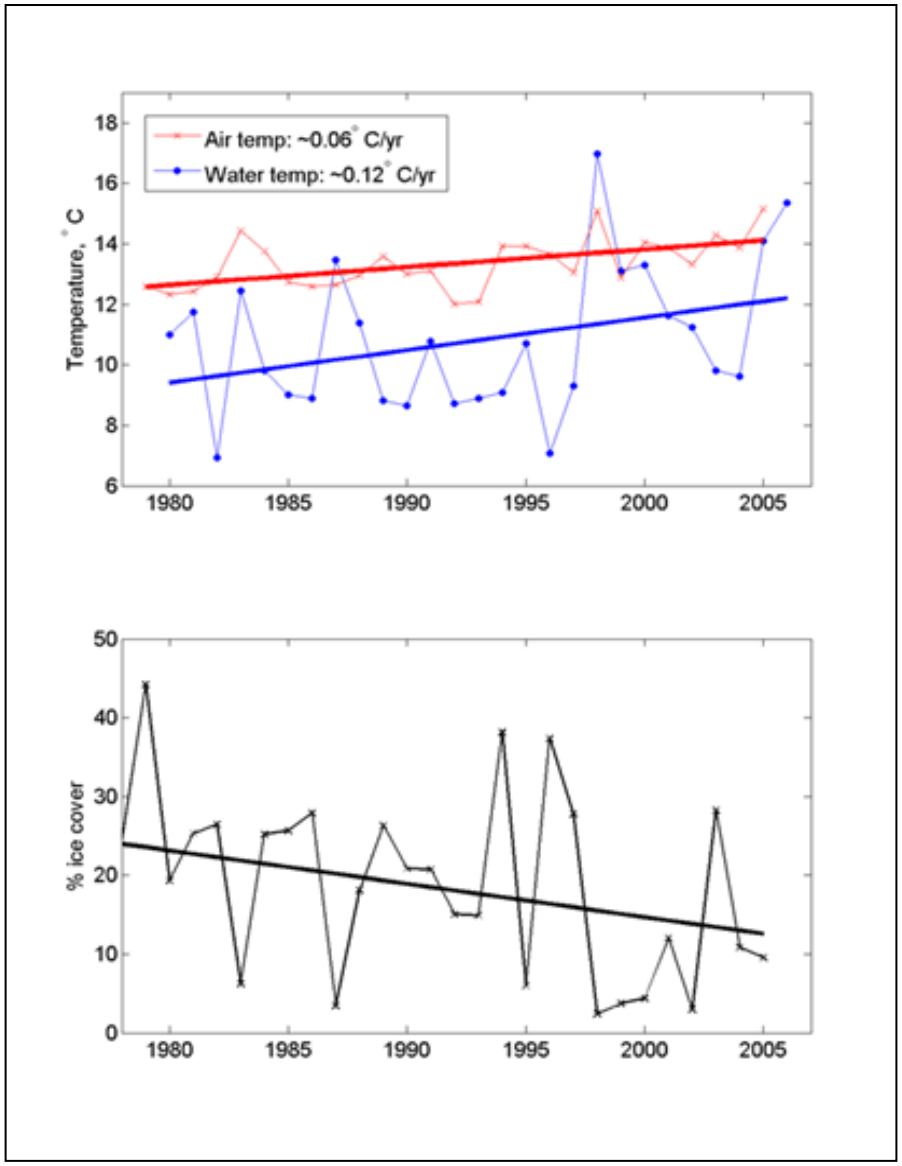


Figure 21: Lake Superior Air Temperature, Water Temperature (Top), and Declining Ice Cover (Bottom) *(Source: GLISA)*

Risks for Marquette County's Water Resources

Ecological Risks for Lakes and Streams

Aquatic ecosystems in Marquette County, and the humans who use or live near aquatic resources, face numerous risks as warmer temperatures and declining water levels stress current ecosystems.

Warming waters, in particular, change physical and ecosystem dynamics of Lake Superior as well as inland lakes and streams. Warmer lake waters overall translate to shifts in the timing of lake stratification. An earlier stratification (and hence longer stratified season) results in even greater

warming of surface waters in a feedback loop. It also increases the risk of developing oxygen-depleted "dead" zones that are deadly for aquatic life. One of the predicted ecological effects is a shift in the composition of the fish community away from cold-adapted species such lake trout and white fish (in Superior) and brook trout (in streams) to warm water species such as walleye, small mouth bass, and crappie.

As Lake Superior water temperatures rise, bacterial growth will be fostered. In addition, extreme precipitation events will produce more runoff into Superior, increasing the input of bacteria, viruses and pollutants. Untreated sewage, such as can enter the Great Lakes from combined sewer overflows, for example, can contain up to 120 viruses; two, *Giardia* and *Cryptosporidium*, are well known to cause widespread illness outbreaks and even death (Saunders et al. 2011). With record Lake Superior temperatures in August 2012 (in the low to mid 70's °F), the City of Marquette was forced to close down city beaches because of a spike in *E. coli* bacteria, indicator of potential presence of other pathogens as well. This closure foreshadows some of the potential recreational risks and deleterious impacts.

Warming waters and temperature fluctuations combined with nutrient pollution (such as runoff containing phosphorus fertilizers and organic material) fuels algal growth in the Great Lakes as well as inland lakes. In particular, *Cladophera*, a green alga of the Great Lakes, experiences growth bursts in warmer waters and when washed up on shore becomes a smelly breeding ground for pathogenic bacteria, contributing to further beach closures (Great Lakes Science Center 2009). There are also food chain effects. In fall 2012, 900 loons died during southward migration along Lake Michigan. Researchers believe that type B *Botulinum* thrived in algae-rich water, working up through the food chain to poison loons (Kraker 2013). High temperatures and low water levels are suspected to amplify these effects. In addition, algal growth in recreational waters decreases their attractiveness, and can eventually depress real estate values.

Extreme Weather Events

As already noted, climate change is increasingly linked to extreme weather events worldwide. In the Great Lakes region, increased evaporation from warmer Great Lakes surface area is believed to amplify precipitation events. Such events increase erosion, leading to sedimentation of valuable trout streams. Heavy runoff brings an increased pollutant load to receiving waters, including Lake Superior. The extreme rain events in 2012 of Thunder Bay, Wawa, and Duluth in the Lake Superior basin have already been noted. Such events frequently cause problems with infrastructure, flooding wastewater treatment facilities and washing out roads and bridges along watercourses. In general, climate adaptation planning needs to include a prioritization of rehabilitation of stormwater and wastewater systems in urban settings, as well as roads and bridges throughout the County.

Drought

Drought has affected the entire Upper Peninsula in recent years, reaching a severe level during the summer of 2007. Long-term drier weather coincided with near record low levels in the Great Lakes. Precipitation eased the drought situation somewhat in the fall of 2007. Marquette County experiences drought about every 20 to 25 years, similar to the state as a whole. As an example, in 2011, Marquette County received below average rain throughout the year. The effects of drought on vegetation (particularly forests and riparian areas), groundwater, and surface waters have already been discussed. Drought presents a far-reaching risk to ecosystems and to human enterprises.

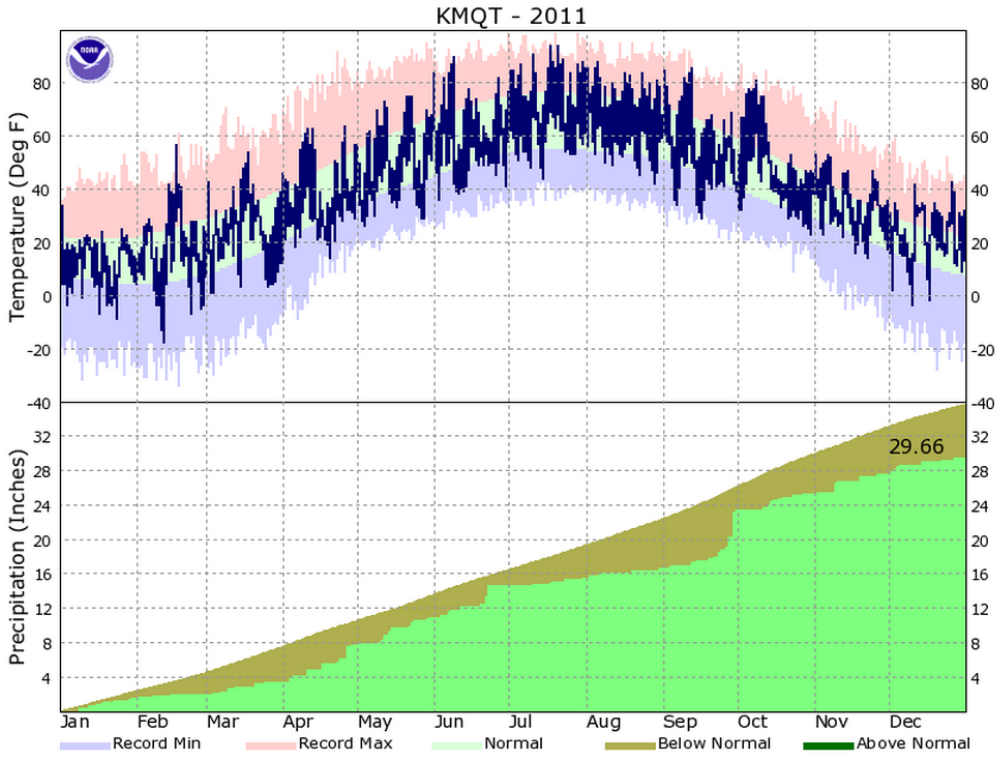


Figure 22: Temperature and precipitation in Marquette County, 2011 *(Source NOAA)*

Synthesis of Risks and Vulnerabilities

To adequately assess and plan for impacts of climate change in Marquette County, two matrices were constructed to assign a level of ***risk*** to natural resources as well as to human well-being. In the two matrices below, the ranking of ***risk*** conveys both the probability of occurrence combined with the predicted impact of a type of effect. With ***risk*** determined, the final step was assigning a ranking of ***vulnerability*** to reflect the ability to cope with impacts (resilience).

In the matrices below (Figures 23 and 24), ***Risks*** and ***Vulnerabilities*** were ranked using **L**, (low), **M**, (medium), or **H**, (high). A high risk ranking (e.g., for flooding) is assigned when an impact is both highly likely to occur and expected to result in significant harm or damage. A high vulnerability ranking (e.g., for shoreline/beach erosion) is assigned when there is a low probability that people or the ecosystem can absorb the impact and recover. Rankings of H/H and M/H reflect scenarios that deserve the most focus; these ultimately served as catalysts for the goals and objectives of this plan. In short, in Figures 23 and 24, the SWP has analyzed most likely anticipated climate change effects and conditions relative to their impacts on natural resources and humans.

Projected Climate Changes	Risk/ Vulnerability	Impact to Natural Resources	Risk/ Vulnerability
Seasonal and Weather Changes • Summers will be hotter, drier and longer • Autumns will be warmer, last longer, and be wetter • Winters will be shorter and milder • Springs will be wetter and longer • Increase in severe weather events	H/M M/M H/M L/M M/H	• Longer agricultural growing season • More flooding issues due to increased rain	M/M H/M
Water Resources • Warming water temperatures • Less ice on Lake Superior and inland lakes • Lake levels dropping	M/H M/H M/L	• Increased water temperatures will increase stress on cold-adapted fish such as salmon and lake trout • More invasive aquatic species due to warmer water • More waves on Lake Superior due to lack of winter ice, leading to erosion of cliffs and beaches • Lower lake levels may threaten shipping industry • Threats to wetlands due to lack of zoning ordinance in Alger County	M/L M/H M/H M/L H/H
Forest/Wildlife Resources • Increase in invasive pests • Drought and changes to soil conditions • Habitats likely to shift	M/M M/M H/H	• Pests and invasives not regulated by cold snaps • Increased deer population • Decline in tree species, such as Sugar Maple, Hemlock, Paper Birch • Habitat for endangered and threatened species such as Kirtland's Warbler, Pitcher's Thistle, Piping Plover, and Grey Wolf will be negatively impacted.	M/M M/L M/M H/H

Figure 23: Risk and Vulnerability Rankings for Climate Change Effects Relative to Natural Resources

Projected Climate Changes	Risk/ Vulnerability	Impact to Human Population	Risk/ Vulnerability
Seasonal and Weather Changes • Summers will be hotter, drier and longer • Autumns will be warmer, last longer, and be wetter • Winters will be shorter and milder • Springs will be wetter and longer • Increase in severe weather events	H/M M/M H/M L/M M/H	• Increased summer tourism affecting hospitality • Decreased winter festivals, such as the U.P. 200 Dogsled Race, affecting hospitality industry. • Increased cost of living in summer (i.e. air conditioning) • Decreased cost of living in winter • Disruption to human operations as Alger County does not have a solid emergency management plan for increasingly severe weather events	L/L H/H H/M L/L M/H
Water Resources • Warming water temperatures • Less ice on Lake Superior and inland lakes • Lake levels dropping • Increased turbidity on Lake	M/H M/H M/L M/M	• Lower lake levels may threaten shipping industry • Damage to property as shorelines erode • Diminished cold water fish species may threaten sport/commercial fishing opportunities • Increased tourism opportunities for fresh water surfing and wind surfing, emerging sports in Great Lakes region	M/L M/M M/H M/H
Forest/Wildlife Resources • Increase in invasive pests • Drought and changes to soil conditions • Habitats likely to shift	M/M M/M H/H	• Pests and invasives not regulated by cold snaps • Increased deer population • Decreased tree population, specifically Sugar Maple, will negatively impact timber products industry and autumn tourism	M/M M/L H/H

Figure 24: Risk and Vulnerability Rankings for Climate Change Effects Relative to Human Well-being

The following action plan was developed to address the high priority risks and opportunities identified by the community and are designed to bring climate resilience to the region.

Goal #1: Assist communities to create water resource resiliency with infrastructure and built environment.

Objective 1.1: Revise conservation subdivision regulations to create incentives for developers to provide greater densities and community services, while achieving open space conservation.

Strategy: Partner with the City and County of Marquette, St Lawrence Cities Initiative, and other interested regional planning entities to research subdivision regulations and coordinate updates.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Analyze governance tables for opportunities to update subdivision regulations	S	Staff Time	Superior Watershed Partnership	Timetable for subdivision modifications	A calendar of when communities will have updates to their zoning policy and regulations
Identify model subdivision regulations to recommend to communities	S	Staff time	Superior Watershed Partnership	Compiled portfolio of model plans/codes	A reference document including highlighted plans in action that work
Integration into county plan update	S-M	Cooperation from County	Dave Stensaas (City of Marquette Planner)	Updated plan with updated subdivision regulations	New county master plan
Integrations into municipal regulation updates	S-M	Cooperation from cities	Dave Stensaas (City of Marquette Planner)	Revised subdivision regulations	New subdivision regulations

Objective 1.2: Protect critical watershed features with enhanced land use including planning, zoning, acquisitions and easements especially river corridors and floodplains to preserve vegetation, retain hydraulic features, and ecological services.

Strategy: Utilize land acquisition through purchase, conservation easements, and purchase of development rights.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Educational session about plan with county planning commission	S	Presentation Literature/handouts on the topic	SWP Staff	Presentation and recommend-ations	Favorable response, request for more Information
Determine calendar for planning and zoning updates	S	Maps of the area, A clear outline of The revision process	SWP Staff County Commission	Calendar	Agreement for goal date to start
Model zoning language and examples for the region	S-M	GIS layers/data for riparian delineation County/ City of Marquette land develop-ment code	SWP Staff County/City planner	SWP's model riparian buffer ordinance	Integration of SWP's model riparian buffer ordinance into county/city zoning documents
Determine available riparian lands for fee simple purchase and/or purchase of development rights	L	County land ownership GIS Layers Land cover/use GIS layers	SWP Staff County/City planner	Prioritized list of available lands within the County	Acquire land or development rights for riparian zones

Objective 1.3: Promote green storm water management.

Strategy: Incentivize residential private property storm water management.					
Actions	**Timing (S,M,L)**	**Resources Needed**	**Responsible Parties**	**Deliverable**	**Success Indicators**
Educate community about personal property storm water management strategies/incentives	S	Advertisements, brochures, other marketing resources regarding storm water treatment	SWP Staff	Presentation and Recommendations	Interested property owners
Develop a tiered storm water rate structure based on a property's amount of impervious surface	M-L	A model storm water rate system (ie Ann Arbor, MI)	SWP Staff City/ County Planners	A document outlining the tiered rate structure	Passage of the rate structure through the city/ county commission
Quantify and map city and county impervious surface in contrast to pervious surface	M	CIR imagery for the County Land owner layers	Matt Koss Cameron Fuess	Map showing county wide pervious and impervious lands	Integration of maps/data into current planning documents
Develop a storm water management code for all new development with impervious areas greater than 200 feet	L	Working model codes from other communities (i.e. Ann Arbor)	SWP Staff City/ County Planners	A document showing standards and codes for new development	Increase in pervious land throughout the County

Objective 1.4: Adopt shoreline adaptation measures for habitat and infrastructure protection.

Strategy: Develop policy and recommendations to further protect and enhance existing shoreline.					
Actions	**Timing (S,M,L)**	**Resources Needed**	**Responsible Parties**	**Deliverable**	**Success Indicators**
ID and map critical habitat for entire Marquette County	S-M	GIS Layers/Data Historical Maps	SWP Staff City/ County Planners	Mapped areas with critically impaired habitat	Map in hand
Establish shoreline protection zone for new development (including set back requirements)	M-L	Model shoreline protection ordinance Current master plans	SWP Staff	Fully executable shoreline protection plan for Marquette County	Adoption of plan by county commission
Restore impaired dune complex along shoreline	S	Funding Volunteers Prioritized list of critical areas in need of restoration	SWP Staff	Map of protected areas	Protected shoreline

Goal #2: Develop a food security plan and work to increase local food production by working with farmers, protecting soils, and encouraging markets.

Objective 2.1: Strengthen the relationship between Marquette, the Michigan Food Policy Council, and the Marquette Food Co-op's regional food hub program.

Strategy: Collaborate with interested partners and networks.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Host a regional food security planning meeting	M-L	Partner contact info Venue to host event	SWP Staff Marquette Food Co-op	List of actions for each partner	Smiling faces, and commitment to participate
Set an annual agenda for partner meetings	M-L	Calendar	SWP Staff Partners	Quarterly dates for meetings	Attendance and commitment

Objective 2.2: Identify areas within the County that could be used for additional market places and space for community gardens.

Strategy: Utilize mapping techniques to find adequate garden areas.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Identify vacant lands within cities and counties	S	Land ownership/ use maps	SWP Staff Marquette Food Co-op	A list of potential properties to be utilized for food production/ distribution	
Rezone city/county lands to agriculture production	M-L	Government request to rezone application Funding	SWP Staff Marquette Food Co-op	A changed zoning map	New areas zoned for community agriculture

Goal #3: Increase public awareness of health related issues associated with climate change.

Objective 3.1: Increase and expand current beach monitoring activities to detect pathogens that affect human health.

Strategy: Acquire and secure funding for further monitoring, as well as distribution of results to the public.					
Actions	**Timing (S,M,L)**	**Resources Needed**	**Responsible Parties**	**Deliverable**	**Success Indicators**
Create a website with municipal water treatment personnel to distribute water quality information for city beaches	S-M	Internet domain space Database to hold water quality results	SWP Staff Marquette Municipal water treatment personnel	A webpage on the City of Marquette's site indicating the quality of city beaches	A public that is more aware of what the water quality is at each city beach
Approach foundations and other possible funding sources	S	Grant Proposals	SWP Staff City of Marquette	Meetings with foundation officers Invitations to submit proposals	A funded monitoring program

Objective 3.2: Prepare and implement emergency response plans for extreme storms, floods, heat, disease or poor air quality periods.

Strategy: Creating a collaboration between local governments and stakeholders to develop response plans.					
Actions	**Timing (S,M,L)**	**Resources Needed**	**Responsible Parties**	**Deliverable**	**Success Indicators**
Host a meeting with local government officials	S-M	Meeting space Prepared information regarding the risks at hand	SWP Staff Local units of government	Meeting minutes	An active collaboration between participating governments
Designate a specific person to create plans addressing emergency responses	M-L	City and County documents Resource maps	Local units of government	Emergency response plans	Active plans addressing emergencies
In collaboration with the County, establish early warning systems about evacuation routes, or other emergency information in an emergency event	M-L	Current warning systems Resource maps Means of outreach	Government staff	A warning system plan of action	A safer, more informed public
Connect emergency centers with onsite renewable energy systems to reduce susceptibility to lapses in conventional energy supply	L	Renewable energy systems A list of emergency centers and their energy demand	Emergency response centers/personnel	Operating renewable systems at emergency centers	Continual operating emergency centers

Goal #4: Maintain forest ecosystem integrity, overall health, and resilience.

Objective 4.1: Determine County forest land holder's risk and vulnerabilities associated with infestations due to climate change.

Strategy: Create a working group to begin plan review process of potential forest risks associated with climate change within the County.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Host a meeting with forest stakeholders	S	Meeting space Literature addressing risks and trends in Marquette County forests	SWP Staff Forest Stakeholders (Plum Creek, NFS, DNR, NRCS, etc)	Task list of next steps to take	Implementing and monitoring tasks
Review current private forest plans for addressing forest infestations	M	Forest owner's management plans	SWP Staff	Combined forest impact findings	Improved awareness of potential impacts to Marquette County forests

Objective 4.2: Adopt a County-wide urban canopy goal of a minimum of 40% and implement a program that monitors documented resiliency values delivered by a diverse, healthy urban tree canopy such as heat island effect and air quality.

Strategy: Adopt urban tree canopy goals into City and County Master Plans.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Develop effective language for inclusion into master plan addressing urban tree canopy goals	M	Model climate resiliency plan from other communities that include urban forestry City/County urban tree canopy details	SWP Staff County Forester City/ County planners	Draft master plan language	Inclusion into master plan

Objective 4.3: Implement a Marquette County Purchase of Development Rights (PDR) program to secure lands from development.

Strategy: Utilize model PDR programs from counties that have working, effective programs initiated (i.e. Grand Rapids, MI).					
Actions	**Timing (S,M,L)**	**Resources Needed**	**Responsible Parties**	**Deliverable**	**Success Indicators**
Acquire model literature including information regarding existing PDR programs	S-M	County plans	SWP Staff	Collaborated segments of working PDR programs crafted into one document	County Commissioners with document in hand with interest in accepting a PDR for Marquette County
Draft a PDR program to implement in Marquette County	M	Land ownership data for the County Estimates for amount of lands to be conserved	SWP Staff County planner	Draft PDR	Interest in the public in implementing the proposed PDR
Host a public hearing to pass the PDR program into effect	M-L	Meeting space Announcement for Public Hearing	County officials	A successful PDR to be initiated once voted into action	A viable, effective PDR program that will preserve Marquette lands in the state they are in

Goal #5: Strengthen the County's main economic bases by helping communities minimize negative impacts on the industries while taking advantages of positive opportunities.

Objective 5.1: Engage economic development organizations and tourism-dependent business in developing an economic development plan specific to tourism with specific goals to help local business minimize economic loss and take advantage of increased tourism opportunities.

Strategy: Focus on climate change predictions that will be beneficial for tourism, for example; longer shoulder seasons, more aquatic based recreation and more property rental opportunities.					
Actions	**Timing (S,M,L)**	**Resources Needed**	**Responsible Parties**	**Deliverable**	**Success Indicators**
Meet with community and business leaders to initiate discussion and awareness of shifts in tourism with relation to shifts in climate	S	Meeting space Research and results pertaining to climate and tourism trends	SWP Staff Community and business leaders	Presentation of economic projections with regards to a changing climate	A band of leaders initiated to tackle the task of economic adaptation
Appoint a member to devise a plan based on discussions and concerns	M	Willing member of the community to create an economic plan	Community and business leaders	An economic development plan specific to tourism	Utilization of the plan to better Marquette County's tourism sector
Promote tourism activities that are likely to increase	M-L	Means of displaying activities that are likely to increase (i.e. films, photos, firsthand accounts)	Community members Michigan Tourism Council (Pure Michigan)	Advertisements that show the grand nature of Marquette County's tourism opportunities	An improved and stable tourism industry within Marquette County

Objective 5.2: Invest in optimal harbor improvement/adaptations to maintain access to water resources.

Strategy: Promote the importance of water based recreation within the County.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Prioritize high use water recreation areas in need of repairs	S-M	Map of water ways, ramps, dams, etc.	Water enthusiasts MDNR	A list of high use water recreation areas in need of repairs/ improvements	Improved recreation areas for water enthusiasts
Secure funding for future repairs or improvements of water resources	M-L	Funding	MDNR	Money set aside specifically to address water based resources	Same as the deliverable
Initiate a state wide campaign to promote tourists to consider Marquette County as a destination due to its water based recreation opportunities	M	Funding Marketing team	Michigan tourism council County of Marquette	Marketing techniques (video, photo, radio) promoting the recreational opportunities	Increased water based tourism within the County

Objective 5.3: Strengthen connectivity between coastal and non-coastal recreational areas to improve resiliency of tourism.

Strategy: Gather county recreation organizations to initiate the objective.

Actions	Timing (S,M,L)	Resources Needed	Responsible Parties	Deliverable	Success Indicators
Initiate a cost reduction program for customers who utilize different recreational areas	M		Recreational organizations	Coupons/ monetary reduction in different recreational uses	More diverse recreational areas throughout the County

Outcomes

The effective implementation of this plan will:

- Maintain the health of 358,462 corporately held forested acres in Marquette County.
- Protect threatened and endangered species within the County.
- Preserve hunting, fishing, hiking, skiing, kayaking, and other outdoor sport activities for public enjoyment and ensuring a resilient and vibrant tourism industry.
- Protect the breeding grounds of cold water fish species such as the Brook Trout, Michigan's State Fish.
- Decrease the presence of invasive aquatic species.
- Protect homeowners from property damage associated with unsustainable development and shoreline infrastructure erosion.
- Ensure economical resiliency and sustainability in Marquette County for decades, through the public and private sectors, specifically the forest products industry.
- Provide climate change related education through a collaboration of the public schools, local units of government, private industry such as the forest products industry, and other vested agencies.
- Protect 80 miles of Lake Superior shoreline.
- Prepare Marquette County's public water infrastructure for climate change, ensuring safe water for over 67,000 residents.
- Reduce the dependency on fossil fuels for energy in Marquette County.

Climate change is upon us. The effects of climate change in Marquette County are tangible and measurable. They stand to change the face of the County in irreversible ways. It is paramount that the people of Marquette County begin to critically think about climate change and prepare for its effects so that the best of Marquette County—its natural resources and its quality of life—is resilient in the face of change. The implementation of the Marquette County Climate Adaptation Plan will serve as an insurance policy for the future. The same way we protect our cars, our boats, our homes, and our health against change or misfortune, we must now prepare Marquette County against the probability of change due to a natural resource shift caused by climate change.

Plan Implementation

While components of this plan require further planning and funding, implementation of this plan should begin immediately. There are several synergistic opportunities for partnerships and engagement that can enable objectives to be met and the creation of mutually beneficial projects or endeavors. Thus, building upon engagement and partnerships, outreach about the plan, and moving forward on synergistic opportunities are the first steps that should occur. This will increase the local capacity to be adaptive and resilient

As years come and go, more and more information has been brought to the table concerning climate related issues. Extreme weather causing flooding, extreme temperatures forcing people to seek refuge, drought conditions harming crop production, are real-life examples of problems facing the world today. Although there may be no way to stop the forces of nature, anticipating the effects of climate change is feasible.

Through working with community members, commissioners, and other representatives, attention must be brought forward to issues that may harm or hinder the community at large. Approaches to secure important facets of local economy, water resources, and forestry must be established with consent of the community at large.

The SWP in collaboration with CSU has indicated these facets of Marquette County's economic, water, and forest resources. Not only were these vulnerabilities brought to the table, they are also backed with detailed goals and strategies to overcome these obstacles in order to provide resiliency to Marquette County.

A great deal of attention has been brought about climate change at a global level. The ability to combat anything at a global scale is hardly attainable, but starting at a local level has potential to create snowball effects for adjacent communities. By working through this plan, implementation measures will easily be achieved. With available funding opportunities, and support from Marquette as a community, the implementation of resiliency focused projects are within near reach.

Literature Cited

Bartlein, Patrick J., and Solomon, Allen M. 1992. Past and future climate change: response by mixed deciduous –coniferous forest ecosystems in northern Michigan. Canadian Journal of Forest Research. 1727-1735.

Brown, Daniel G. undated report submitted to the Great Lakes Regional Assessment.

Great Lakes Science Center, "Algal (*Cladophora*) Mats Harbor High Concentrations of Indicator Bacteria and Pathogens," U.S. Geological Survey, 2009, http://www.glsc.usgs.gov/_files/factsheets/2009-1%20Cladophora.pdf.

Herzog, Tim, J. Pershing, and K.A. Baumert. 2005. Navigating the Numbers: Greenhouse Gas Data and International Climate Policy. World Research Institute.

King, James E. 1981. Late Quaternary Vegetational History of Illinois. Ecological Monographs 51:43–62.

Kraker, Dan, "Scientists Suspect Great Lakes Invaders in Loon Deaths," *Minnesota Public Radio*, March 11, 2013, www.sctimes.com/article/20130311/SPORTS05/303110057/Scientists-suspect-Great-Lakes-invaders-loon-deaths?nclick_check=1.

Natural Resource Program Center, National Park Service, U.S. Department of the Interior. (2010). Understanding the Science of Climate Change. Talking Points – Impacts to the Great Lakes. Natural Resource Report NPS/NRPC/NRR – 2010. Accessed online at: http://www.nps.gov/climatechange/docs/GreatLakesTP.pdf.

Saunders, Stephen, et al., "Great Lakes National Parks in Peril: The Threats of Climate Disruption," The Rocky Mountain Climate Organization, July 2011, http://www.rockymountainclimate.org/images/GreatLakesParksInPeril.pdf.

Union of Concerned Scientists. (2009). Confronting Climate Change in the U.S. Midwest – Michigan.

Accessed online at: http://www.ucsusa.org/assets/documents/global_warming/climate-change-michigan.pdf.

Wuebbles, D.L. and K. Hayhoe. (2003). Climate Change Projections for the United States Midwest. Mitigation and Adaptation Strategies for Global Change 9: 335-363.
Accessed online at: http://www.springerlink.com/content/k0667176715811161/.