RAMSEY COUNTY
Saint Paul – Ramsey County Public Health

Climate Change Health Vulnerability Assessment

April 2016

CONTENTS

EXECUTIVE SUMMARY

Climate Change & Vulnerability

In accordance with its 2014-2018 Strategic Plan, Saint Paul- Ramsey County Public Health (SPRCPH) conducted a climate change vulnerability assessment (CCVA) to identify populations and geographic areas that may be especially susceptible to the negative effects of climate change at the local level.

The goals of this report are to:

- communicate climate change trends in Ramsey County;
- explain how these trends directly and indirectly affect human health;
- identify characteristics that increase individual vulnerability to the effects of climate change; and
- demonstrate geographic regions of vulnerability in the county using a variety of maps.

The purpose of this report is to serve as an informational resource to aid in the conversation regarding the development of climate change adaptation measures in Ramsey County.

Adaptation refers to strategies to promote risk communication, community and infrastructure planning, and emergency preparedness in order to prepare for the effects of climate change.

Vulnerability refers to the characteristics and situation of a person or group that negatively affect their ability to anticipate, adapt to, and recover from the effects of a climate hazard (e.g., *low socioeconomic status, limited education, pre-existing physical or mental health illnesses, barriers in communication, and very old or very young age)*.

Environmental risk factors refer to aspects of the environment that increase the negative impact of a climate hazard; they are independent of population characteristics.

Vulnerability is combined with environmental risk factors to describe the overall impact of a climate hazard.

VULNERABILITY + ENVIRONMENTAL RISK FACTORS = IMPACT

This assessment focused on six topics related to climate change and vulnerability in Ramsey County:

- Extreme heat events
- Poor Air Quality
- Changes in Precipitation
- Changing Ecologies
- Changing Demographics
- Psychological Impacts

Extreme Heat Events

Extreme heat events are increasing in Minnesota.

Extreme heat causes a variety of heat-related illnesses, such as heat stress and heat stroke. Everyone is susceptible to extreme heat, although poverty, old or young age, and pre-existing disease increase vulnerability.

Extreme heat will affect all of Ramsey County; however, the GIS analysis demonstrates that the impact will be greatest in downtown Saint Paul, areas north and slightly south of I-94, areas around I-35E, portions of Saint Paul's East Side and West Side, along West 7th Street, and in isolated suburban pockets.

Poor Air Quality

Air pollutants, such as ozone, $PM_{2.5}$, and allergens, pose acute and chronic respiratory and cardiovascular threats.

Rising temperatures and changes in precipitation patterns may lead to increased air pollution.

Vulnerabilities include: older adults, young children, and those with respiratory difficulties.

Poor air quality can be experienced throughout Ramsey County. However, the areas where people will be most affected are primarily in and around downtown Saint Paul, along I-94, and between I-35E and Highway 61.

Changes in Precipitation

Flash flooding is unpredictable and threatens health in several direct and indirect ways, such as drowning, injury, exposure to mold and waterborne disease, economic loss, and property damage.

Changes in precipitation due to climate change will likely increase extreme rain events, leading to more flash floods.

Vulnerabilities include: older adults, especially living alone, those with pre-existing health conditions, those with limited mobility, and those under economic strain.

Droughts have a slow onset and create a cascade of negative environmental and health effects, such as agricultural loss, economic loss, mental and physical stress, and exacerbated respiratory illnesses.

Vulnerabilities include: older adults, young children, and those with respiratory illnesses.

Changing Ecologies

Vector-borne disease transmission is expected to increase due to changes in the distributions of ticks, mosquitoes, and other insect vectors as a result of warming temperatures and changing precipitation patterns.

Disease of concern: West Nile Virus, human anaplasmosis, and Lyme disease.

Vulnerabilities include: those who spend much time outdoors (outdoor workers, children, athletes, etc.). Older adults and the immunocompromised are susceptible to more severe illness once infection has occurred.

Invasive species, such as emerald ash borer, zebra mussels, and buckthorn, may increase in numbers as climate change increases habitat suitability. For instance, warmer temperatures may increase habitat suitability in the county for *Aedes aegypti* or *Aedes albopictus*, the mosquito species that transmit Zika, dengue, and chikungunya viruses.

This will lead to more severe environmental and health impacts, such as compromised food and water quality and compromised water bodies used for fishing, recreation, or industrial processes.

Vulnerabilities are generally indirect yet may include: those who rely heavily on water bodies for food or recreation and those who regularly interact with the environment via agriculture, gardening, or landscaping.

Changing Demographics

In the coming years, both an aging population and substantial immigrant and refugee populations will need to be taken into account when planning climate change adaptation measures.

Psychological Impacts

Climate change not only affects physical health, but also can lead to negative mental health outcomes. These mental health outcomes can be caused by the acute trauma of an extreme weather event or the gradual onset of climate change, such as drought conditions or warmer temperatures. Climate change will likely start a complex cascade of mental health issues, including anxiety, stress, depression, and PTSD.

Vulnerabilities include: older adults, children, women, those with disabilities or poor physical or mental health, those with minimal education, those in poverty, and immigrants or refugees.

Steps to prevent and prepare for mental stress include bolstering community engagement, education, and infrastructure related to climate change, fostering safety and optimism, and paying special attention to vulnerable populations.

Limitations of this study

There are a number of limitations with this assessment including limited data availability and quality, limitations in spatially assessing some climate hazards, and limitations in representing only a snapshot in time, not necessarily future vulnerability trends.

Next Steps

Next steps include regularly updating this assessment as new and better data become available and commencing the planning of climate change adaptation efforts in Ramsey County.

Conclusion

The information presented in this report characterizes the health impacts of climate change. It does so by incorporating environmental risk factors and individual vulnerabilities within the context of specific climate hazards, such as extreme heat, poor air quality, flooding, drought, and vector-borne disease. These quantitative and qualitative assessments provide a preliminary framework for future discussions regarding adaptation strategies. SPRCPH will regularly update this analysis to improve upon this framework in the future.

The results of this assessment indicate the impact of climate change on human health in Ramsey County is complex and affected by both environmental risk factors and social vulnerability. Understanding how vulnerability contributes to the impact of climate change will prove beneficial as the county continues discussions regarding how it should respond to the health effects of climate change in a manner that protects all Ramsey County residents, including the most vulnerable, to ensure healthy people, healthy communities, and a healthy environment.

Although this document provides a good informational foundation regarding climate change and vulnerability, the true impact will lie within future adaptation plans. In other words, while vulnerability should still be explored, measured, and quantified, the ultimate goal is to take that information and eventually turn it into practical yet potent action so that Ramsey County is appropriately prepared in the wake of climate change.

INTRODUCTION

Ramsey County is home to 19 cities, over 520,000 residents, 15 colleges, universities, and post-secondary institutions, 20 public libraries, 81 lakes, 15 county and regional parks, and 7 hospitals. As the most densely populated and racially diverse county in Minnesota, Ramsey County embraces a unique urban and suburban blend of cultures, activities, sports, Fortune-500 companies, and natural resources (SPRCPH, 2013).

Saint Paul – Ramsey County Public Health (SPRCPH), the largest public health department in Minnesota, continually strives towards its mission to protect and improve the health of people and the environment in Ramsey County. In the SPRCPH 2014-2018 Strategic Plan, Goal 3 aims to promote adaptive approaches to the public health impacts of a changing climate. Within this goal, Objective 2 commits to the completion of a vulnerability and risk assessment of the public health impacts associated with climate change every two years beginning June 30, 2015 (SPRCPH, 2014a). Responding to this objective, SPRCPH conducted a climate change vulnerability assessment in order to identify populations and geographic areas that may be especially susceptible to the negative effects of climate change at the local level.

While substantial work evaluating the human health impacts of climate change exists at the global, national, and state levels, it is prudent to assess this impact from a local perspective. In particular, among Minnesota counties, Ramsey County faces a unique combination of factors, such as increasing immigrant and diverse cultural populations, an aging population, the highest level of poverty in the state, a fully developed urban and suburban infrastructure, and various natural resources, all which must be considered when assessing the potential local health impacts of climate change.

This report, called a climate change vulnerability assessment (CCVA), is the second in a series of three reports to address the health impacts of climate change. The first, *A Changing Ramsey County*, served as a scoping document to identify potential public health issues associated with climate change (SPRCPH, 2014b). As the second step in this process, this vulnerability assessment aims to communicate four concepts:

- Climate change trends in Ramsey County;
- How these trends directly and indirectly affect human health;
- Characteristics that increase individual vulnerability to The effects of climate change; and
- When possible, identify specific geographic areas of vulnerability in Ramsey County using Geographic Information Systems (GIS).

This report is directly related to adaptation to climate change. While *mitigation* refers to the promotion of activities to reduce greenhouse gas (GHG) emissions, *adaptation* refers to understanding how climate change affects human health and which populations are likely to be most affected by climate change. Adaptation strategies promote risk communication, community and infrastructure planning, and emergency preparedness (MDH, 2012). This report provides the information necessary to help further the discussion regarding adaptation specifically in Ramsey County, which will be the focus of the third and final report in this series.

The CCVA also provides information based on the first step of the Building Resilience Against Climate Effects (BRACE) framework, outlined by the Centers for Disease Control and Prevention (CDC) in 2014. The first step in the BRACE framework focuses on forecasting climate impacts as well as assessing community vulnerabilities (Manangan, 2014).

The Minnesota Department of Health (MDH) published a state-wide CCVA in October of 2014. Using that initiative as a framework, SPRCPH sought to replicate that study at the county level, focusing on factors specifically pertinent to Ramsey County.

Following a brief background, this report addresses how changing patterns in temperature and precipitation will lead to more extreme weather patterns as well as affect air quality and water and food quality and supply. These outcomes, in turn, are likely to affect the health of vulnerable Ramsey County residents (SPRCPH, 2014b). Finally, characteristics of potential vulnerability are both identified and mapped (when possible) for future local planning purposes.

A Note about the Purpose of this Report:

This report represents SPRCPH's analysis of vulnerabilities at one point in time. As outlined in SPRCPH's Strategic Plan, assessing public health vulnerabilities associated with a changing climate will be a continual process. This report addresses public health impacts of climate change and identifies in a qualitative and quantitative manner the geographic areas or communities that are more vulnerable to the negative impacts of climate change hazards.

Because of limitations in data availability and quality as well as assumptions made in the mapping process, generated maps are intended to identify general trends and are not meant to pinpoint specific sites that would require action. These maps should be used to aid in the conversation about developing adaptation measures and how they may be allocated, but not to specifically target resources.

Everyone can connect with the weather. It has inspired us, humbled us, scared us, disappointed us, tortured us, and restored us. It bookmarks significant events in our lives as we remember the weather from the day of a wedding, of a child's birth, of a family reunion, or of that Vikings/Packers game at the old Met.

-Mark Seeley-
Minnesota Weather Almanac

BACKGROUND: CLIMATE CHANGE & VULNERABILITY

Climate vs. Weather

The terms climate and weather are often misunderstood or used synonymously. Therefore, it is important to understand the difference between weather and climate as well as how they relate to each other. *Weather* refers to the conditions of the atmosphere over a short period of time, while *climate* refers to the conditions of the atmosphere over long periods (at least 30 years) of time (MDH, 2012). The climate dictates the everyday patterns of weather.

According to the Environmental Protection Agency (EPA), *Climate change* is defined as a "significant change in the measures of climate lasting for an extended period of time" (EPA, 2013). Measured changes may include changes in temperature, precipitation, wind patterns, or frequency and severity of extreme weather events.

Global warming as a result of the accumulation of atmospheric greenhouse gases (GHG) is the primary mechanism for climate change. GHG trap heat from the sun, causing climate patterns to change gradually (EPA, 2013). While some degree of heat retention via GHG is necessary to maintain life on Earth, an over-abundance of GHG, whether natural or man-made, can lead to detrimental climate change and subsequent negative health outcomes (EPA, 2013).

Climate Change in Ramsey County

The concepts of climate change and global warming may seem relevant only from a global perspective. However, climate change is pertinent not only on the global scale but also at the local level, where individuals intimately experience its effects (Clayton, 2014). Furthermore, most adaptation actions will occur at the local level.

At the state level, three climate change trends have warranted concern in Minnesota:

- An increase in average temperature, with winter and overnight low temperatures rising faster than maximum daytime temperatures;
- A potential increase in the number of days with high (thus uncomfortable) dew point temperatures (≥ 70°F); and
- Changes in the characteristics of precipitation, including areas facing an increase in local heavy precipitation events as well as areas facing a precipitation deficit (MDH, 2014a & Seeley, 2015).

The resultant hazards associated with such changes in the climate include warmer winters and more severe weather events, such as extreme heat events, mega-rainfall events, and flash floods. This can also lead to changes in air quality, compromised food and water quality and supply, and changes in vector-borne disease ecology (MDH, 2014a & Seeley, 2015). SPRCPH chose to focus specifically on these hazards as they relate to health vulnerability in Ramsey County.

Vulnerability + Environmental Risk Factor → Impact

The terms, *hazard*, *vulnerability*, *environmental risk factor*, and *impact* are used frequently in this report. According to MDH, a *hazard* refers to a weather event (e.g., violent storm or extreme heat), an environmental condition (e.g., compromised water quality), or biological threat (e.g., vector-borne disease) which can harm individuals, property, ecosystems, or livelihoods (MDH, 2014a).

Indicators of *vulnerability* refer to the characteristics and situation of a person or group that negatively affect their ability to anticipate, adapt to, and recover from the effects of a climate hazard. Vulnerability can be situational, meaning an individual may only be vulnerable in the wake of a climate hazard, not necessarily inherently vulnerable. Vulnerability can be temporary and dynamic, such as with the case of pregnancy or homelessness (MDH, 2014a). Finally, vulnerability can be broad because it can apply to individuals, groups, or sweeping parts of the county.

Environmental risk factors refer to aspects of the environment that could increase the negative impact of a climate hazard. They are <u>independent</u> of the characteristics of the individuals living there. In other words, they are factors that would increase the severity of the hazard's impact, regardless of individual vulnerability factors.

Indicators of vulnerability and environmental risk factors combine to determine the overall *impact* of a climate hazard.*

For instance: extreme heat is a climate hazard. Environmental risk factors that increase the severity of extreme heat in an area would be: reduced air quality, a high ratio of impervious surfaces to trees and greenery, and large distances to cooling centers and emergency medical services. Indicators of vulnerability (person-specific) would be working outdoors, living with chronic illnesses, experiencing poverty, and being elderly or very young. Therefore, given the presence of several environmental risk factors AND individual vulnerabilities, the impact of extreme heat to the people in that area would be very great.

This report identifies climate hazards specific to Ramsey County. For each hazard, it outlines specific indicators of vulnerability in individuals as well as environmental risk factors. Together, they combine to create a full impact assessment. Geographic Information Systems (GIS) were used to map both vulnerability and environmental risk factors when possible (some analyses were limited due to lack of data or because they were beyond the scope of this project). GIS was then used to assess the overall impact of each climate hazard.

The following section briefly outlines the basic procedure of the CCVA. A more detailed methodology regarding the GIS protocol is available from SPRCPH upon request.

**Note: the classic risk assessment structure (Risk = Probability x Impact) is not followed in this report, since establishing the probability of a climate hazard occurring was outside the scope of this report. Instead, SPRCPH specifically focused on impact, noting both environmental risk factors and indicators of vulnerability (Impact = Environmental Risk Factors + Individual Vulnerability).*

The signal of climate change is essentially lost in the noise of daily and seasonal weather variation.

The phenomenon seems distant from people's lives: something that will be experienced by other, faraway people at some point in the future.

The very terms used to describe it, "climate change" and "global warming," draw attention to its global scale.

-Clayton, 2014-

METHODS

Quantitative & Qualitative Assessment

The CCVA consisted of both quantitative and qualitative assessment. The quantitative portion used GIS and spatial data to identify regions in Ramsey County with environmental risk factors as well as show where people vulnerable to the effects of climate hazards reside. In the absence of sound spatial data or when mapping was not possible, a qualitative assessment was conducted. While qualitative assessment is not ideal, it nevertheless highlights the need to address particular health impacts of climate change, such as its effects on mental health or within the refugee population. SPRCPH acknowledges the need for these data at the sub-county level. Because this CCVA is to be updated regularly, there will hopefully be ample opportunity to include these data as they become available.

Establishing Vulnerability & Environmental Risk

The CCVA approached vulnerability in two ways. First, base vulnerability was defined. *Base vulnerability*, in this case, refers to the set of characteristics in individuals that are, more or less, equally problematic across all climate hazards relevant to Ramsey County. This set of indicators created a foundation to which specific vulnerabilities were added when assessing a given hazard. This additional vulnerability is called *hazard-specific vulnerability*. Together, base vulnerability and hazard-specific vulnerability combined to determine overall vulnerability. For instance, vulnerability due to extreme heat consisted of base vulnerability with additional specific vulnerability indicators, such as age-adjusted rates of hospital visits for chronic obstructive pulmonary disease (COPD) and asthma.

The indicators used for base vulnerability focused on five broad factors:

- Socioeconomic status
- Age
- Barriers in communication
- Mobility
- Additional factors, such as housing situation and outdoor employment

Table 1 outlines the data source, justification for selection, and limitations for each indicator used for base vulnerability. Note that *land use* was used as a multiplier in order to apply the proper weight to each indicator based on if the land was commercial, residential, or vacant.

Environmental risk factors were determined for two climate hazards: extreme heat and air quality. (Flooding was excluded for the time being due to the need to conduct an in-depth flash flood analysis, which was outside the scope of this project.) It is important to note that because of the relatively small size of Ramsey County, it was difficult to address large-scale climate projections, such as annual rainfall or average temperature, due to a lack of variation in the study area.

Together, base vulnerability, hazard-specific vulnerability, and environmental risk factors were overlaid to create a full impact assessment for each climate hazard. **Figure 1** illustrates this concept.

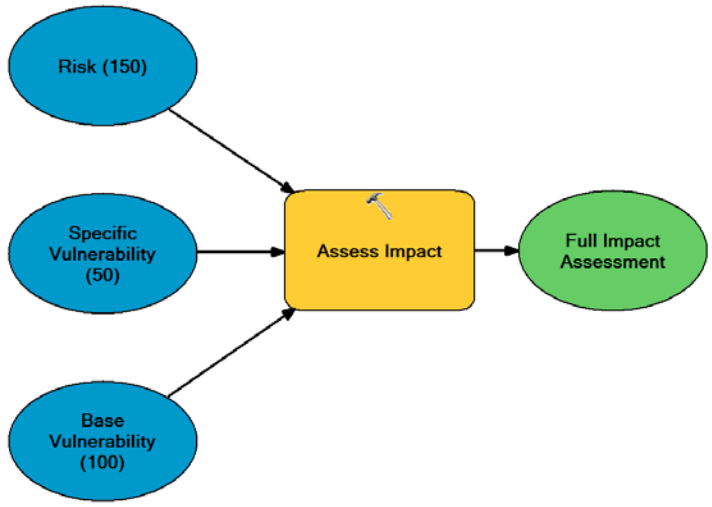


Figure 1. The full impact assessment for each climate hazard consisted of base vulnerability, hazard-specific vulnerability, and environmental risk factors. Numbers below each component indicate their respective weights for computational analysis. Together, base vulnerability and hazard-specific vulnerability were weighted the same as environmental risk.

Standard vs. Normalized Data

Vulnerability data were treated in the two following ways:

- With *standard treatment*, the absolute numbers from census data were used. For instance, if there were 20 individuals without access to a vehicle in a defined area, the absolute count of 20 was used for that area.
- With *normalized treatment*, a percentage of the total container population was used. For instance, if there were 20 individuals without access to a vehicle within a defined area of 100 residents, the proportion of 20/100 (or 0.2) was used in that area. Normalized treatment helps control for large areas being over-weighted for risk.

Regarding emergency preparedness, standard data are helpful to determine resource allocation in a specific area. Normalized data are useful to compare land areas of different sizes and populations. For example, even though the impact of extreme heat in a particular area might be "very high" as a result of normalized treatment, it may only have four vulnerable individuals within a total population of six. Therefore, it is important to note this discrepancy when interpreting results based on standard and normalized treatments in order to efficiently prioritize emergency response services.

For extreme heat and air quality, two impact assessments were carried out: one using a standard treatment and one using a normalized treatment. For the For instance, say the overwhelming majority of Ramsey County residents were outdoor workers and only a few residents worked indoors. This relative approach still portions out the data and compares it to the rest of the county, even if there isn't a large difference in the values represented by warmer versus cooler colors. As a result, areas of red, orange, yellow, green, and blue would be demonstrated, even though most of Ramsey County housed a large concentration of outdoor workers.

[b]*A complete methodology regarding the GIS protocol used in this assessment is available from SPRCPH upon request.*

purposes of this report, SPRCPH presents here the results of the normalized treatment only.[a] The reasons for this are twofold: first, normalized maps avoid characterizing larger areas as higher risk simply because they have a larger population. Instead, normalized treatment controls for population size. Second, standard maps are excluded for the sake of simplicity in this report.

[a]*Models and maps using standard data are available upon request.*

A Note on Maps & Relative Risk

Several maps in this assessment demonstrate relative risk, relative impact, relative concentration, density, etc. When this is the case, high-risk values (denoted in red) represent the highest values compared to the rest of the dataset (i.e., the rest of Ramsey County). Conversely, low-risk values (in blue) represent the lowest values of the dataset. In other words, each region is compared to the rest of Ramsey County.

One caveat about a relative approach is that it relies on comparisons. Given how the spatial data were analyzed[b], the high-valued data were assigned red colors, and the low-valued data were assigned blue colors. As a result, it is possible that red parts of the county may not be as drastically different from blue parts the county in some cases. This is one disadvantage in using a relative approach and should be noted when interpreting subsequent maps.

Table 1.Indicators of Base Vulnerability

Indicator	Additional Notes	Justification for Selection	Limitations
		Socioeconomic Status	
People living below 200% of poverty threshold[1]	Used in this assessment, the poverty threshold for a family of 4 was an income of $23,492 in 2012.[3] Block group data*	SPRCPH sought to use a measure of poverty consistent with previous reports, such as the Community Health Assessment of 2013.[7] Poverty poses an additional vulnerability to weather-related negative health outcomes due to limitations in education, employment, living conditions, and access to necessary health and safety services.[4]	ACS 5-year summaries increase statistical reliability for less-populated regions, yet are estimations, not true counts. This measure also captures those with incomes that are so low that they live in public housing, which has strict building and fire code requirements. Thus, those with qualifying incomes living in public housing may have less vulnerability than those with slightly higher incomes yet living in substandard conditions in owner-occupied housing.
Less than high school diploma for those 25+[1]	Block group data	Educational level may increase population vulnerability.[4] Education is consistently linked to health even when controlling for income.[7]	Estimations, not true counts.
		Age	
Population under 5 years[2]	Block level data	Children under 5 years of age are more vulnerable due to the developing state of their immune systems and their dependence on adult supervision. In addition, their bodies are not able to regulate temperature as well.[4]	
Population over 80 years[2]	Block level data	Older adults tend to be more vulnerable to the negative impacts of climate change especially extreme weather events, such as periods of intense heat and humidity. Vulnerability is due to a variety of factors, such as limited mobility, existing chronic conditions or multiple illnesses, and dependence on others for basic care needs.[4]	
Householders 65 years and older who live alone[1]	*Householder* refers to the individual who owns or manages the house. Block group data	Older adults tend to be more vulnerable to the negative impacts of climate change. Older adults who live alone are likely more vulnerable due to potential isolation during an extreme weather event.[4]	Estimations, not true counts.

		Barriers in Communication	
Number of occupied housing units without telephone service[1]	Telephone service includes both landlines & cell phones. Block group data	In the event of a weather emergency, it may be more difficult to relay messages to those without telephone service. In addition, those without telephone service may not be able to request help during a weather emergency.	Estimations, not true counts.
Speak English < "very well"[1]	Includes respondents who report speaking English "well", "not well", or "not at all". Block group data	Speaking a language other than English within Ramsey County presents a communication barrier, especially during weather emergencies.[4] While Ramsey County is working with community organizations to mitigate this vulnerability, the opportunity to improve communication persists. [5]	Estimations, not true counts.
		Mobility	
Number of occupied housing units without vehicle access[1]	Occupied housing units include houses, apartment units, condos, townhouses, & mobile homes. Block group data	Limited mobility due to lack of vehicle access may present challenges during emergency evacuation situations, especially for individuals in high-risk areas. In addition, limited mobility can inhibit access to cooling stations (public facilities with air conditioning) during extreme heat events and/or access to hospitals or clinics.[4]	Estimations, not true counts.
People 16 years and older who walk or bike to work[1]	Block group data	Those who walk or bike to work are likely routinely exposed to extreme weather and/or poor air quality conditions, thus increasing their vulnerability.	The data provided do not elucidate average travel distances or travel time. Also, this indicator does not necessarily account for potentially better health due to the physical activity to get to work. Estimations, not true counts.

Additional Indicators

All occupied housing units in multi-family housing[1]	Multi-family housing is defined as more than 4 units in a single structure. Block group data	This indicator may be more helpful for emergency planning purposes, for in the event of a flood, water main break, or power outage, a high density of people would be affected.	The data do not necessarily indicate inherent vulnerability, yet would be helpful in focusing relief efforts during an extreme weather event. Multifamily housing in areas, such as downtown Saint Paul, captures potentially *less* vulnerable populations because of nicer building structures with access to AC, proper ventilation, etc. Estimations, not true counts.
Number of occupied mobile homes[1,3]	SPRCPH custom generated this indicator using two datasets in order to capture the true extent of mobile home parks.	Mobile homes may provide only minimal protection from extreme weather, such as a flood. Should a flood occur in an area with a large number of occupied mobile homes, a high density of people would be affected, indicating a potential target for increased relief efforts.	The data do not indicate the average number of people living in each mobile home.
Employed people 16 years and older who work outside[1]	Block group data	Those who work outdoors have increased exposure to extreme weather, especially extreme heat and cold. These individuals may be at an increased risk of the negative effects of extreme weather.[4]	Data are based on household location rather than work location. Individuals who live in Ramsey County may work in a different county. Estimations, not true counts.

		Multiplier	
Land Use[6]	Land uses include industrial/commercial, residential, and vacant lands.	As the multiplier, land use was applied to all vulnerability indicators (except environmental risk factor indicators). Vacant land was removed from the assessment due to the low probability of people located in those areas during a weather emergency. Industrial/commercial areas received half the weight of residential areas because individuals at work are under additional protection from employers by law and therefore, are less vulnerable.	This approach requires the application of sweeping generalizations but is necessary to identify where vulnerability truly lies.

*Census blocks represent the smallest geographic area that the U.S. Census Bureau collects census data. Block groups, as their name suggests, represent a combination of blocks, and therefore, are the next level in the hierarchy.[8]

Sources:

1. **U.S. Census Bureau. 2008-2012. American Communities Survey, 5-year summary.**
2. **U.S. Census Bureau. 2010. Decennial Census.**
3. **U.S. Census Bureau. 2012a. Poverty thresholds by size of family & number of children. http://www.census.gov/hhes/www/poverty/data/threshld/index.html**
4. **Minnesota Department of Health (MDH). 2014a. Minnesota Climate Change Vulnerability Assessment. http://www.health.state.mn.us/divs/climatechange/docs/mnclimvulnreport.pdf**
5. **Boyd, C. 2013. Explaining Minnesota's severe weather to new immigrants. *MinnPost.* https://www.minnpost.com/community-sketchbook/2013/01/explaining-minnesota-s-severe-weather-new-immigrants**
6. **Ramsey County. 2014. Land use or tax assessment data.**
7. **Saint Paul - Ramsey County Public Health (SPRCPH). 2013. Health status & trends of our community: Ramsey County Community Health Assessment. https://www.ramseycounty.us/sites/default/files/Open%20Government/Public%20Health%20Data/community_health_assessment_030515.pdf**
8. **U.S. Census Bureau. 2012b. Geographic terms & concepts – block groups.** https://www.census.gov/geo/reference/gtc/gtc_bg.html

EXTREME HEAT EVENTS

Background

Higher daytime temperatures and more days with high dew points have resulted in more extreme heat events. An *extreme heat event* (EHE) is characterized by an abnormally high heat index, which takes into account air temperature and dew point temperature (MDH, 2014a & Seeley, 2015). The definition of extreme heat takes into consideration the normal warm weather patterns in an area; for instance, extreme heat in Texas is defined differently than extreme heat in Minnesota, because residents in Texas are more accustomed to higher temperatures (MDH, 2014a).

Two notification tools are used to warn residents of extreme heat events. The National Weather Service (NWS) station for the metro area issues heat advisories and excessive heat warnings based on the observed weather in that particular area (MDH, 2014a). **Table 2** defines both notification tools.

Table 2. Notification Tools for Extreme Heat in Ramsey County

Heat Advisory	**Parameters**
Issued when an EHE is imminent, occurring, or likely to occur Refers to less serious conditions that *may* threaten life/property	Max heat index at MSP is expected to reach or exceed 95°F for 1 day **OR** Max heat index is expected to reach or exceed 95°F with an overnight low no cooler than 75°F for 2 consecutive days
Excessive Heat Warning	**Parameters**
Issued when an EHE is imminent, occurring, or likely to occur Refers to conditions that threaten life/property	Max heat index at MSP reaches or exceeds 100°F for 1 day **OR** When a heat advisory is expected 4 consecutive days (A research-based tool must recommend said warning)

Without precautions, extreme heat can cause heat-related illnesses characterized by heat rash, edema, breathing difficulties, muscle cramps, dizziness or fainting, profuse sweating, weakness, nausea or vomiting, dehydration, headache, confusion, unconsciousness, and even death. Extreme heat can also exacerbate existing illnesses and chronic health conditions (MDH, 2014a).

Urban Heat Island Effect

Central and southern Minnesota experience extreme heat more often than northern Minnesota. Furthermore, urban areas experience pockets of heat due to the *urban heat island effect*. Little vegetation coupled with ample impervious surfaces (e.g., pavement or buildings) lead to the absorption of the sun's heat during the day. This heat is then released at night, resulting in warmer temperatures than in less developed areas (MDH, 2014a).

This effect is relevant and local to the metro area. At the University of Minnesota, Peter Snyder, Tracy Twine, and colleagues currently research and monitor the urban heat island effect in the Twin Cities, with the goal of better understanding the factors contributing to the effect as well as finding ways to mitigate the effect using landscape design (UM IOE, 2011).

For this assessment, three indicators were used to map the risk of the heat island effect in Ramsey County:

- Impervious surfaces
- Biomass (e.g., grass & trees)
- Land & water cover (water moderates temperature)

Figure 2 demonstrates the results of this analysis. While high-risk areas tend to correlate with the location of major roads and highways, there is also a distinct high risk pattern in the industrial area of South Saint Anthony Park (I-94 and Highway 280), the commercial area (including Rosedale Mall) near Highway 36 and I-35W, and, most notably, downtown Saint Paul.

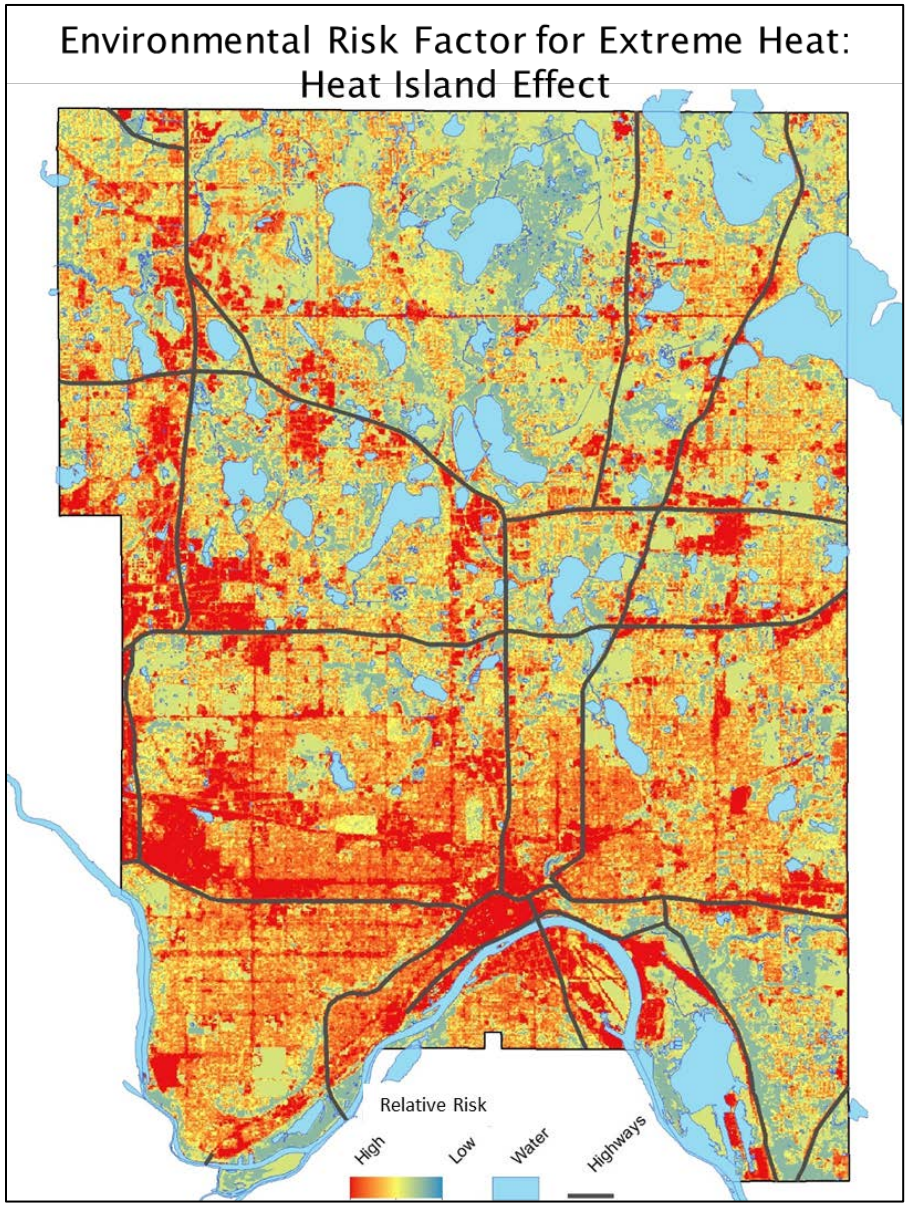


Figure 2. The risk of the urban heat island effect, represented by impervious surfaces, biomass, & land/water cover. Note the higher risk in downtown Saint Paul.

Environmental Risk Factors for Extreme Heat

Several environmental risk factors were used to describe the potential severity of extreme heat in Ramsey County. These factors included:

- Heat island effect
- Reduced air quality
- Distance to cooling centers
- Distance to emergency medical services
- Distance to hospitals

Together, these environmental risk factors created a composite map, shown in **Figure 3**. Note areas with more risk (shown in red/orange), including downtown Saint Paul, just north of I-94, and along West 7th Street.

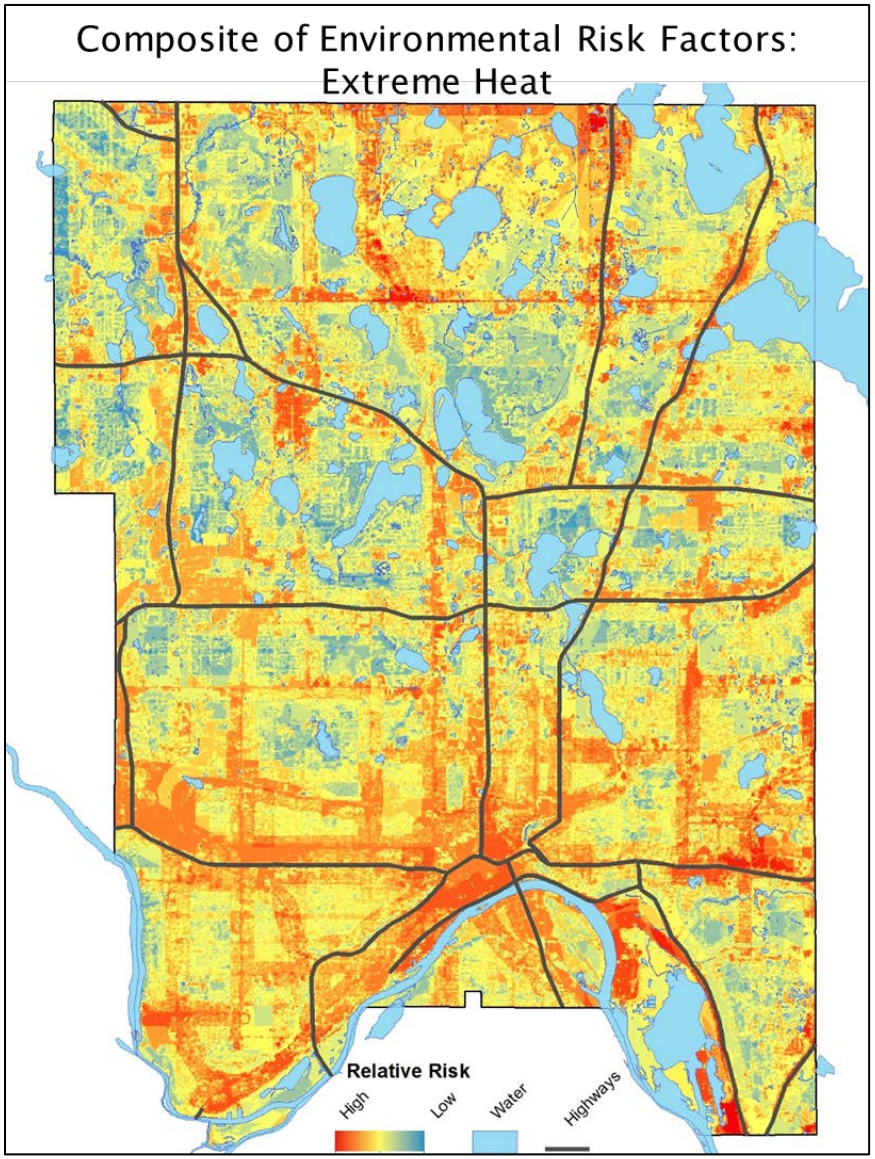


Figure 3. Composite of risk factors for extreme heat in Ramsey County, represented by heat island effect, reduced air quality, & distance to cooling centers, emergency medical services, & hospitals. Note areas of higher risk, including downtown Saint Paul, just North of I-94, & along West 7th Street.

Populations Vulnerable to Extreme Heat

Because climate change will likely increase the number of extreme heat events in Ramsey County, it is important to identify populations most vulnerable to its effects. While everyone is susceptible to heat-related illnesses, the following populations are especially vulnerable:

Older adults; young children; those who are homeless, living in poverty, without access to air-conditioning, with pre-existing health conditions, or living alone; those using certain medications; those living in nursing homes or who are bedridden; outdoor workers and outdoor athletes; and those living in urban areas or in top-floor apartments (MDH, 2014a).

For this assessment, SPRCPH chose several indicators of vulnerability specific to extreme heat. These indicators were added to base vulnerability and are listed as follows:

- **Base Vulnerabilities:**
  - Occupied housing units without phone access
  - Occupied housing units without vehicle access
  - Occupied housing units in multifamily housing
  - Occupied mobile homes
  - Population 25+ without a high school diploma
  - Population 16+ who walk or bike to work
  - Population 65+ & living alone
  - Population 5+ who speak English < "very well"
  - Population that works outdoors
  - Population living below 200% of poverty threshold
  - Population under 5 years
  - Population 85+
- **Additional Hazard-Specific Vulnerabilities:**
  - Age-adjusted rates of COPD-related hospitalizations
  - Age-adjusted rates of asthma-related hospitalizations

Because some vulnerability indicators are especially important regarding extreme heat, several are highlighted in the following three subsections.

65+ & Living Alone

Those 65 years and older constitute a notably vulnerable population in Ramsey County. This population has the highest rates of heat-related illnesses and deaths (MDH, 2014a). Furthermore, those 65+ who are living alone may be especially vulnerable due to potential social isolation during an EHE. **Figure 4** demonstrates the distribution of this particular population in Ramsey County. In general, higher concentrations live in areas between I-94 and Highway 36, Vadnais Heights, Shoreview, Roseville, and in pockets throughout Saint Paul. It should be noted that this population is also vulnerable to additional types of climate hazards, such as flooding and poor air quality.

Below 200% of the Poverty Threshold

According to the Minnesota Department of Health, individuals with low socioeconomic status are at an increased risk of suffering from heat-related illnesses (MDH, 2014a). Although this may be caused by a variety of factors, those at or below the poverty threshold are:

- less likely to have air conditioning in their homes;
- more likely to live in deteriorating/substandard homes;
- less able to pay for increased energy usage during periods of extreme heat; and
- potentially less likely to seek cooling centers or open doors/windows due to safety concerns (MDH, 2014a).

Figure 5 demonstrates the distribution of Ramsey County residents near the poverty threshold. Higher concentrations of poverty are shown in areas along and north of I-94, Saint Paul's East Side and West Side, and in pockets in the surrounding northern suburbs. Similar to those 65+ and living alone, this population is also vulnerable to additional types of climate hazards, such as flooding and poor air quality.

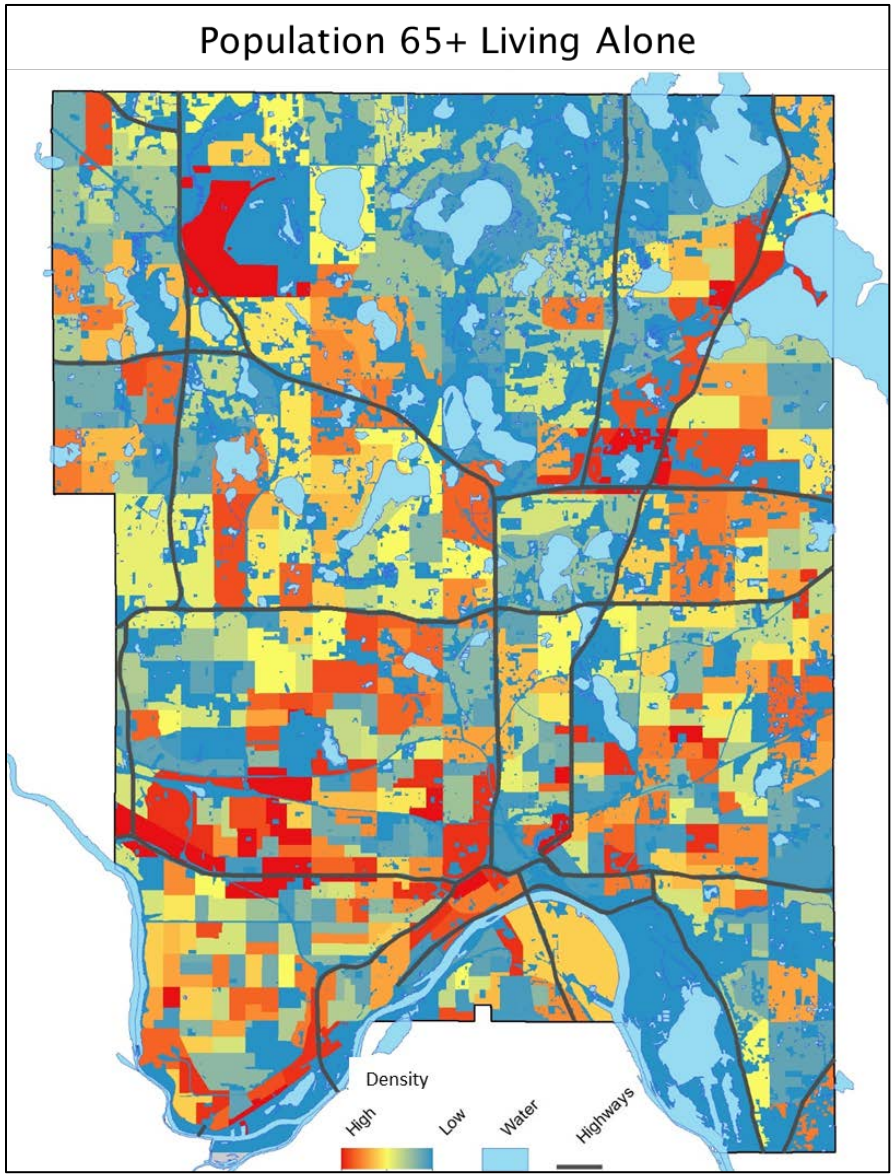


Figure 4. Ramsey County residents 65+ who live alone (normalized data). Higher concentrations live in areas between I-94 & Highway 36, Vadnais Heights, Shoreview, Roseville, and in pockets throughout Saint Paul.

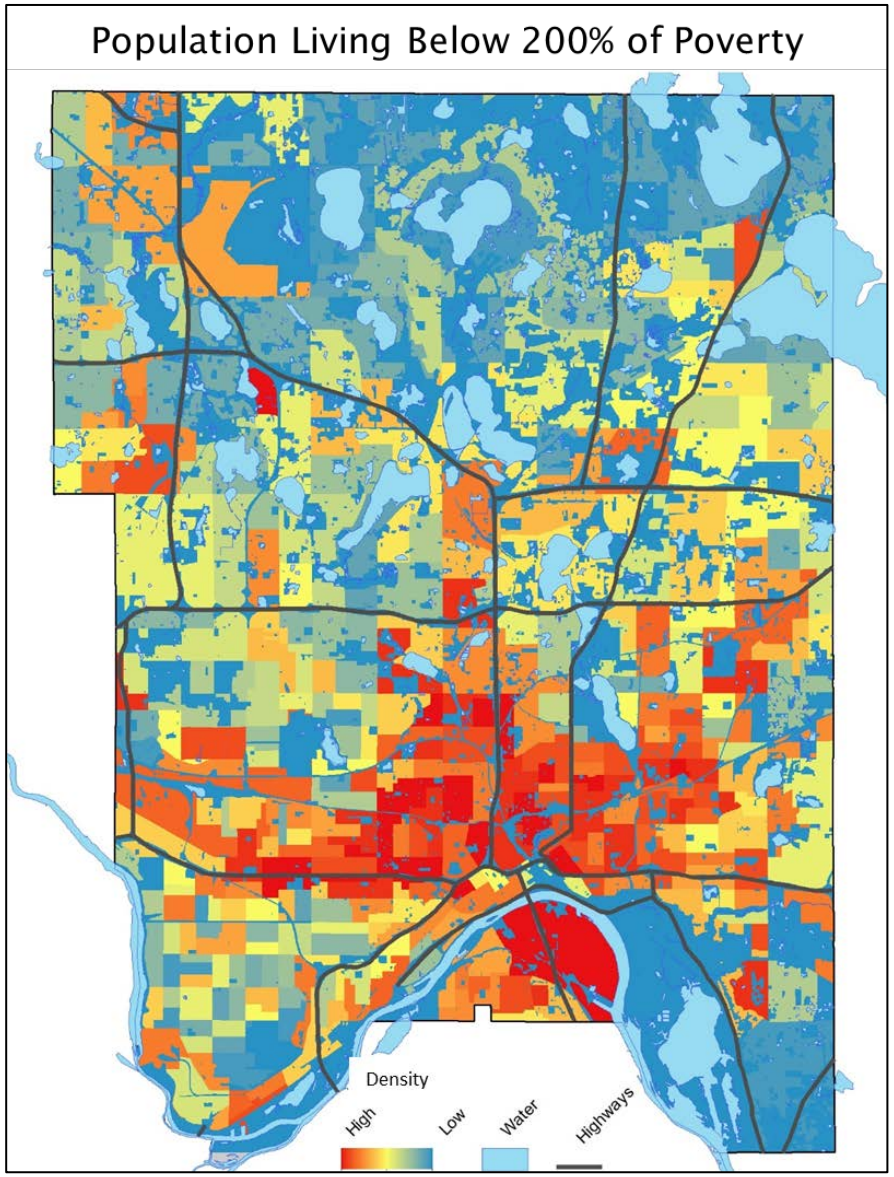


Figure 5. Ramsey County residents living at or below 200% of the poverty threshold (normalized data). Higher concentrations are shown in areas along & north of I-94, Saint Paul's East Side & West Side, & in areas in St. Anthony, Mounds View, Shoreview, & Maplewood.

Multifamily Housing

Because heat rises, those living in top-floor or high-rise apartments are vulnerable to extreme heat, especially without access to air conditioning or if the power goes out during an EHE (MDH, 2014a). Multifamily housing also indicates where large concentrations of residents could be affected by extreme heat. Therefore, it is important to understand the distribution of multifamily housing in Ramsey County to aid in emergency preparedness efforts.

Figure 6 depicts the distribution of occupied units in multifamily housing in Ramsey County. Multifamily housing refers to buildings with more than four units. Higher concentrations are located in downtown Saint Paul, along West 7th Street, north of Highway 36 at I-35W, north of I-94 at Highway 280, and west of I-35E at Highway 36.

As noted previously in Table 1, multifamily housing in areas, such as downtown Saint Paul, also captures potentially *less* vulnerable populations because of nicer building structures with access to air conditioning, proper ventilation, etc. Therefore, in some cases, vulnerability may be overestimated in specific areas.

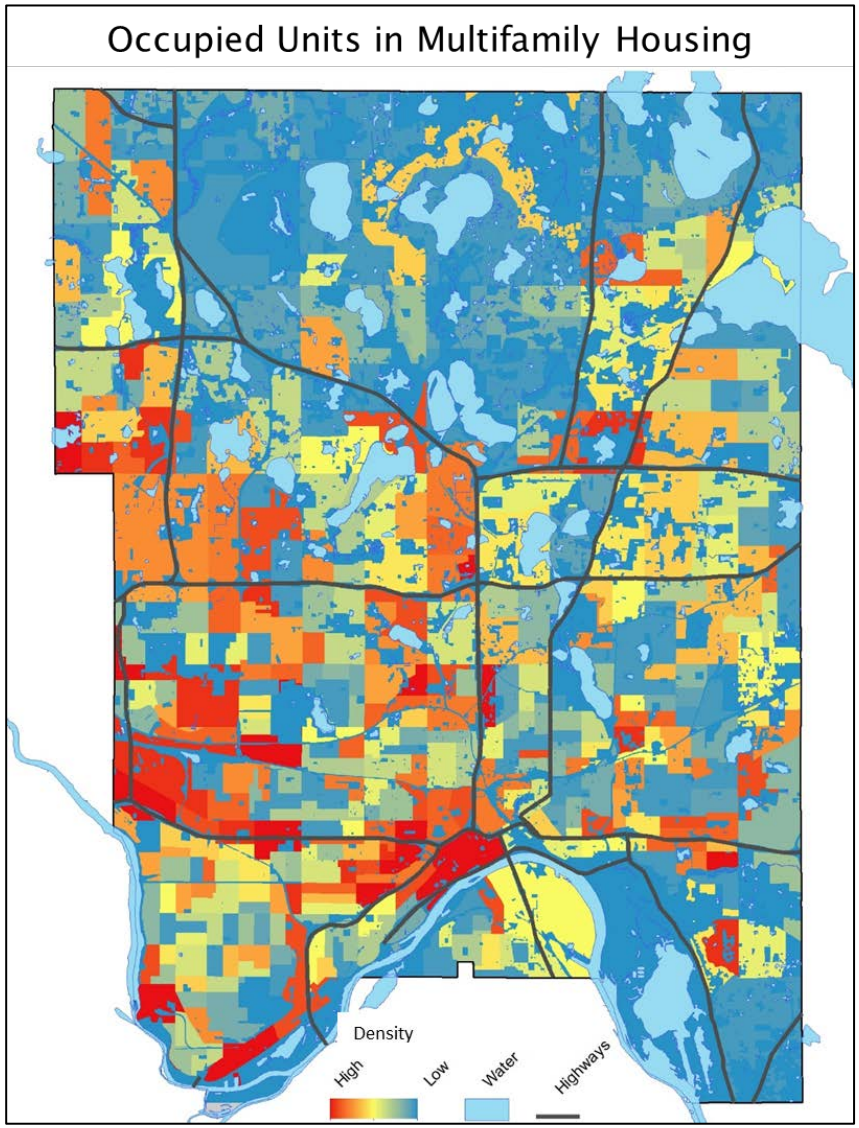


Figure 6. Occupied units in multifamily housing (> 4 units) (normalized data). Higher concentrations are located in downtown Saint Paul, along West 7th Street, north of Highway 36 at 35W, north of I-94 at Highway 280, and west of I-35E at Highway 36.

Extreme Heat Full Impact Assessment

The extreme heat full impact assessment included both environmental risk factors for extreme heat in Ramsey County as well as the outlined individual vulnerabilities. The full impact assessment is shown in **Figure 7**. Areas with warmer colors (red and orange) indicate regions with more environmental risk factors AND where certain populations are more vulnerable to extreme heat. As a result, people living in these areas may suffer the most from extreme heat. In other words, extreme heat will likely have a stronger relative impact at these locations compared to the rest of Ramsey County.

Strongly impacted areas include in and surrounding downtown Saint Paul, north and slightly south of I-94, northward along I-35E, and in isolated pockets in the suburbs.

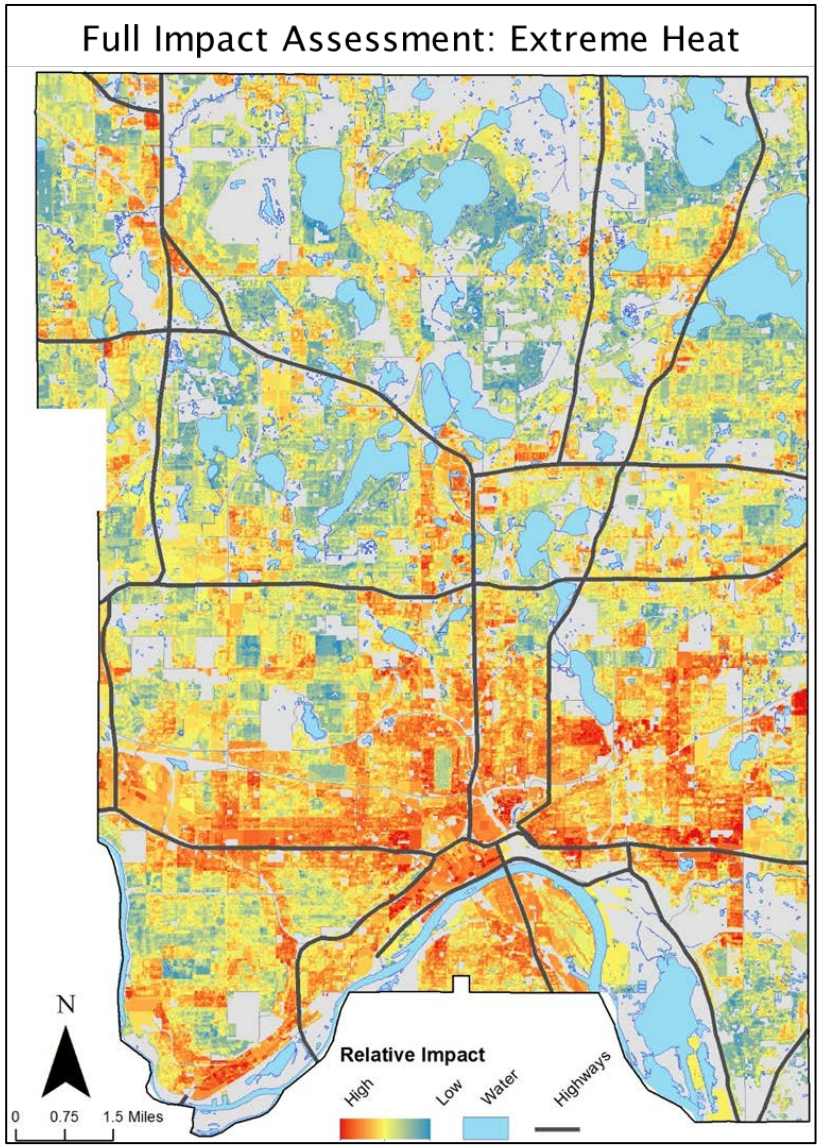


Figure 7. Extreme heat full impact assessment (normalized data). Warmer colors indicate regions with more environmental risk factors & more individual vulnerability. Note strongly impacted areas, such as downtown Saint Paul, north & slightly south of I-94, along I-35E, along West 7th Street, & in isolated suburban pockets.

Key Takeaways: ***Extreme Heat in Ramsey County***

Climate Hazard	Environmental Risk Factors	Indicators of Vulnerability	Full Impact Assessment
Extreme Heat ▪ The number of extreme heat events has increased in MN. ▪ Extreme heat can cause a variety of heat-related illnesses. ▪ The urban heat island effect is apparent in Saint Paul.	▪ Heat island factors o Impervious surfaces o Biomass o Land/water cover ▪ Distance to cooling centers ▪ Distance to emergency medical services ▪ Distance to hospitals ▪ Reduced air quality	**Base Vulnerabilities:** ▪ Occupied housing units without phone access ▪ Occupied housing units without vehicle access ▪ Occupied housing units in multifamily housing ▪ Occupied mobile homes ▪ Population 25+ without a high school diploma ▪ Population 16+ who walk or bike to work ▪ Population 65+ & living alone ▪ Population 5+ who speak English < "very well" ▪ Population that works outdoors ▪ Population living below 200% of poverty threshold ▪ Population under 5 years ▪ Population 85+ **Hazard-Specific Vulnerabilities:** ▪ Age-adjusted rates of COPD-related hospitalizations ▪ Age-adjusted rates of asthma-related hospitalizations	Strongly impacted areas include: ▪ Downtown Saint Paul ▪ Areas north & slightly south of I-94 ▪ Areas around I-35E ▪ Portions of Saint Paul's East Side and West Side ▪ Areas along West 7th Street ▪ Isolated suburban pockets

Conclusion: All of Ramsey County is vulnerable to extreme heat, but those most vulnerable to negative health impacts are generally located in areas near downtown Saint Paul, along I-94, around I-35E, and in isolated pockets throughout the county. Extreme heat can affect anyone. However, it is important to pay special attention to populations, such as the elderly, young children, those with pre-existing diseases, and those in poverty.

Limitations: Data regarding actual temperatures throughout the county were not incorporated in this assessment. The urban heat island effect map simply indicates where the effect will likely occur due to other environmental factors.

AIR QUALITY

Background

The three main climate trends of concern in Minnesota (i.e., increase in average temperatures, increase in days with high dew points, and changes in precipitation) can directly and indirectly affect the air quality in Ramsey County.

Three factors of poor air quality negatively impact human health in Ramsey County:

- Increased levels of ground-level ozone, especially in the summer.
- Increased levels of $PM_{2.5}$ (particulate matter 2.5 microns in diameter or less)
- Increased levels of pollens and allergens, due to a longer growing season (SPRCPH, 2014b).

Ozone

Although atmospheric ozone protects humans from harmful ultraviolet radiation, ground-level ozone is considered an air pollutant. Chemical byproducts of fossil fuel combustion (from automobiles, for instance) react with oxygen in the presence of sunlight and heat to produce ground-level ozone. Therefore, ozone production tends to be a problem primarily during the summer months (MDH, 2014a).

Ozone negatively affects respiratory and cardiovascular health, causing lung inflammation or irritation, difficulty breathing, and exacerbation of COPD, asthma, and chronic lung diseases (MDH, 2014a).

$PM_{2.5}$

$PM_{2.5}$ is produced directly from fossil fuel combustion as well as indirectly from atmospheric reactions of precursor emissions, such as volatile organic compounds (VOCs), sulfur dioxide, nitrogen oxides, and gaseous ammonia (MDH, 2014a). Acute exposure to $PM_{2.5}$ exacerbates respiratory and cardiovascular illnesses; chronic exposure can lead to prolonged cough, bronchitis, chest illness, and an increased risk of developing respiratory conditions, such as COPD (MDH, 2014a).

Pollen & Allergens

Although pollen and other allergens are not considered air pollutants like ozone and $PM_{2.5}$, an overabundance of allergens can also affect respiratory health. Increasing average temperatures in Minnesota may lead to longer plant growing seasons and a greater release of pollen. In addition, changes in precipitation could amplify mold growth and/or increase airborne dust. As a result, Ramsey County residents would be exposed to extended and more intense allergy seasons (SPRCPH, 2014b).

Overall Air Quality

Together, increased levels of ozone, $PM_{2.5}$, and allergens lead to an overall poorer air quality in Ramsey County. Generally, Minnesota has good air quality, which has improved over the past two decades. However, current levels of pollutants still contribute to health impacts (MPCA, 2015a). While, it should be noted that ozone and $PM_{2.5}$ levels are generally low in Minnesota, higher concentrations of these pollutants are found in the metro area, largely due to increased concentrations of people, transportation systems, and industrial processes.

A changing climate and/or stricter air quality standards could rapidly change the air quality status quo in the metro area. For instance, increasing summer temperatures may catalyze ozone production and stimulate VOC emissions from various sources. In addition, increasing temperatures could indirectly increase $PM_{2.5}$ due to amplified energy demands for air conditioning and other needs (MDH, 2014a).

Proactively approaching the potential for poor air quality in the midst of a changing climate is an important adaptation step in Ramsey County.

Environmental Risk Factors for Poor Air Quality

Three environmental risk factors were used to describe the potential severity of poor air quality in Ramsey County. These factors included:

- Average concentration of ozone
- Average concentration of $PM_{2.5}$
- Proximity to major roadways

The latter variable was used because air quality can be especially poor near major roadways due to vehicle use (MPCA, 2015a). Also, it should be noted that data representing pollen and other allergens were not included in this assessment.

Figure 8 depicts average 8-hour ozone concentrations (ppb) from May through September, 2008 in the county. This time period was selected because higher temperatures and abundant sunlight during the warmer months stimulate the most ozone production. Note an increasing risk of exposure from southwest to northeast Ramsey County. This is to be expected. Ozone reacts with higher levels of nitric oxide (a byproduct of fossil fuel combustion) in urban areas to form oxygen and nitrogen dioxide (NO_2). This creates a "titration effect", in which regions outside the city experience higher levels of ground-level ozone due to lower levels of ozone-depleting nitric oxide (MDH, 2014a). Finally, it should be noted that the concentration of ozone ranges from 40.3 ppb to 41.9 ppb. Although this is a statistically significant gradient, the variations throughout the county are relatively small (MPCA, 2015b).

Figure 9 demonstrates average $PM_{2.5}$ concentrations ($\mu g/m^3$) from 2008. Unlike ozone, note a decreasing risk of exposure from southwest to northeast Ramsey County. It should be noted that the concentration of $PM_{2.5}$ ranges from 10.4 $\mu g/m^3$ to 11.6 $\mu g/m^3$. Therefore, despite the stark color scheme in Figure 9, the county as a whole is exposed to a relatively uniform concentration of $PM_{2.5}$, with the southwest experiencing only a slightly higher concentration (MPCA, 2015b).

Together, ozone concentration, $PM_{2.5}$ concentration, and proximity to major roadways created a composite map of overall environmental risk, shown in **Figure 10**. In general, higher risk is demonstrated in south Ramsey County, especially in and surrounding downtown Saint Paul. Northwest Ramsey County is at a lower risk. Finally, note the universal trend of higher risk due to close proximity to roads.

It should be noted that because of the GIS methods used in this assessment, the trend for ozone and $PM_{2.5}$ "cancel out" in some areas in Figure 10, creating a false representation of lower risk. In reality, while some areas are subject to higher levels of ozone, others are subject to higher levels of $PM_{2.5}$. Therefore, as a whole, most of Ramsey County contains an environmental risk factor for poor air quality, though the type of air pollution varies.

A Note on Air Quality Data

Data used for ozone and $PM_{2.5}$ are based on estimates using the CDC and EPA's Downscaler model. This model blends actual measurements from the EPA's Air Quality System (AQS) monitors with modeled air quality data from the EPA's Community Multiscale Air Quality (CMAQ) model. In other words, a combination of measured and modelled data is used in downscaler data (CDC, 2013a). While monitoring data are considered the "gold standard" for determining air quality in reference to the National Ambient Air Quality Standards (NAAQS), these data are limited because monitors usually take measurements once every three days; furthermore, ozone monitors usually only operate between May and October (CDC, 2013b). Therefore, downscaler data are useful in determining air quality in regions without air quality monitors as well as to fill in the time gaps when monitors do not take measurements (CDC, 2013b). Downscaler data allowed SPRCPH to spatially demonstrate ozone and $PM_{2.5}$ at the sub-county level.

These data were also used by the Minnesota Pollution Control Agency (MPCA) and MDH in their report, *Life & Breath: How Air Pollution Affects Public Health in the Twin Cities* (MPCA, 2015b).

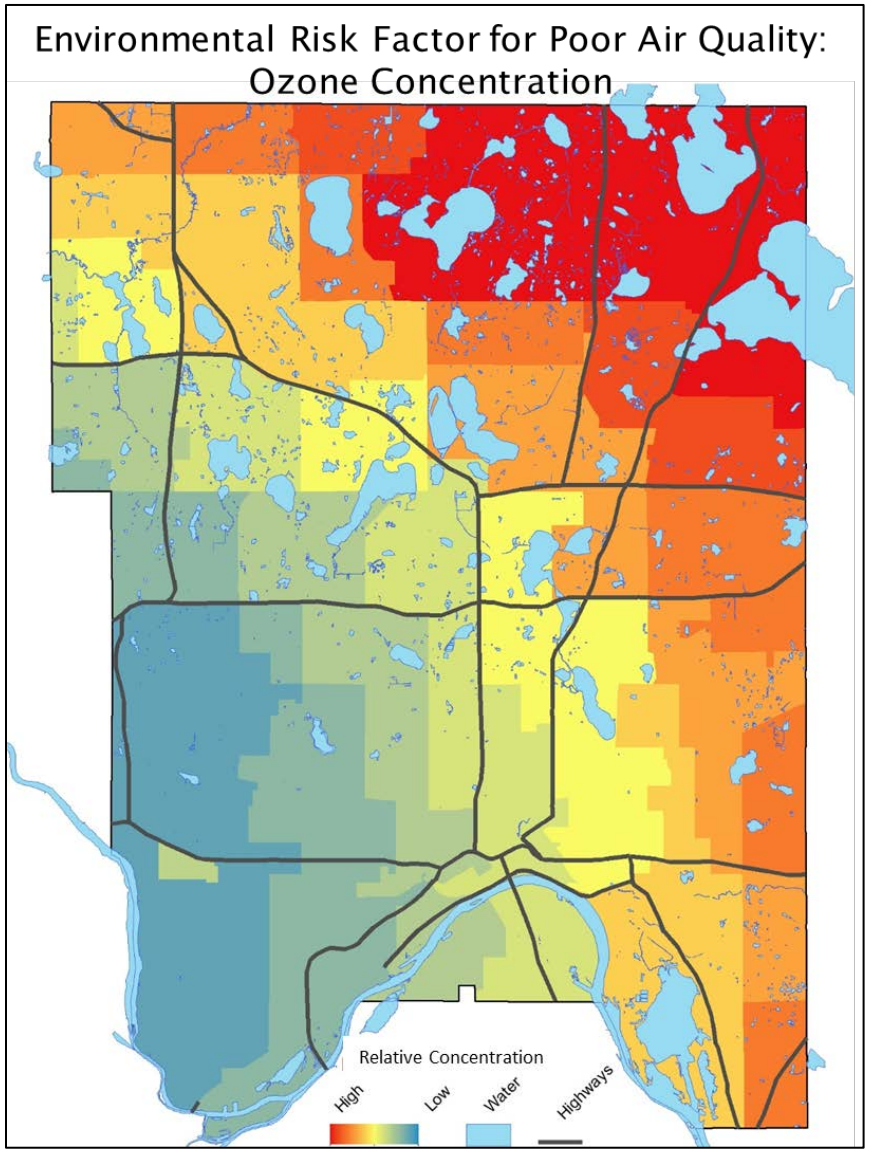


Figure 8. Average 8-hour max ozone concentrations (ppb) from May through September, 2008. Note the northeast trend of increasing concentrations, ranging from 40.3 ppb to 41.9 ppb. Although this is a statistically significant gradient, the variations throughout the county are still relatively small.

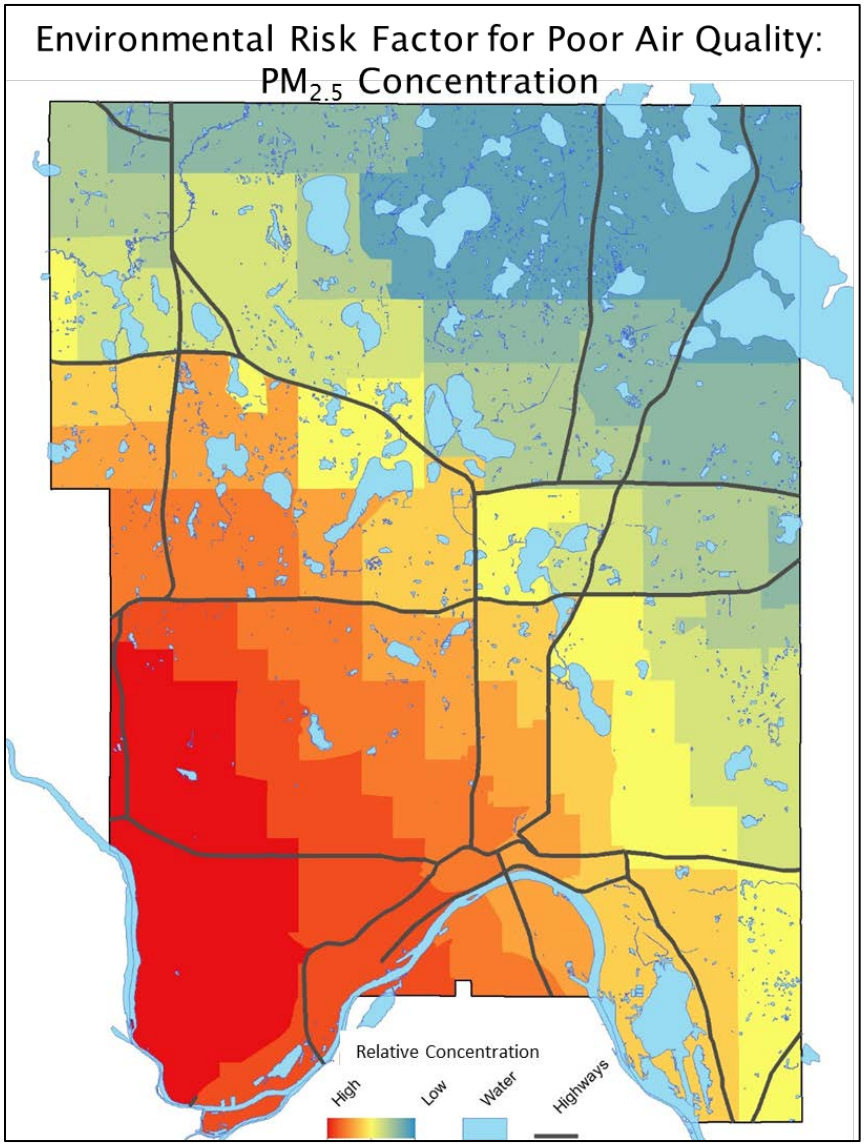


Figure 9. Yearly average concentration of $PM_{2.5}$ ($\mu g/m^3$) in 2008. Note the southwest trend of increasing concentrations. The difference in the range of values is very small (10.4 $\mu g/m^3$ to 11.6 $\mu g/m^3$). Therefore, the county as a whole is exposed to a relatively uniform concentration of $PM_{2.5}$, with the southwest experiencing only a slightly higher concentration.

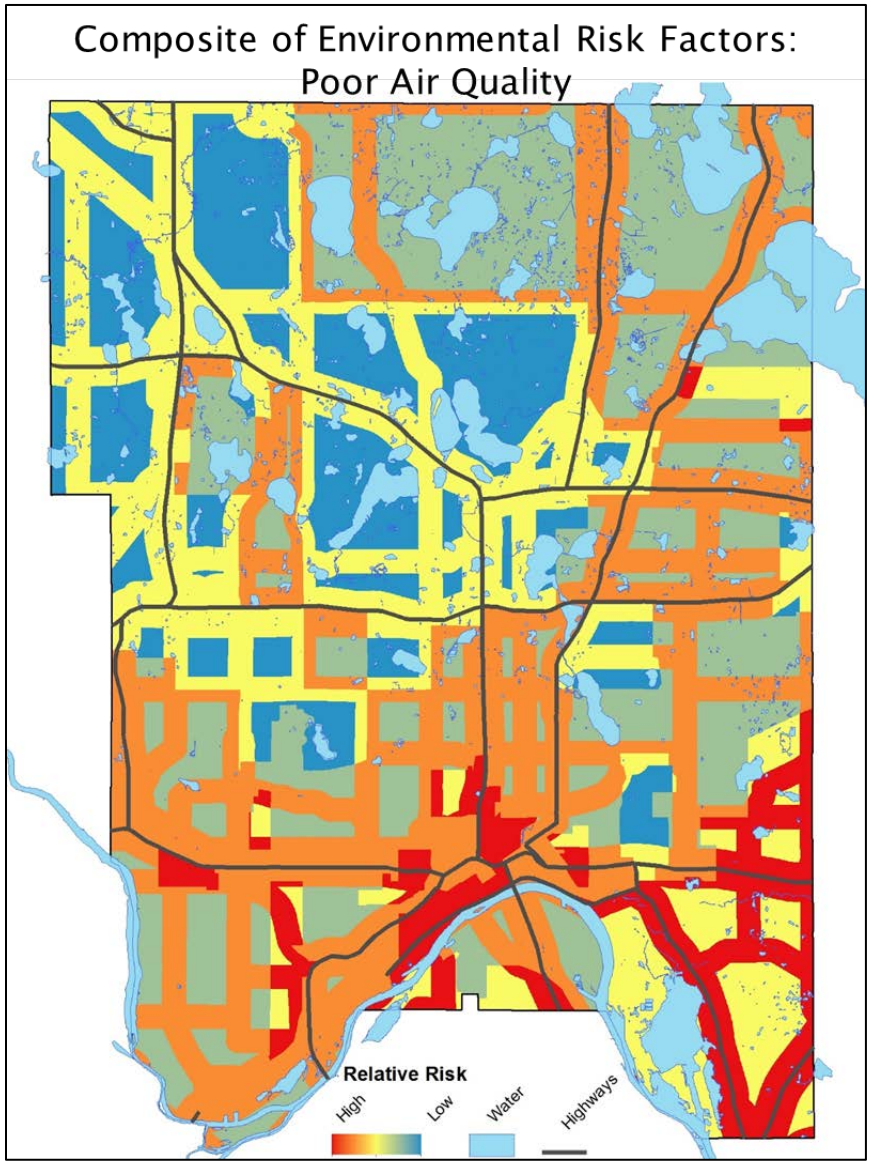


Figure 10. Composite of risk factors for poor air quality in Ramsey County, represented by ozone & $PM_{2.5}$ concentrations & proximity to major roadways. Note areas of higher risk, including downtown & surrounding Saint Paul & along several major roadways throughout the county.

Populations Vulnerable to Poor Air Quality

The risk for poor air quality is an unfortunate side effect of warming average temperatures and irregular precipitation coupled with burning fossil fuels for transportation, home use, and industrial use. According to MDH, populations vulnerable to poor air quality include the following:

Young children; older adults; outdoor workers; outdoor athletes; and those with existing cardiovascular or respiratory diseases, such as asthma, COPD, and lung cancer (MDH, 2014a).

Furthermore, those with mild to severe allergies to pollen, mold, or other airborne allergens are also vulnerable to poor air quality because ozone and $PM_{2.5}$ also can aggravate the allergic response (MDH, 2014a).

For this assessment, SPRCPH chose several indicators of vulnerability specific to poor air quality. These indicators were added to base vulnerability and are listed as follows:

- **Base Vulnerabilities:**
  - Occupied housing units without phone access
  - Occupied housing units without vehicle access
  - Occupied housing units in multifamily housing
  - Occupied mobile homes
  - Population 25+ without a high school diploma
  - Population 16+ who walk or bike to work
  - Population 65+ & living alone
  - Population 5+ who speak English < “very well”
  - Population that works outdoors
  - Population living below 200% of poverty threshold
  - Population under 5 years
  - Population 85+
- **Additional Hazard-Specific Vulnerabilities:**
  - Age-adjusted rates of COPD-related hospitalizations
  - Age-adjusted rates of asthma-related hospitalizations

Several vulnerabilities are outlined in the following sub-sections.

Working Outdoors

Those who work outdoors, such as in construction or agriculture, are vulnerable to extreme weather, likes extreme heat, extreme cold, and poor air quality. Isolated days of poor air quality put outdoor workers at risk of acute exposure. Repeated exposure to poor air quality increases the risk of chronic cardiovascular or respiratory illnesses. **Figure 11** demonstrates the distribution of outdoor workers in Ramsey County. One limitation of these data is that they indicate household location of outdoor workers, not the location of employment. However, household location may be helpful in targeting general areas that may benefit from preventive education regarding the health risks of poor air quality when working outdoors.

Asthma & COPD

Figures 12 & 13 demonstrate the age-adjusted rates of asthma-related and COPD-related hospitalizations (respectively) from 2007-2011. Age adjustment is a technique that standardizes age distributions among regions so that they are comparable without bias toward certain age groups. The rate for each age group is adjusted to the age distribution of a "standard population". The standard population used for these datasets are the U.S. 2000 Standard population (MDH, 2016).

Higher rates of asthma-related hospitalizations are largely shown in downtown Saint Paul, south Maplewood, near Lake Como, along I-94, and in northwest Ramsey County, such as Mounds View, New Brighton, and Arden Hills. Higher rates of COPD-related hospitalizations are demonstrated between I-35E and Highway 61, south Maplewood, Highland Park, and west of I-35E at North Oaks and Vadnais Heights.

Other vulnerabilities to poor air quality to note are 65+ and living alone (**Figure 4**, page 20) and those living in poverty (**Figure 5**, page 20).

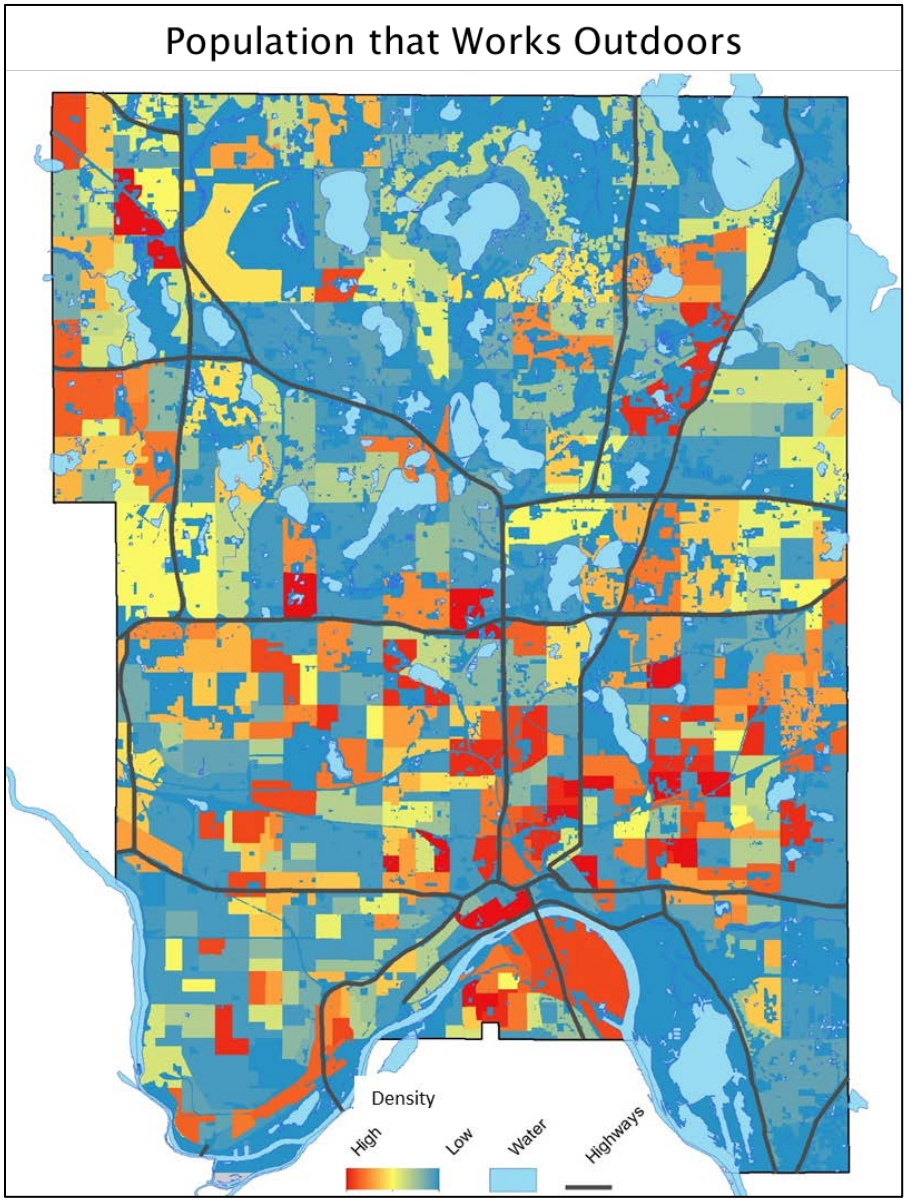


Figure 11. Ramsey County residents who work outdoors (normalized data). Note: data indicate home addresses of outdoor workers, not necessarily locations of employment.

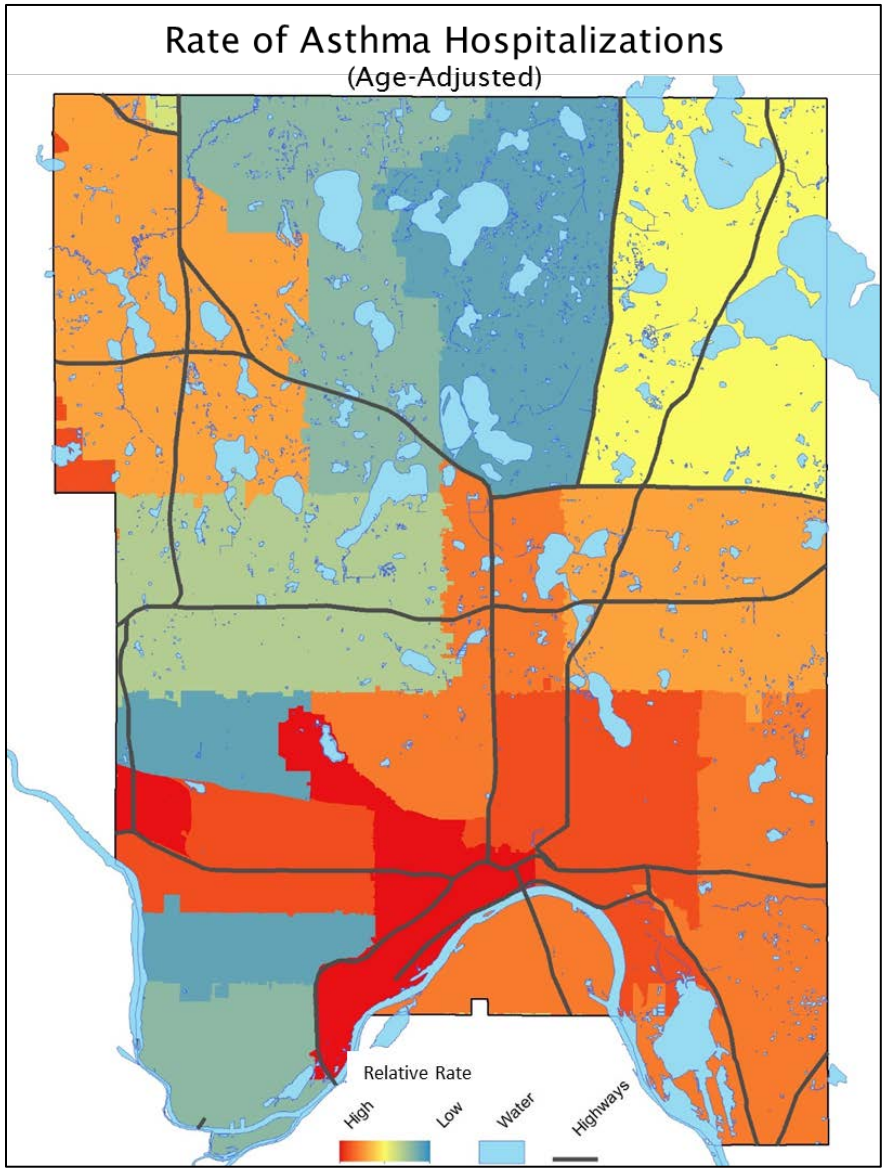


Figure 12. Age-adjusted rates of asthma-related hospitalizations from 2007-2011 based on zip code. High rates are shown in downtown Saint Paul, south Maplewood, near Lake Como, along I-94, & in northwest Ramsey County.

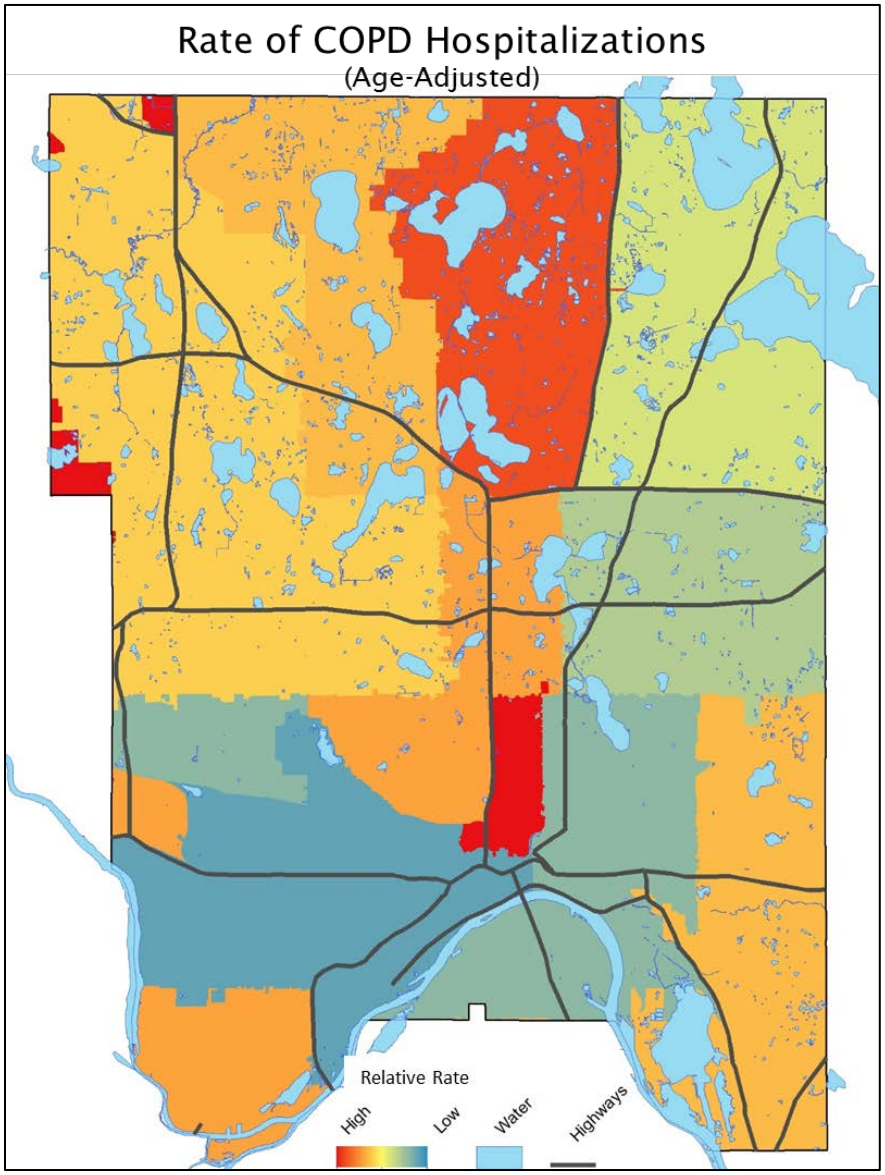


Figure 13. Age-adjusted rates of COPD-related hospitalizations from 2007-2011 based on zip code. High rates are shown between I-35E & Highway 61, south Maplewood, Highland Park, & west of I-35E at North Oaks & Vadnais Heights.

Poor Air Quality Full Impact Assessment

The full impact assessment for poor air quality included both environmental risk factors for poor air quality in Ramsey County as well as the outlined individual vulnerabilities. The full impact assessment is shown in **Figure 14**. Areas with warmer colors (red and orange) indicate regions where poor air quality will likely have a stronger impact relative to the rest of the county.

Strongly impacted areas include in and around downtown Saint Paul, along I-94, between I-35E and Highway 61, Saint Paul's East Side and West Side, and south Maplewood.

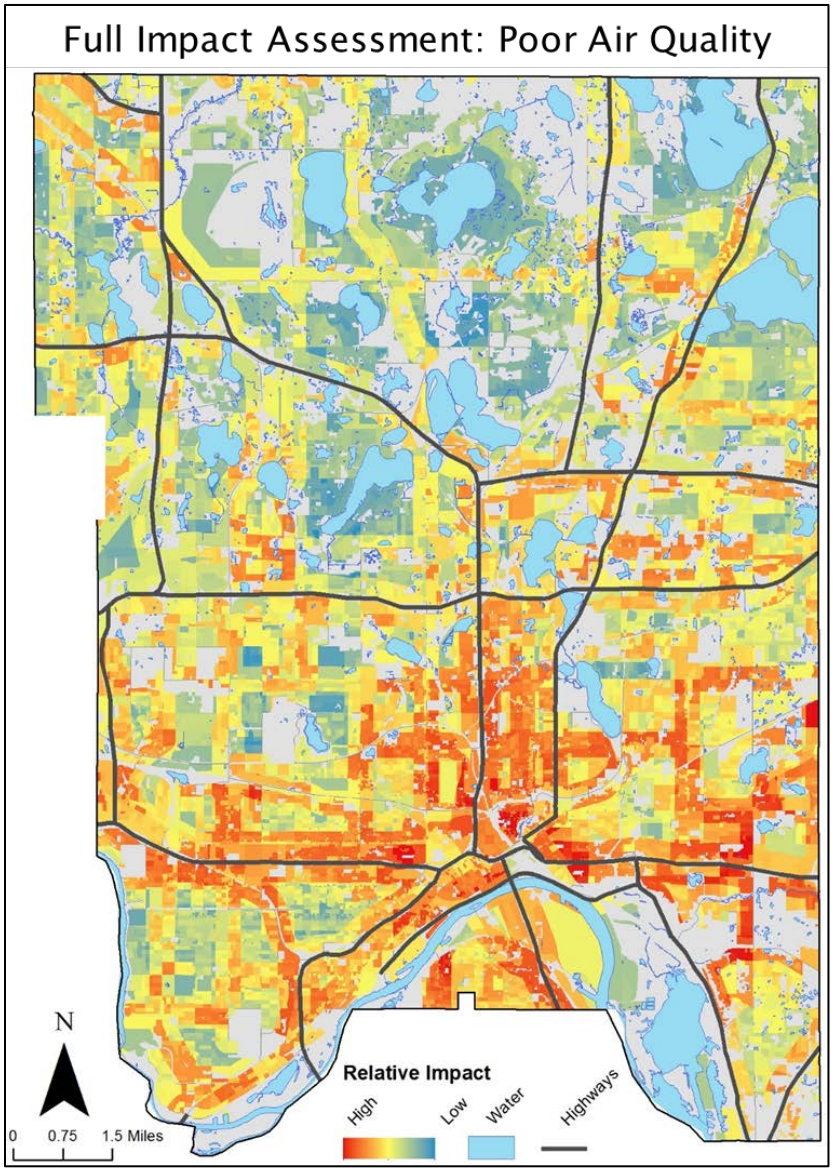


Figure 14. Full impact assessment for poor air quality (normalized data). Warmer colors indicate regions with more environmental risk factors & more individual vulnerability. Strongly impacted areas include in & around downtown Saint Paul, along I-94, & between I-35E & Highway 61.

Key Takeaways: ***Poor Air Quality in Ramsey County***

Climate Hazard	Environmental Risk Factors	Indicators of Vulnerability	Full Impact Assessment
Poor Air Quality ▪ A warming climate and changes in precipitation patterns increase levels of ground-level ozone, $PM_{2.5}$, and outdoor allergens. ▪ These pollutants pose acute and chronic threats to cardiovascular and respiratory health. ▪ Although the number of poor air quality days is relatively low in the metro area, this status quo may change significantly due to small fluctuations in the climate.	▪ Concentration of ozone ▪ Concentration of $PM_{2.5}$ ▪ Proximity to major roadways	**Base Vulnerabilities:** ▪ Occupied housing units without phone access ▪ Occupied housing units without vehicle access ▪ Occupied housing units in multifamily housing ▪ Occupied mobile homes ▪ Population 25+ without a high school diploma ▪ Population 16+ who walk or bike to work ▪ Population 65+ & living alone ▪ Population 5+ who speak English < "very well" ▪ Population that works outdoors ▪ Population living below 200% of poverty threshold ▪ Population under 5 years ▪ Population 85+ **Hazard-Specific Vulnerabilities:** ▪ Age-adjusted rates of COPD-related hospitalizations ▪ Age-adjusted rates of asthma-related hospitalizations	Strongly impacted areas include: ▪ In & around downtown Saint Paul ▪ Areas along I-94 ▪ Areas between I-35E & Highway 61 ▪ Saint Paul's East Side & West Side ▪ South Maplewood

Conclusion: The impact of poor air quality follows a pattern roughly similar to that of extreme heat. Most of Ramsey County is vulnerable to health effects associated with poor air quality, with those most vulnerable located near major roadways. Populations, such as the young, elderly, and those with respiratory difficulties, are most vulnerable to poor air quality.

Limitations: The use of downscaler data does not represent actual sub-county concentrations of ozone and $PM_{2.5}$. The distribution of ozone and $PM_{2.5}$ somewhat "cancel out", creating a slightly misleading environmental risk factor composite map. Data representing pollen and other allergens were not included in this assessment.

CHANGES IN PRECIPITATION

Background

A changing climate in Minnesota will likely bring about changes in the characteristics of precipitation. This could lead to more extreme precipitation events, such as heavy rainfall, followed by longer periods of drought (MDH, 2015a). The risk of flash flooding as a result of extreme precipitation is important to consider. Therefore, both drought and flash flooding due to the shift in precipitation characteristics are addressed in this section.

Flooding

General vs. Flash Flooding

There are two types of flooding, differentiated by seasonality. General flooding occurs during the spring as a result of melting snow and spring rain. It usually occurs within floodplains near large rivers and lakes. Conversely, flash flooding occurs in the summer or early fall due to heavy rains. By definition, a flash flood is characterized by a flood that results during or after a rain event of six or more inches within a 24-hour period, and the greater geographic area (in square miles) reports four or more inches of rain (Seeley, 2015). Both types of flooding are influenced by topography, watershed capacity, and land use characteristics (MDH, 2014a).

From 1950 to 2015, 15 flash floods were reported in Ramsey County, versus six floods during the same time period (NOAA, 2015). Because a changing Minnesota climate will bring about more extreme rain events, flash floods are expected to increase accordingly (MDH, 2015a). Unfortunately, flash floods are much less predictable than springtime flooding and, therefore, may pose a higher risk to individuals due to a lack of time to prepare or evacuate.

Although general flooding can bring about significant environmental effects, the acute nature of flash floods puts Ramsey County residents at a higher public health risk due to their unpredictability. Therefore, SPRCPH chose to emphasize flash floods in this section with the objective of providing the information needed to plan and prepare for future flash flooding events.

Environmental Risk Factors for Flooding

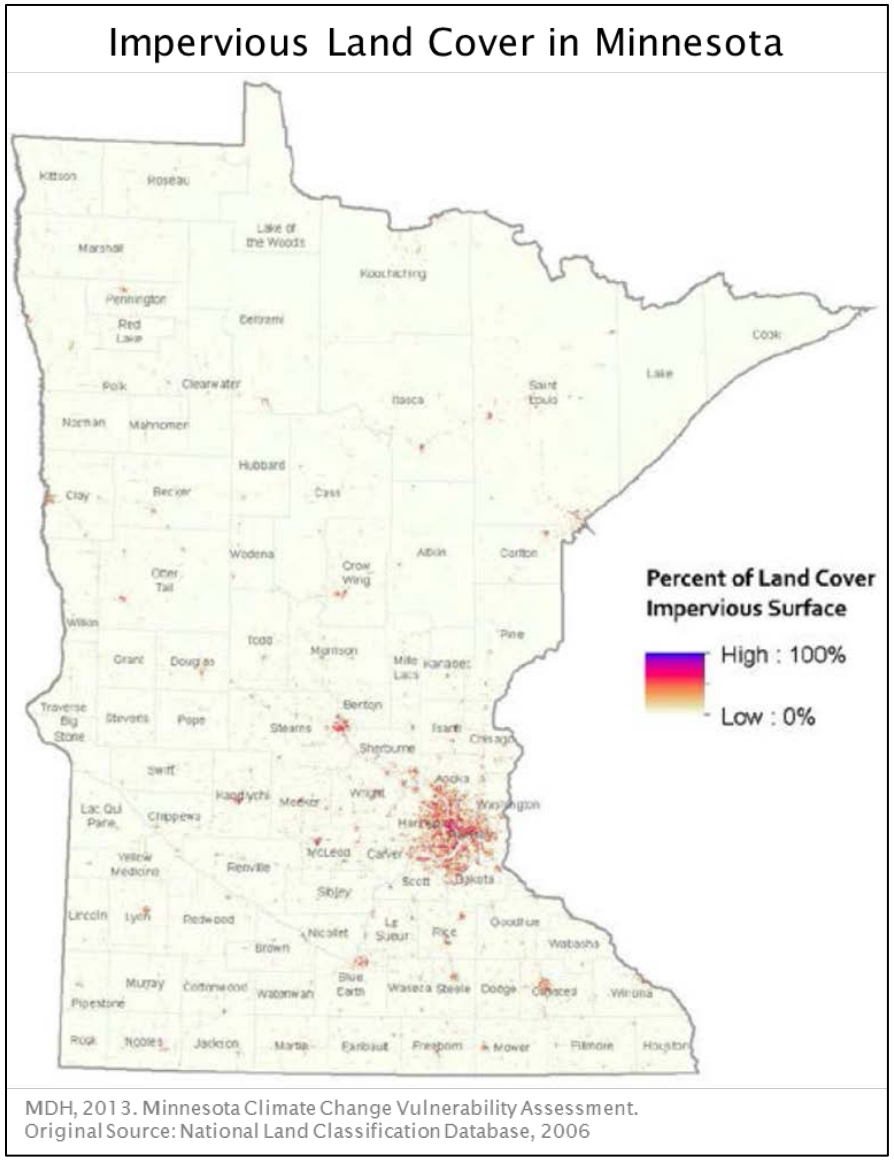
Although flash flooding is unpredictable, certain environmental characteristics increase the risk of flash flooding. For instance, impervious surfaces, such as roads, increase the risk for flash flooding by hindering water absorption into the ground (MDH, 2014a). Although impervious surface data were not available at the sub-county level, state level data were available. (Sub-county data will be available in the near future, and subsequent vulnerability assessments will include that analysis.) **Figure 15** demonstrates the distribution of impervious surfaces throughout Minnesota. As is expected, the metro area contains a higher degree of impervious surfaces compared to the majority of the state, indicating an increased risk for flash flooding in the metro area (MDH, 2014a).

Flash flooding is also influenced by topography. For instance, low-lying riparian areas (those that are adjacent to waterbodies) are more prone to flash flooding (MDH, 2015a). Areas adjacent to steep hills or at lower elevations are also at risk of flash flooding.

Furthermore, soil characteristics affect water absorption into the ground. Saturated soil, frozen soil, or extremely dry soil prevent water absorption, increasing water runoff (MDH, 2014a). Clay soil does not absorb water as readily as sandy soil due to its higher density (NRCCA, 2010).

Finally, the depth of the water table as well as stormwater sewer capacity can increase the risk of flash flooding. The water table refers to the point dividing saturated and unsaturated zones underneath the land surface. The water table is relatively close to the land surface (a few tens of feet) throughout most of Minnesota (DNR, 2016b). Stormwater sewers collect runoff during precipitation events. Overwhelmed storm water systems or even overwhelmed or blocked storm drains can increase the risk for flash flooding (MDH, 2015a).

Flash flooding is a possibility wherever heavy rains fall in a short amount of time. However, a thorough understanding of the factors that increase flash flood risk are helpful to prioritize high-risk regions. For the purposes of this report, an adequate environmental flash flood spatial analysis was not conducted because it was outside the scope of this initial assessment. SPRCPH will be able to include a spatial flash flood assessment as data become available.



MDH, 2013. Minnesota Climate Change Vulnerability Assessment.
Original Source: National Land Classification Database, 2006

Figure 15. The metro area has a higher degree of impervious surfaces compared to the majority of Minnesota.

Effect of Flash Floods on Human Health

Flash floods can trigger a plethora of direct and indirect human health effects. Flash flooding directly poses significant acute health threats, including drowning, injury, electrocution, and exposure to hazardous chemicals and sewage. Chronic health threats during the recovery phase of a flash flood include exposure to mold and mildew which may exacerbate respiratory illnesses. Individuals may be exposed to waterborne diseases, such as *Cryptosporidium*, *E. coli* O157, *Legionella*, and norovirus. Furthermore, exposure to and proper disposal of water-damaged debris, especially chemical waste, can pose additional health risks. Finally, mental stress can also be a direct health threat following a flash flood (MDH, 2015a).

There are also several indirect health effects of flash flooding. Mental and physical stress may be triggered by economic loss due to flood damage, strained essential services, or high health care bills due to injury (MDH, 2015a). Business closures and lay-offs can also instigate stress and economic loss (MDH, 2014a). Disruptions in social and economic services as well as damaged infrastructure, such as roads, railways, water systems, and sewer systems may affect health. Finally, compromised food and water quality and supply can also affect human health.

The resultant direct and indirect health effects are numerous after a flash flood and should be acknowledged in the context of planning emergency services to those most vulnerable and affected by this climate hazard.

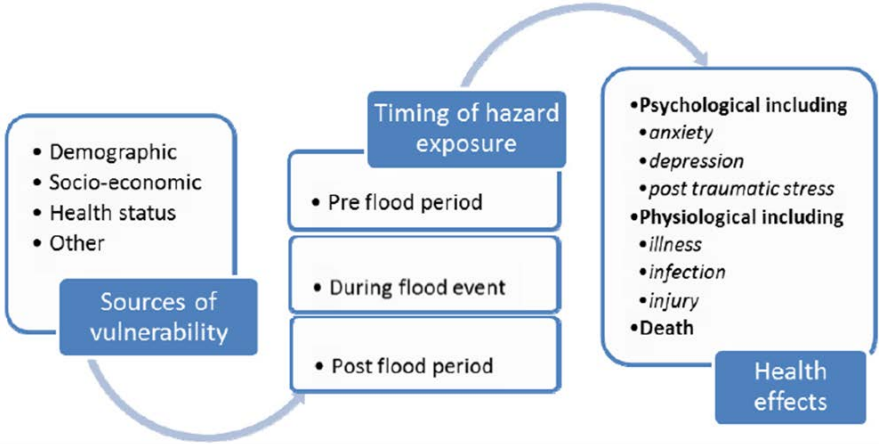
Populations Vulnerable to Flooding

Several populations are vulnerable to flooding. According to MDH, these populations include the following:

Older adults, especially living alone; those with physical or mental illnesses that hinder the ability for self-care; those under economic strain; those living in substandard housing or mobile homes; those without vehicle access; those with limited English proficiency; those who rely on private wells; and those with respiratory illnesses who may be susceptible to mold following flooding (MDH, 2014a).

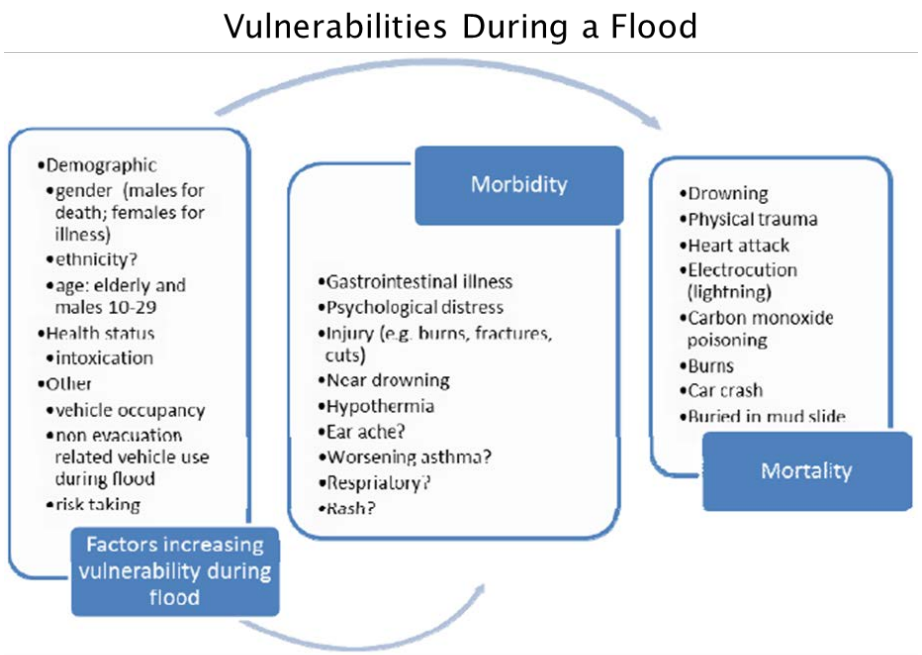
In their meta-analysis, Lowe and colleagues describe vulnerability according to the timing of a flood (e.g., before, during, and after a flood), as is represented by

Figure 16 (2013). These vulnerabilities are complex and lead to complex health outcomes. For instance, vulnerabilities during and after a flood are demonstrated in **Figures 17** and **18**. Note the similarities and differences among vulnerable characteristics before and after a flood. In particular, many more vulnerabilities are relevant after a flood versus when a flood is actually occurring.



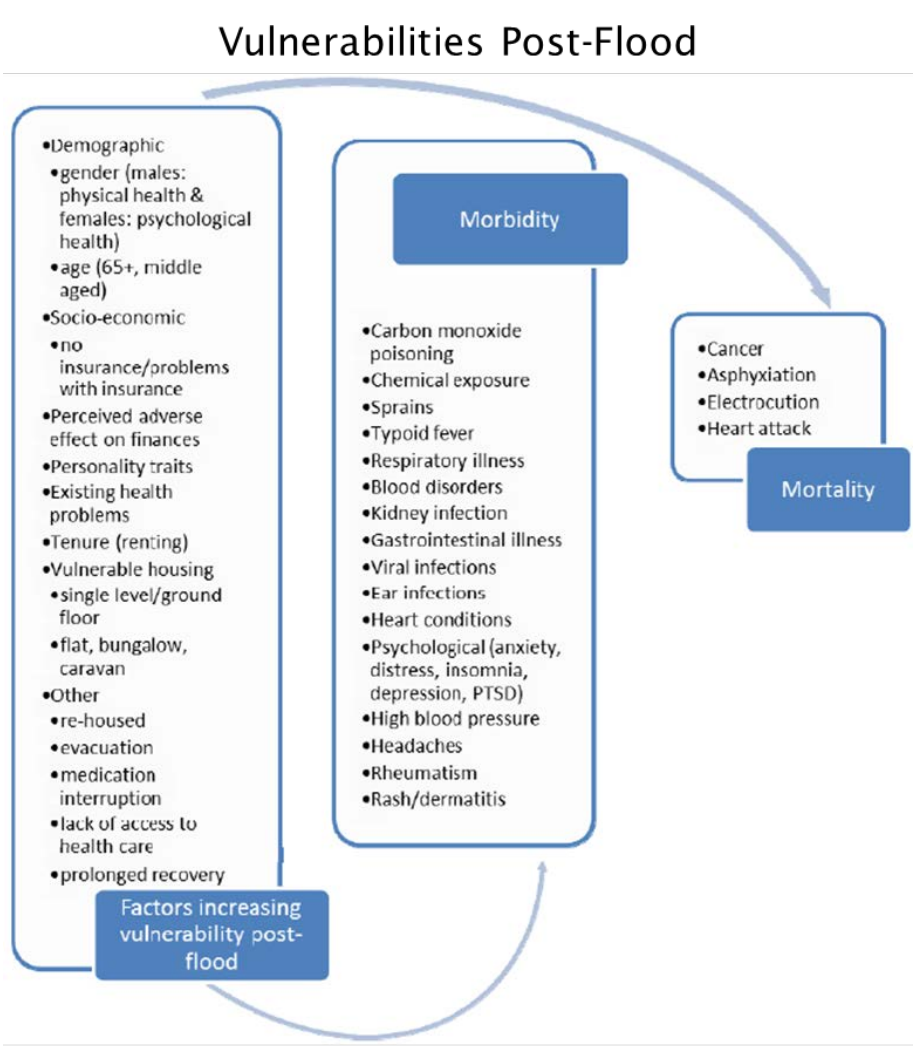
Lowe, D., Ebi, K. L., & Forsberg, B. (2013). Factors increasing vulnerability to health effects before, during, & after floods. Int J of Environmental Res. Public Health. 10(12): 7015-7067.

Figure 16. Negative health outcomes are influenced by vulnerabilities before, during, and after a flood.



Lowe, D., Ebi, K. L., & Forsberg, B. (2013). Factors increasing vulnerability to health effects before, during, & after floods. Int J of Environmental Res. Public Health. 10(12): 7015-7067.

Figure 17. Morbidity & mortality during a flood are affected by several vulnerabilities. Question marks indicate some degree of uncertainty due to statistics, study design, and/or written clarity of studies included in the meta-analysis.



Lowe, D., Ebi, K. L., & Forsberg, B. (2013). Factors increasing vulnerability to health effects before, during, & after floods. Int J of Environmental Res. Public Health. 10(12): 7015-7067.

Figure 18. More vulnerabilities affect health outcomes after a flood than during the flood itself.

As Lowe and colleagues highlight in their meta-analysis, it is very important to acknowledge the complexities of vulnerability in the context of flooding when planning emergency response services so that the appropriate individuals receive aid at the appropriate times.

Although SPRCPH did not conduct a full impact assessment for flash flooding, some vulnerabilities are important to note spatially nevertheless. These include those with limited English proficiency, those 65+ and living alone, and those in poverty.

Limited English Proficiency

In the event of a flash flood, it is essential to communicate effectively and efficiently, especially if individuals need to evacuate or protect themselves. Because Ramsey County has rather large immigrant and refugee populations, it is important to confirm messages are relayed and understood in a timely manner in the midst of possible language barriers (SPRCPH, 2013). The distribution of those who self-report as speaking English less than "very well" is shown in **Figure 19**. In general, higher concentrations of those with limited English proficiency are located north of I-94 at I-35E & Highway 61, Saint Paul's East Side & West Side, south Highland Park, & in Maplewood & Little Canada.

65+ & Living Alone and Poverty

Additional indicators of vulnerability to flooding that are important to note include those 65+ and living alone (**Figure 4**, page 20) and those in poverty (**Figure 5**, page 20). Older adults who are living alone may be especially vulnerable due to potential isolation as well as lack of assistance to evacuate or recover from a flood (MDH, 2014a). In addition, individuals or families with lower incomes are vulnerable due to the additional cost of evacuating, reestablishing, and recovering from a flood (MDH, 2014a).

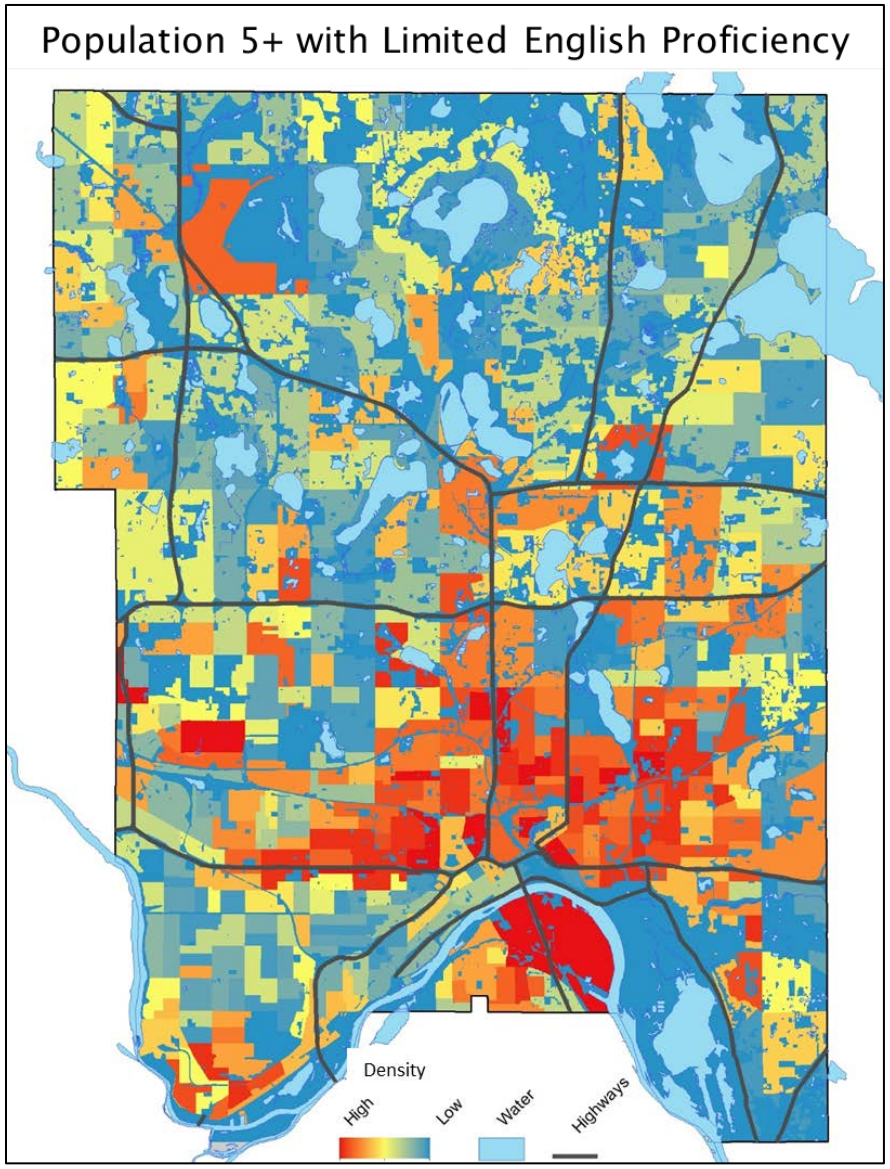
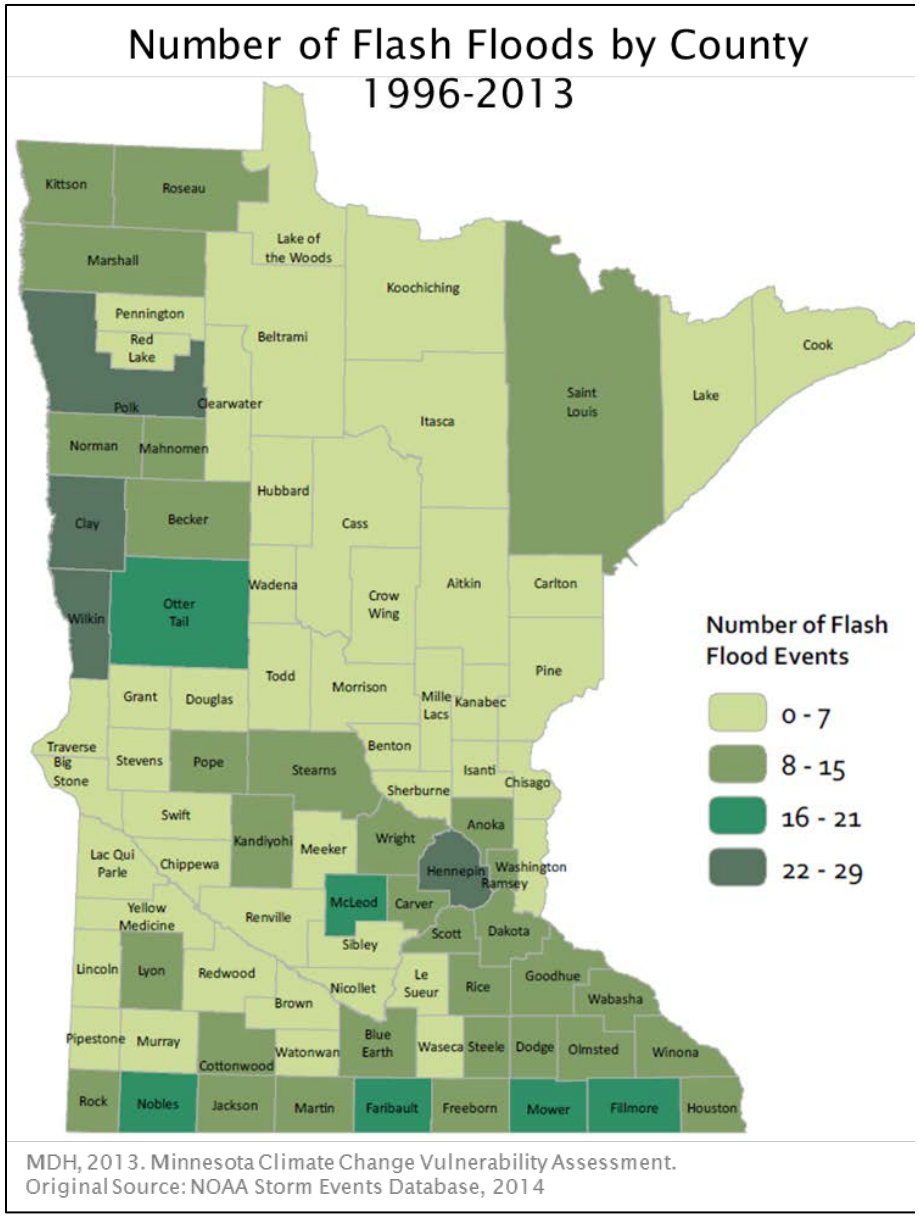


Figure 19. Population 5+, who self-report as speaking English less than "very well" (normalized data). Note areas with higher concentrations, including north of I-94 at I-35E & Highway 61, Saint Paul's East Side & West Side, south Highland Park, & in Maplewood & Little Canada.

The Impact of Climate Change on Flash Flooding

Climate change is expected to increase the frequency of flash flooding as a result of more frequent extreme rain events (MDH, 2014a & Seeley, 2015). Between 1996 and 2013, there were over 860 flash flood events in Minnesota, with nearly a third of them occurring between 2010 and 2013 (MDH, 2015a). This statewide flash flood incidence is represented in **Figure 20**. During this time period, flash floods were directly attributed to 13 deaths, almost $13 million in crop loss, and over $134 million in property damage (MDH, 2015a). As flash flooding becomes a more frequent occurrence, Ramsey County will need to be prepared for the resulting physical, economic, and health repercussions as well as take steps to spatially identify regions and populations most vulnerable to flash flooding in the area.



MDH, 2013. Minnesota Climate Change Vulnerability Assessment.
Original Source: NOAA Storm Events Database, 2014

Figure 20. Minnesota experienced a total of 860 flash flood from 1996 to 2013.

Drought

Defining Drought

Although there are several ways to define drought, a drought usually refers to an extended period of time with below normal amounts of precipitation (MDH, 2014a). There are four types of drought:

1. **Meteorological Drought** – below normal precipitation over time
2. **Hydrological Drought** – when meteorological drought affects streams, reservoirs, and groundwater
3. **Agricultural Drought** – when low soil moisture affects crop production
4. **Socioeconomic Drought** – when the supply and demand of certain commodities are affected by drought

Effect of Drought on Human Health

Although drought conditions have a slow onset, they nevertheless can cause a domino effect on the environment and human health. For instance, long droughts can affect crops, livestock, and dairy production, which can result in decreased food security and significant agricultural losses. Drought can also compromise water quality and supply, thereby affecting agriculture and even human health (due to a concentration of water-borne pollutants or pathogens). Finally, drought can increase the risk of wildfires and airborne dust, which have significant safety, economic, and respiratory health implications (MDH, 2014a).

Populations Vulnerable to Drought

Largely because drought can impact air quality, populations vulnerable to drought include young children, older adults, and those with respiratory conditions, such as asthma and COPD. **Figure 12** (page 29) demonstrates asthma-related hospitalizations in Ramsey County, and **Figure 13** (page 29) indicates COPD-related hospitalizations. Regarding older adults, **Figure 4** (page 20) shows the distribution of residents 65+ who live alone.

Figure 21 represents the population under five years of age in Ramsey County. Several areas contain high concentrations of this population, such as between I-94 & Highway 36, Saint Paul's East Side and West Side, along West 7th Street, and in pockets throughout northwest and northeast Ramsey County.

It is important to note that drought can greatly affect individuals or communities that rely heavily on agriculture for their livelihoods. In addition, drought can affect entire communities that depend heavily on regional power generation systems (MDH, 2014a). In these cases, drought may have a more indirect effect on human health.

The Impact of Climate Change on Drought

As mentioned earlier, one climate trend in Minnesota that warrants concern is the changing characteristics of precipitation. Although the amount of precipitation is projected to increase slightly, the annual variability of precipitation is also expected to increase. For instance, while some regions might experience heavy deluges of precipitation, others may experience localized drought (MDH, 2014a).

In the Midwest, the duration of droughts has not changed significantly. However, the projected increase in temperature coupled with changing precipitation patterns may increase the demand for water use, which could exacerbate the effects of future droughts (MDH, 2014a).

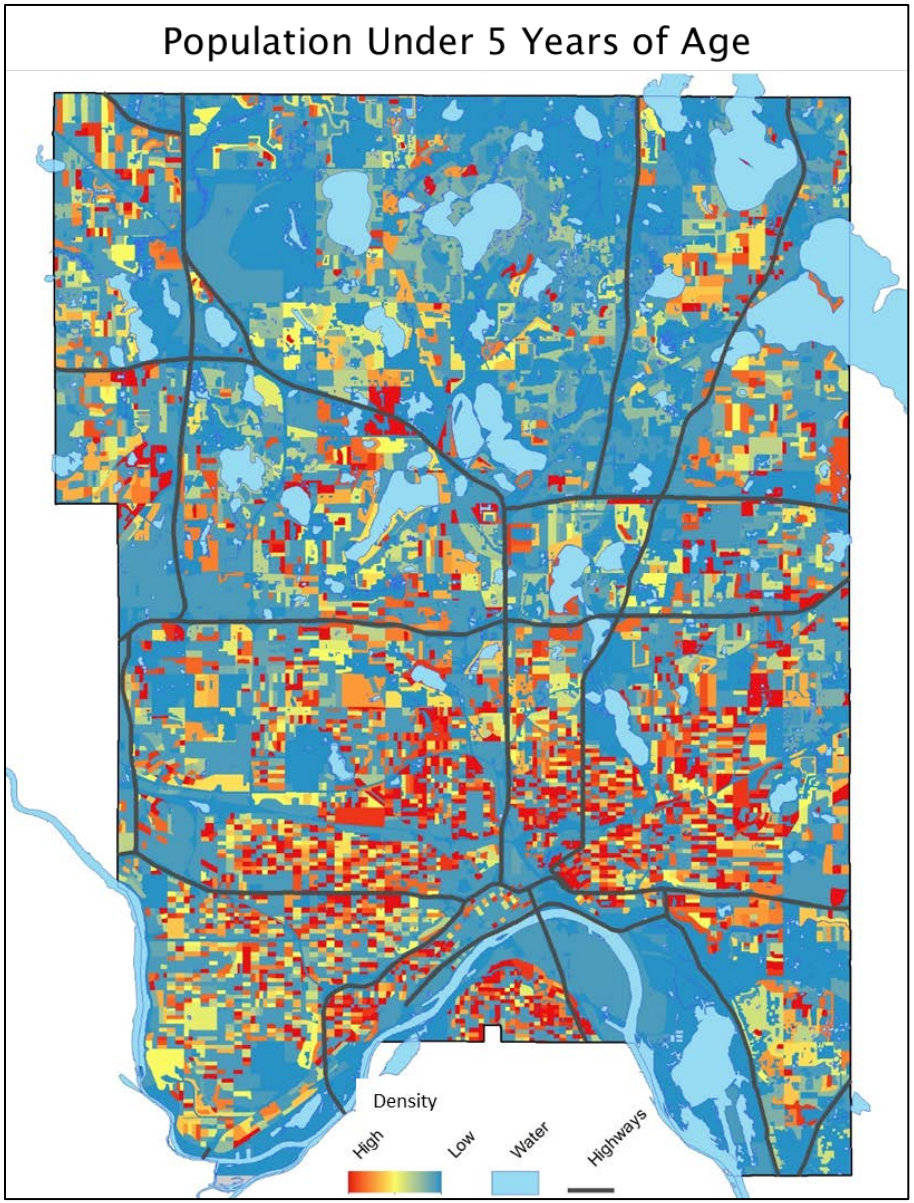


Figure 21. Population under five years of age in Ramsey County (normalized data, block level). Several areas contain high concentrations of this population, such as between I-94 & Highway 36, Saint Paul's East Side and West Side, along West 7th Street, and in pockets throughout northwest and northeast Ramsey County.

Key Takeaways: *Changes in Precipitation in Ramsey County*

Climate Hazard	Environmental Risk Factors	Effects on Human Health	Vulnerable Populations
Flash Flooding ▪ Although general flooding has its own negative impacts, flash flooding is less predictable, & therefore, of more concern in reference to human health. ▪ Changes in precipitation due to climate change will likely increase extreme rain events, which could lead to more flash floods.	▪ Impervious surfaces ▪ Topography ▪ Soil characteristics ▪ Depth of water table ▪ Stormwater sewer capacity	▪ **Direct Effects:** o Drowning, injury, electrocution, mental stress, exposure to hazardous chemicals, sewage, mold & mildew, & waterborne disease ▪ **Indirect Effects:** o Economic loss, property damage, business closures, lay-offs, damaged infrastructure, compromised food & water quality & supply	▪ Older adults, especially living alone; those with physical or mental illnesses; those under economic strain, living in substandard housing, or without vehicle access; those with limited English proficiency; those who rely on private wells; those with respiratory illnesses ▪ Vulnerabilities shift before, during, & after a flood
Drought ▪ Has a slow onset & creates a cascade of negative environmental & health effects. ▪ Increased variability in precipitation may lead to more droughts interspersed with extreme precipitation events.	N/A	▪ Mental & physical stress due to economic loss & agricultural loss ▪ Mental & physical effects of decreased food & water quality & supply ▪ Exacerbated respiratory illnesses due to increased risk of airborne dust & wildfires	▪ Young children, older adults, & those with respiratory illnesses ▪ Those who rely heavily on agriculture for their livelihoods

Conclusion: Changes in precipitation patterns in Ramsey County may lead to an increased frequency of extreme rain events (thus increasing the risk of flash flooding) in some areas and drought conditions in other areas. Both droughts and flash floods impact human health in a variety of ways. It is important to acknowledge this when planning future adaptation measures.

Limitations: Spatial analyses were not carried out for flash flooding due to lack of data. In addition, a thorough flash flooding analysis was outside the scope of this project. Spatial analyses were not carried out for drought as well.

CHANGING ECOLOGIES

Vector-Borne Disease

A vector-borne disease is characterized as a pathogen transmitted to humans and animals via the bite of an infected insect, usually a tick or mosquito (SPRCPH, 2014b). In Minnesota, the most noteworthy vector-borne diseases are Lyme disease, human anaplasmosis, and West Nile virus (MDH, 2014a). A shifting Minnesota climate may affect the ecology of such diseases due to changes in vector distribution, resulting in more vector-borne disease transmission throughout Ramsey County.

Lyme Disease & Human Anaplasmosis

Lyme disease, caused by the bacterium *Borrelia burgdorferi*, is transmitted to humans by the bite of an infected blacklegged tick (also known as the deer tick). Symptoms of Lyme disease include fever, chills, headache, muscle and joint pain, and fatigue. A characteristic bull's eye rash may form near the tick bite or in multiple places as the bacteria travel throughout the body. Chronic symptoms include fatigue, weakness, arthritis, and problems with the nervous system (MDH, 2015c).

Blacklegged ticks search for hosts from within low-lying brush or leaf debris in heavily wooded areas and are most active on warm, humid days (MDH, 2014a). Therefore, most exposure to blacklegged ticks and Lyme disease occurs from May through September (SPRCPH, 2013). Immature ticks, or nymphs, tend to transmit *B. burgdorferi* since they are more difficult to see on the body than adult ticks (CDC, 2015).

Human anaplasmosis (HA), caused by the bacterium *Anaplasma phagocytophilum*, is also transmitted to humans via blacklegged ticks (MDH, 2014a). Symptoms of HA include fever, severe headache, muscle aches, chills, and shaking. HA ranks second behind Lyme disease in regards to reported tick-borne disease cases in Minnesota (MDH, 2014a). **Figure 22** demonstrates reported cases of Lyme disease and HA from 2000 to 2011 in the county. Although there are annual variations in reported cases, there is an overall increasing trend for both tick-borne diseases. Several factors may be contributing to this trend, such as increased awareness in the health care field, increasing transmission rates in ticks, and a growing vector distribution (MDH, 2014a).

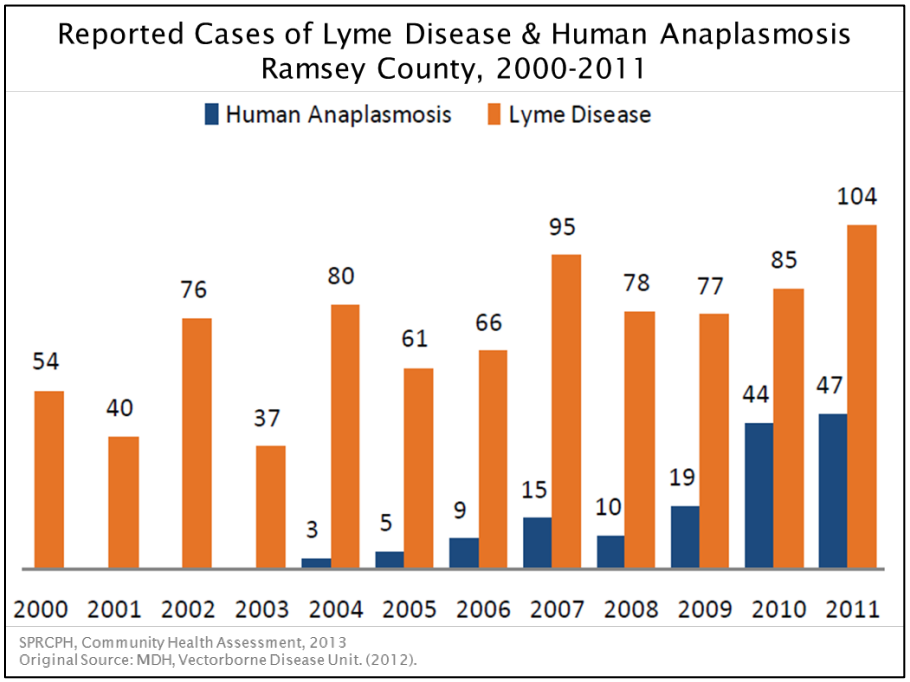


Figure 22. The two most commonly reported tick-borne diseases in Ramsey County are Lyme Disease & HA. Reported cases for both diseases followed a general increasing trend from 2000 to 2011.

It should be noted that reported cases are based on home address, not the location of likely exposure. Nevertheless, tick-borne disease remains relevant in Ramsey County, because a changing climate may alter human outdoor activities and exposure as well as shift the vector distribution further into Ramsey County, thereby increasing the risk of contracting Lyme disease or HA.

West Nile Virus

West Nile virus (WNV) is the most commonly reported mosquito-transmitted disease in Minnesota. It is transmitted to humans via the bite of the infected mosquito, *Culex tarsalis*, the primary vector (MDH, 2015b). Although most individuals with WNV are asymptomatic or mildly ill, those with West Nile fever

develop fever, headache, muscle aches, joint pain, and nausea (i.e., similar to the flu). Fewer than 1% of cases develop West Nile encephalitis, a more severe form of the disease characterized by swelling of the brain (MDH, 2015b).

C. tarsalis prefer warm, dry conditions and are most prevalent in western and central Minnesota, due to the presence of expansive farmland. As a result, most cases of WNV are reported from this region, versus the heavily forested regions of northeast Minnesota (MDH, 2014a). Twenty-four cases of WNV have been reported since 2002, with an average of 1.8 cases reported each year (MDH, 2014c). This reflects the relatively low risk of WNV in Ramsey County compared to the drier conditions in western Minnesota. However, the effect of climate change could shift this risk via creating a more suitable habitat for *C. tarsalis* in the county.

Vector-Borne Disease Risk & Climate Change

Temperature and precipitation are two important variables in addressing current and future vector-borne disease distribution and burden. Regarding climate trends in Minnesota, warming average temperatures, changes in precipitation, and a potential increase in high dew point days not only affect vector distribution, but also human behavior and outdoor engagement (MDH, 2014a).

Previous & Current Disease Risk

Throughout Minnesota, the distribution of Lyme disease cases has increased since 1996. During this time period, more Lyme disease cases have been reported in and surrounding Ramsey County. This is likely due to increased surveillance efforts as well as expanding geographic spread. **Figure 23** demonstrates this trend.

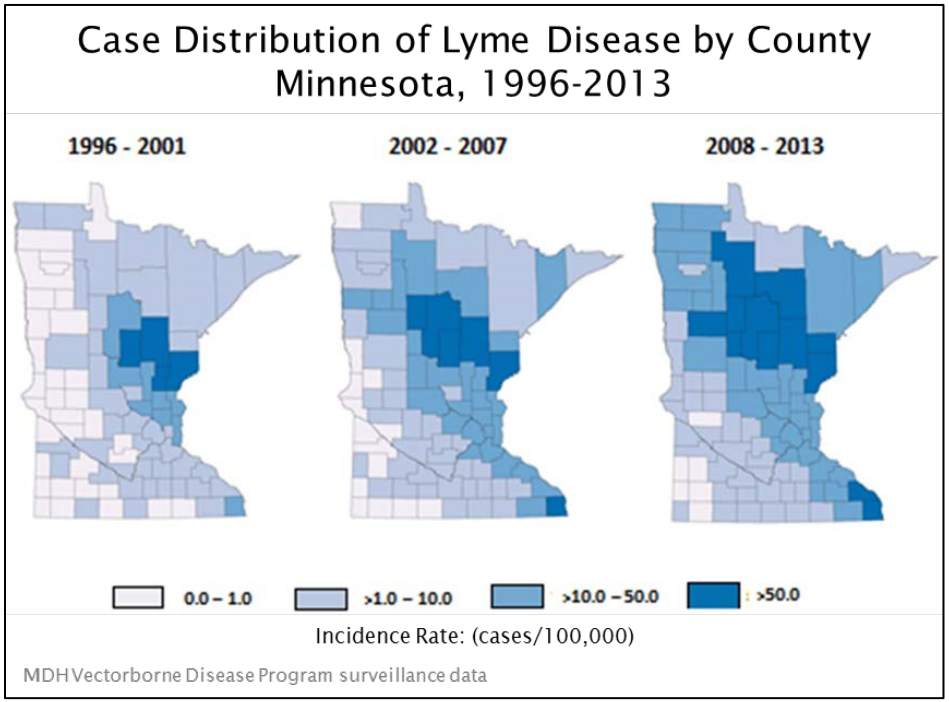


Figure 23. The distribution of reported Lyme disease cases in Minnesota spread significantly from 1996 to 2013.

Based on previous Lyme disease and HA data from 2007-2011, Ramsey County has been identified as a region at moderate risk for tick-transmitted disease (see **Figure 24**). It should be noted that two neighboring counties, Anoka and Washington, are characterized as high risk regions for tick-borne disease (SPRCPH, 2013).

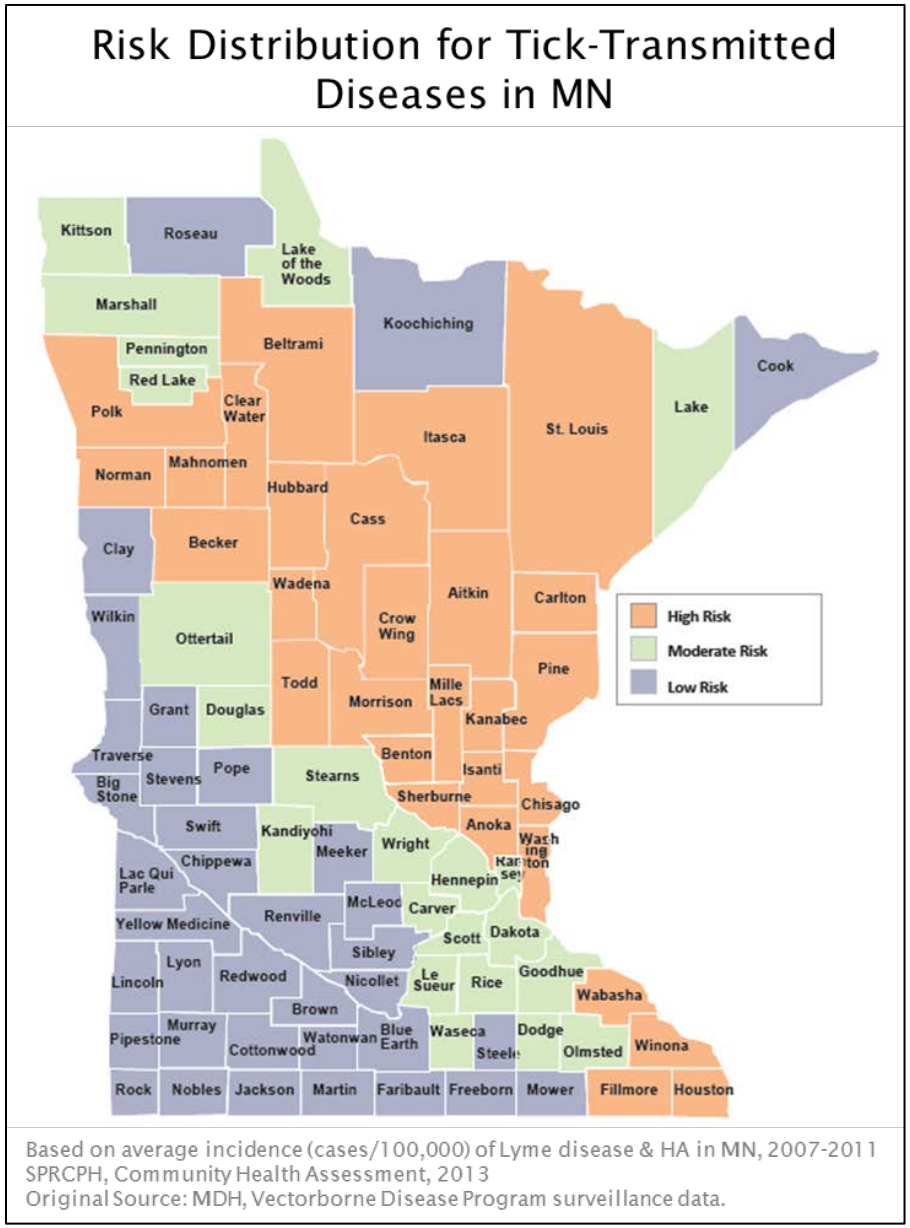


Figure 24. Based on previous Lyme disease & HA incidence data, Ramsey County is at moderate risk for tick-borne disease transmission.

The Effect of Climate Change

Warming average temperatures as well as changing precipitation patterns will likely affect the types, quantities, and distributions of vectors (SPRCPH, 2014b). For instance, blacklegged ticks, which prefer low-lying vegetation and leaf debris, thrive in regions with many deciduous trees. A warming climate will likely shift the state's primarily coniferous forests northward and increase the distribution of deciduous forest. As a result, the ideal habitat for blacklegged ticks may expand, leading to an increased risk of tick-borne disease transmission (MDH, 2014a).

Furthermore, warming temperatures coupled with precipitation variability also may increase the risk of WNV. This is because extended growing seasons allow for more mosquito generations as well as increased virus amplification within infected mosquitoes. In addition, precipitation variability may lead to more drought conditions, in which *C. tarsalis* thrive the most (MDH, 2014a).

Populations Vulnerable to Vector-Borne disease

Although vulnerable populations were not mapped in regards to vector-borne disease, it is important to note these populations throughout Ramsey County.

Those who spend much time outdoors during the warmer months, especially in wooded areas (Lyme disease and HA) or in agricultural regions (WNV) are vulnerable to vector-borne transmission (MDH, 2014). Additional populations may include children, outdoor workers, outdoor athletes, and those experiencing homelessness (SPRCPH, 2014b). Note that although Ramsey County itself may not put individuals at high risk of vector-borne disease, many people temporarily travel outside the county for outdoor recreational activities, thereby increasing their likelihood of exposure. Furthermore, should infection occur, older adults and those who are immunocompromised are more vulnerable to vector-borne disease severity (MDH, 2014a).

Invasive Species

In addition to changes in the risk of vector-borne disease, Ramsey County is also susceptible to an increased incidence of invasive species as a result of a changing climate. According to the Minnesota Department of Natural Resources (DNR), invasive species are non-native to Minnesota as well as negatively affect the environment, economy, or human health (DNR, 2016a).

Invasive species may be aquatic or terrestrial, and include both plants and animals (DNR, 2016a). Within Ramsey County, some prominent invasive species include the following:

- **Buckthorn** – plant species that outcompetes forest floor native plants for light, nutrients, and water within forests, wetlands, prairies, and other habitats.
- **Japanese Knotweed** – shrub-like plant species that forms dense thickets, especially near lakeshores & other low-lying areas. It outcompetes native vegetation and tolerates full shade, high temperatures & salinity, and drought.
- **Japanese Beetle** – insect that feeds on more than 300 plant species, skeletonizing leaves. Plants usually recover unless already stressed by another factor, such as drought.
- **Emerald Ash Borer** – insect that kills ash trees due to feeding on inner bark (DNR, 2016a).

These, and many other invasive species, are already a threat to Ramsey County's ecosystems, resources, and those systems or populations who depend on or heavily utilize them. Unfortunately, climate change will likely exacerbate the effects of current, and potentially new, invasive species.

Figure 25. Examples of invasive species in Ramsey County.

The Effect of Climate Change

The double-edged climate change sword may reduce habitat suitability for native Minnesota species as well as increase habitat suitability for invasive species (DNR, 2011). According to the United States Forest Service, the effects of climate change on invasive species are multidimensional (USDA, 2012). The impact of climate change involves a complex web of interaction among the following:

- The impact of both warming temperatures and changes in precipitation on the distribution and population dynamics of species;
- The impact of extreme weather-related or non-weather-related environmental events, such as tornadoes or wildfires;
- The impact of elevated CO_2 levels, augmenting the tenacity of invasive plant species; and
- The impact of native species and ecosystem survival due to increased habitat and climate stress (USDA, 2012).

For example, Eurasian watermilfoil is an invasive aquatic plant found in nearly 250 bodies of water in Minnesota as of 2010. It is known for outcompeting native aquatic plants. As an "evergreen" perennial, Eurasian watermilfoil needs a small amount of sunlight during the winter to survive. Long winters with ample snow cover starve the plant of sunlight, thereby inhibiting its competitive advantage over native plants. However, shorter winters coupled with less snow cover allow for more sunlight to reach these plants and survive until the warmer months. In addition, milder winters along with longer growing seasons will likely allow Eurasian watermilfoil to continue to thrive (DNR, 2011).

The Impact of Invasive Species

The impact of intensified non-native species invasion will likely be complex. Although there may not be obvious populations in Ramsey County who are vulnerable to the impact of invasive species, it is important to address the direct and indirect impacts on residents nonetheless.

For instance, wild parsnip is a perennial that directly poses a health hazard to humans. Contact with the sap of the plant tissue in the presence of sunlight causes a rash and blistering and discoloration of the skin. Wild parsnip tends to grow in disturbed habitats and along habitat edges yet is usually outcompeted by healthy prairies (DNR, 2016a).

Aquatic invasive species may compromise water bodies used for fishing, recreation, or industrial processes. This is already the case for zebra mussel infestations, which can clog water intake pipes as well as pose a safety hazard to swimmers (DNR, 2016a). Those involved in any of these activities may be directly or indirectly vulnerable, due to productivity or financial loss as well as the inability to enjoy outdoor aquatic habitats. These outcomes could indirectly affect human health due to financial strain or psychological impacts.

Additionally, some invasive species can spread disease (UMass, 2014). Hypothetically, should the *Aedes aegypti* or *Aedes albopictus* mosquito be introduced as well as adapt to a changing Minnesota climate, Ramsey County might face the potential and novel threat of Zika, dengue, and chikungunya virus transmission (CDC, 2016). Furthermore, invasive plant species may present an allergen risk, especially for previously unexposed Ramsey County residents (personal communication, Brenda Hoppe, Minnesota Department of Health, March 11, 2016).

Additional indirect health concerns due to invasive species include compromised food or water security (UMass, 2014). For instance, due to bottom feeding, invasive carp muddy bodies of water as well as release phosphorous, which stimulate algae growth. This hinders survival of other aquatic plants and fish (DNR, 2016a).

Finally, it is important to note that some invasive species may not currently pose a significant threat to the ecosystem and human health. However, in the context of climate change, these negative effects may magnify. For instance, the Japanese beetle feeds on the leaves of over 300 plant species. Plants usually recover unless already facing a stressor, such as drought (DNR, 2016a). Should climate change bring about more frequent and more intense drought, the effects of the Japanese beetle could intensify.

Key Takeaways: *Changing Ecologies in Ramsey County*

Climate Hazard	Impact of Climate Change	Vulnerable Populations/Impact on Human Health
Vector-Borne Disease ▪ Pathogens transmitted to humans via insect bite, usually a tick or mosquito ▪ Most prominent vector-borne pathogens: Lyme disease (via tick), human anaplasmosis (via tick), & West Nile virus (via mosquito)	▪ Warming average temperatures & changing precipitation patterns will likely affect the types, quantities, and distributions of vectors. o This may increase human exposure to vector-borne disease.	▪ At risk of exposure & infection: o Those who spend much time outdoors during warmer months, esp. in wooded areas o Children o Outdoor workers, outdoor athletes o Those experiencing homelessness o Those who travel outside the county for outdoor activities ▪ Should infection occur, those at risk of more severe illness: o Immunocompromised o Older adults
Invasive Species ▪ Non-native to MN & negatively affect environment, economy, or human health ▪ Examples include: buckthorn, Japanese knotweed, Japanese beetle, emerald ash borer, zebra mussels, Eurasian watermilfoil, and common carp	▪ Impacts are multidimensional & complex ▪ May reduce habitat suitability for native species ▪ May increase habitat suitability for invasive species	▪ Vulnerable populations include: o Those who utilize or rely heavily on water bodies for fishing, recreation, or industrial processes o Those who regularly interact with the environment via agriculture, gardening, or landscaping ▪ Other health impacts: o Compromised food & water security o Increased disease transmission carried by invasive species

Conclusion: One of the indirect consequences of climate change is a gradual change in species ecology. Concerns regarding an increased risk of vector-borne disease as well as the intensified effect of invasive species are relevant to Ramsey County and its residents.

Limitations: Vector-borne data were lacking or of insufficient quality at the sub-county level (e.g., vector distributions), so a full impact analysis was not feasible at this point.

CHANGING DEMOGRAPHICS

Background

When considering Ramsey County's vulnerabilities to the effect of climate change, it is also important to note the current and future trends of the general population. Regarding potential vulnerability, two demographic shifts are most noteworthy in Ramsey County: an aging population and increasing immigrant and refugee populations.

Aging Population

Of Minnesota's 683,121 residents age 65 and older, nearly half live within the metro area. Of the metro counties, Ramsey County is home to the highest percentage (12.4%) of this age group with females accounting for about 60% of this population (SPRCPH, 2013).

Regarding distribution, older adults are more likely to live in established suburbs versus new suburbs or urban communities (SPRCPH, 2013). **Figure 26** demonstrates the distribution of this population throughout the metro area. In Ramsey County, higher percentages of older adults live in or near communities, such as Roseville, North Oaks, New Brighton, Maplewood, and White Bear Lake.

As the baby boomer generation ages and life expectancy increases, the senior population in the metro area is projected to double between 2010 and 2030. As a result, this population will become a substantial portion of the Ramsey County community, with one in five residents being 65 or older by 2035. **Figure 27** demonstrates the projected trends of the senior age groups in Ramsey County. Furthermore, the ratio of workers to retirees will decrease from 5:1 in 2010 to 3:1 by 2030 (SPRCPH, 2013).

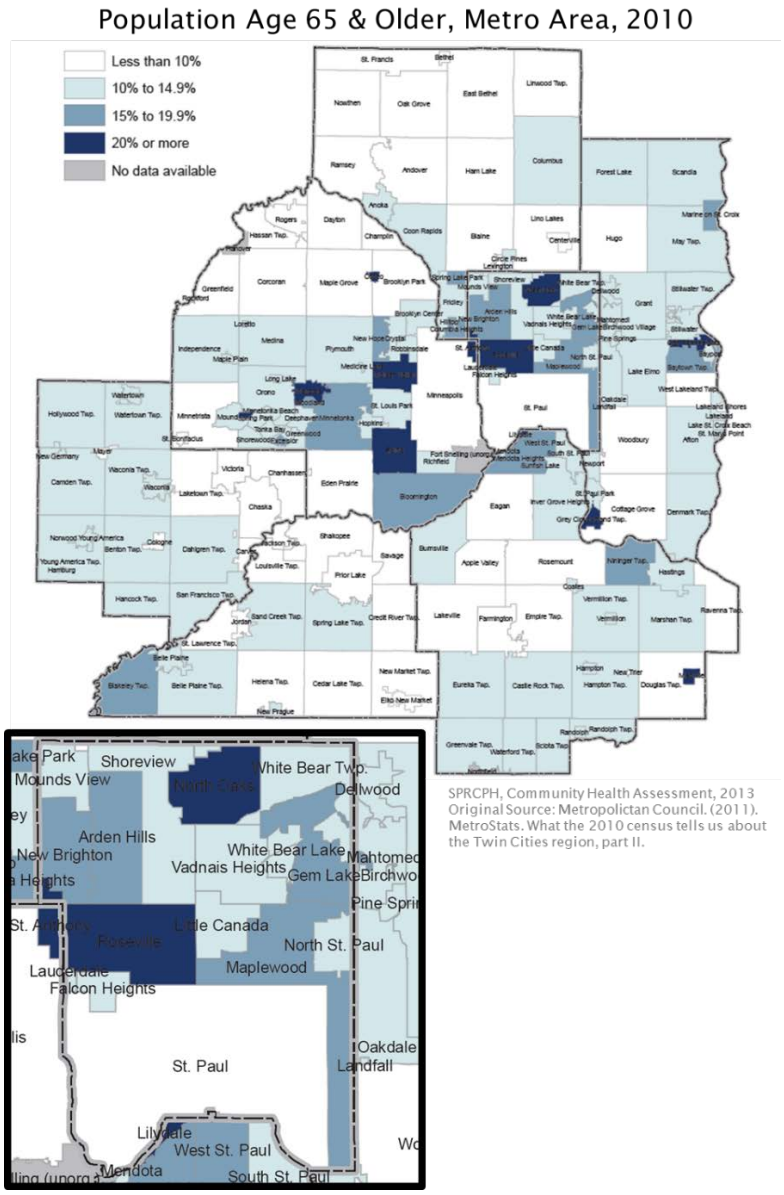


Figure 26. Among the metro counties, Ramsey County is home to the highest percentage (12.4%) of those age 65 and older. This population tends to live in established suburbs versus city centers or new suburbs.

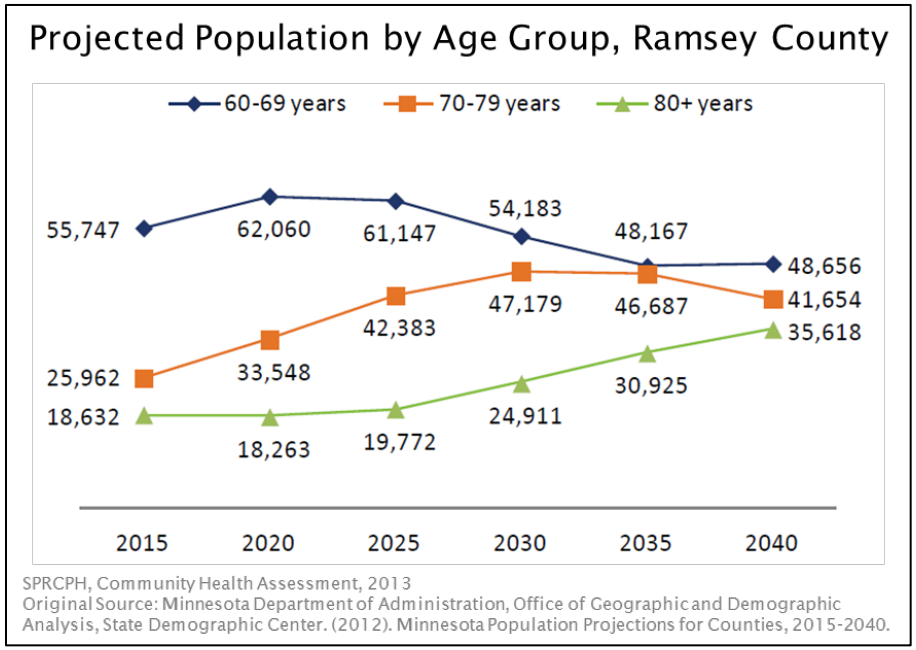


Figure 27. The senior population is projected to shift dramatically as the baby boomer generation ages and life expectancy increases.

Vulnerability of an Aging Population

As a large portion of the population ages, the county will need to accommodate resultant vulnerability to the effects of climate hazards. As stated previously, older adults tend to be more vulnerable to the negative effects of extreme heat, poor air quality, flooding, drought, and complications from vector-borne disease. The vulnerability distributions described in this report represent a snapshot in time. As the demography of Ramsey County shifts towards an older population, it will be important to plan accordingly regarding housing, healthcare, transportation, and emergency services in light of a changing climate.

Increasing Immigrant & Refugee Populations

Ramsey County is also home to a large percentage of immigrants. Following Brooklyn Center, Brooklyn Park, and Richfield, Saint Paul ranks fourth in the state, with 17% of its population being foreign-born (13.4% of Ramsey County residents are foreign-born) (SPRCPH, 2013).

In addition, because Minnesota is a designated refugee resettlement area, one in five new immigrants has been a refugee or asylee. In the past ten years, the majority of Ramsey County refugees were from Burma (39%), Laos (33%), Somalia (15%), Ethiopia (9%), and Bhutan (4%). These demographics, however, appear to be shifting based on the U.S. Department of State's preliminary data from 2012, demonstrating that Ramsey County welcomed significantly more Burmese refugees (72% of all arrivals), followed by refugees from Somalia (12%), Bhutan (9%), Ethiopia (4%), and Iraq (3%) (SPRCPH, 2013). **Figure 28** demonstrates these trends.

Furthermore, during FY 2016 (10/31/15 – 1/31/16), the U.S. Department of State reported the highest percentage of refugees fled to Minnesota from Somalia (47%), followed by Burma (29%), Ethiopia (5%), Bhutan (5%), Iraq (5%) and Ukraine (5%) (2016).

Over the next 30 years, the metro area will continue to be a hub for immigrants, with 83% of new immigrants expected to be people of color from all continents and the remaining 17% being white, non-Hispanic (SPRCPH, 2013).

Finally, the direct and indirect health impacts of climate change in other regions may drive immigration to more hospitable climates (McMichael, 2012). In 2002, it was estimated that climate change will cause 200 million "environmental refugees" by the year 2050 (Meyers, 2002). This adaptation strategy may result in a greater influx of immigrants to the county.

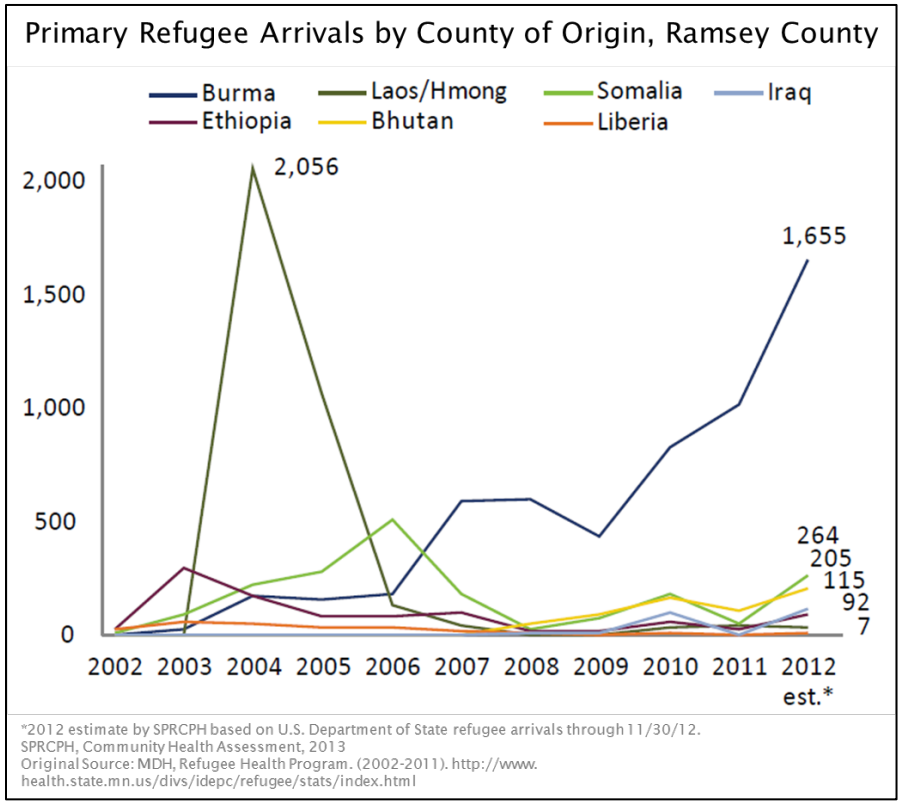


Figure 28. The trend of refugee arrivals and countries of origin has varied over time.

Vulnerability of Immigrants & Refugees

As Ramsey County continues to welcome immigrants and refugees, it will be important to incorporate their unique health needs and potential vulnerabilities into the framework regarding climate change adaptation strategies. Although this population tends to be very resilient, possible vulnerabilities include the following: language barriers; adapting to a new climate, culture, and social situation; and physical or mental health issues due to previous malnutrition, poverty, separation from family, trauma, and social, political, or religious persecution.

Regarding the many hazards associated with climate change in particular, it will be increasingly more beneficial to develop programs to overcome language barriers so information regarding potential climate hazards (extreme heat, for instance) is properly understood and leads to the appropriate precautions.

This assessment did not include immigrant and refugee data as part of the spatial component of this report; nevertheless, it is an important topic to consider at least from a qualitative perspective. Future vulnerability assessments will likely benefit from spatially representing these populations within Ramsey County.

Key Takeaways: *Changing Demographics in Ramsey County*

Aging Population	▪ Ramsey County is home to the highest percentage of those 65+. ▪ The senior population is projected to double by 2030. ▪ Ramsey County will need to accommodate the resultant vulnerability shift in the wake of climate change.
Increasing Immigrant & Refugee Populations	▪ 13.4% of Ramsey County residents are foreign-born. ▪ Over the next 30 years, the metro area will continue to be a hub for immigrants & refugees. ▪ Potential Vulnerabilities include: o Language barriers o Physical & mental health issues o Difficulty adapting to a new situation ▪ Ramsey County will need to accommodate the unique health needs & vulnerabilities in the context of climate change.

Conclusion: In the coming years, both an aging population & substantial immigrant population should be taken into account when planning climate change adaptation measures.

Limitations: A spatial distribution of immigrant/refugee populations was not included in this assessment.

PSYCHOLOGICAL IMPACTS OF CLIMATE CHANGE

Background

Understanding the psychological context of perceiving and understanding climate change is very important when addressing the mental health impacts of climate change. Climate change can be difficult to internalize because it seems far away and in the distant future. One strategy to overcome this is to communicate the specific local impacts of climate change so it resonates closer to home (Clayton, 2014).

Studies have demonstrated that understanding increases when an individual has had direct experience with climate change and its effects, although the extent of this phenomenon is still unclear. Complicating the matter are an individual's existing worldviews and ideologies, which can hinder openness to understanding climate change. In fact, some studies show that individuals who were *less* engaged in climate change were more likely to change their beliefs on climate change based on personal experiences (Clayton, 2014). Because the psychology of climate change is so complex, a similar psychological response to the negative impacts of climate change is to be expected and acknowledged within Ramsey County.

Mental Health Impacts of Acute Disasters & Gradual Climate Change

The psychological impacts of climate change involve a complex web of direct and indirect mental health consequences. These impacts result from both acute weather events, such as a flood, as well as from the slow onset of a changing climate, such as gradually increasing average temperatures (Clayton, 2014).

Weather disasters put individuals and communities under great distress. One in five people experience psychological stress after a severe weather event (MDH, 2015a). Immediate psychological effects of weather disasters include trauma and shock due to personal injury, the death of a loved one, damaged or loss of personal property, etc. The aftereffects of a disaster may result in lingering mental health distress, such as stress, anxiety, depression, and post-traumatic stress disorder (PTSD). The trauma of a disaster and its long-term effects may also lead to complicated grief, characterized by a more intense and longer lasting form of grief, in which individuals have a difficult time returning to their normal lives (Clayton, 2014). These long-term psychological stressors may persist due to negative experiences with organizations during recovery, such as builders or insurance companies (MDH, 2015a). Social relationships may also be strained, due to family displacement or separation, the loss of a home, or missing school or work. Consequently, these psychological stressors have been linked to several physical health problems, such as an impaired immune system (Clayton, 2014).

Apart from isolated extreme weather events, the gradual onset of climate change itself may bring about psychological strain as well. Due to an increase in overall stress, climate change may indirectly lead to substance abuse, anxiety, and depression. There may be more mental health emergencies; evidence has shown that an increase in average temperatures is correlated with increased use of emergency mental health services, possibly due to the additional stress of extreme heat hindering coping ability (Clayton, 2014). Additional psychological effects of gradual climate change can include feelings of loss, helplessness, frustration, loss of autonomy and sense of control, and loss of personal or occupational identity (Clayton, 2014).

Beyond the individual, climate change can affect overall community health as well. These impacts include decreased community cohesion, a disrupted sense of belonging, and increased crime, social instability, and domestic abuse (Clayton, 2014).

Figure 29 summarizes the mental health, physical health, and community health impacts of climate change. Note the domino effect initiated by the physical impacts of climate hazards.

Physical & Psychological Impacts of Climate Change

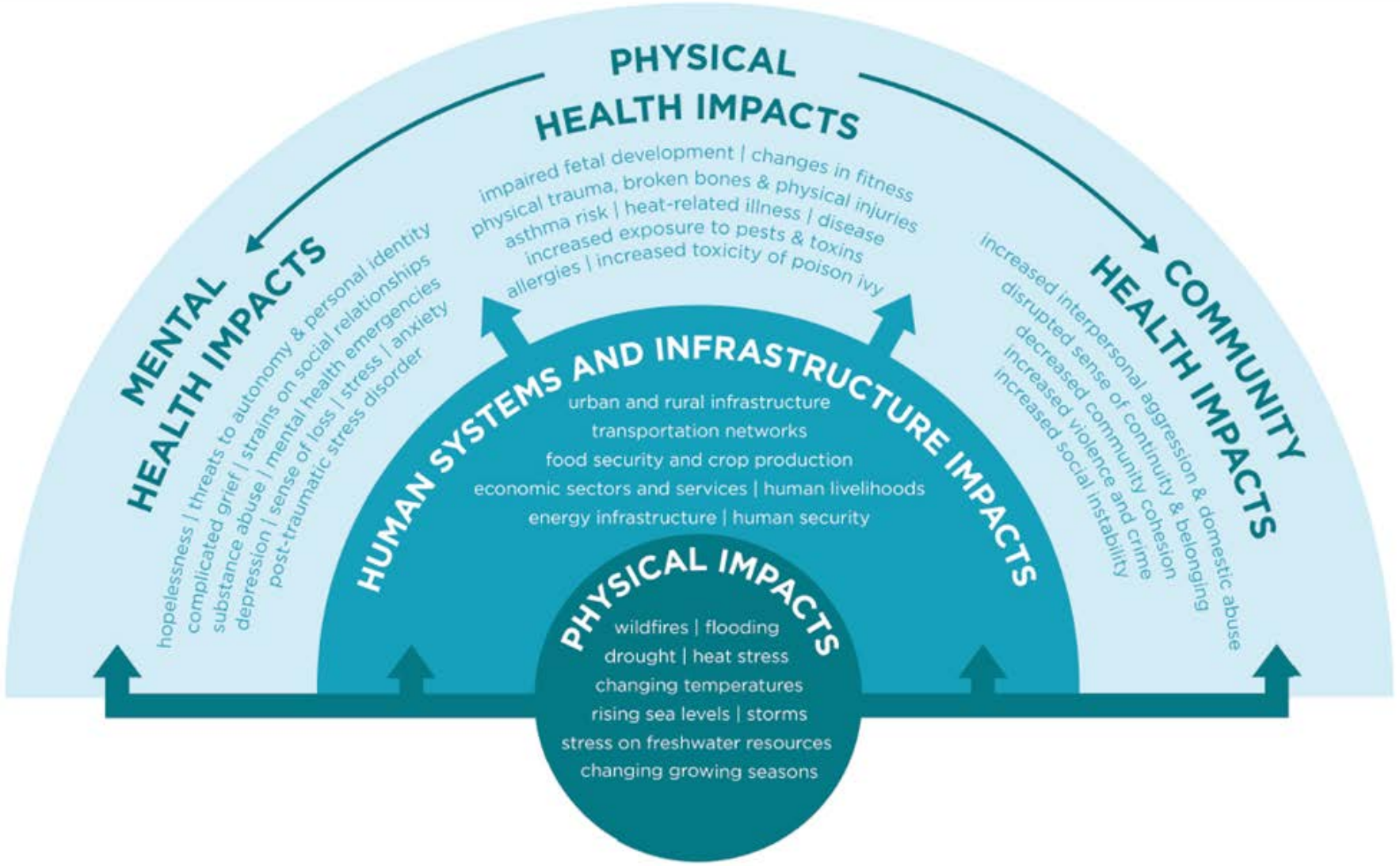


Figure 29. Climate change impacts physical health, mental health, and community health. The complexity of such a cascade is important to note when planning adaptation strategies in Ramsey County.

Clayton, S., Manning, C. M., & Hodge, C. (2014). Beyond storms & droughts: The psychological impacts of climate change. Washington, DC: American Psychological Association and ecoAmerica.

Vulnerabilities to Psychological Impacts of Climate Change

Similar to the physical impacts of climate change, some characteristics make individuals and communities more vulnerable to the psychological impacts of climate change. According to the American Psychological Association and MDH, vulnerabilities exist at the individual and community levels and include the following:

- **Individual Level**
  - Older adults; children & infants; women; those with disabilities; those with pre-existing mental health conditions; recently-arrived immigrants or refugees; those in poverty; those with minimal education; those without adequate health care or health insurance; those with existing poor health; and those who rely on the climate for their livelihood
- **Community Level**
  - Outdated physical infrastructure (e.g., inadequate extreme weather warning systems or storm sewer systems)
  - High levels of social inequality
  - Low social cohesion and community connectedness
  - Distrust between residents and institutions (Clayton, 2014 & MDH, 2014b)

Although each individual reacts differently to the effects of climate change due to several factors (e.g., location of residence, occupation, and previous interactions with the environment), it is important to note the particular vulnerabilities that may aggravate the psychological response (MDH, 2014b).

Mental Health in Ramsey County

Given current and projected climate trends of warming average temperatures, changes in precipitation, and possible increases in the number of days with high dew points, Ramsey County can expect to see a subsequent cascade of direct and indirect mental health consequences. As such, it is necessary to note the current state of mental health in Ramsey County in order to prepare for a possibly greater mental health burden due to climate change.

In Ramsey County, the average number of reported poor mental health days within the last 30 days among adults is 2.5, which is relatively average among the metro counties (see **Figure 30**). Factors, such as the presence of a caring adult for children or the presence of good emotional and social support for adults, help build resiliency against poor mental health (SPRCPH, 2013). Among adults who receive good social and emotional support in Ramsey County, only 1-2% were dissatisfied with life, versus 8-18% among adults with inadequate support (see **Figure 31**).

Furthermore, because poor mental health has been strongly associated with an increased risk for disease, illness, injury, and immune function, it is necessary for Ramsey County to account for both the physical and mental health impacts of climate change (SPRCPH, 2013). This is especially true for the most vulnerable populations in Ramsey County (Clayton, 2014).

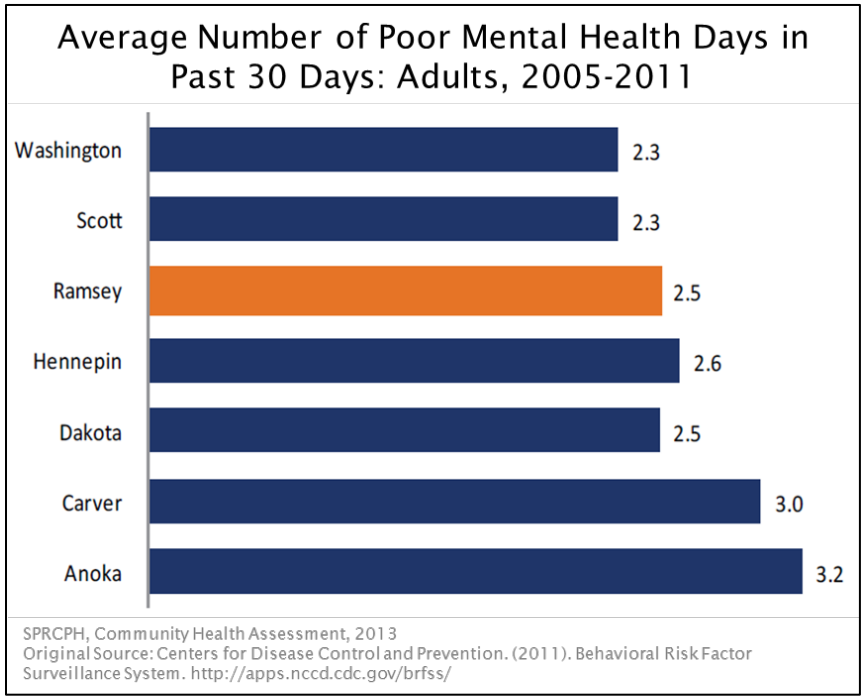


Figure 30. The average number of poor mental health days among adults in Ramsey County is relatively average compared to the rest of the metro counties.

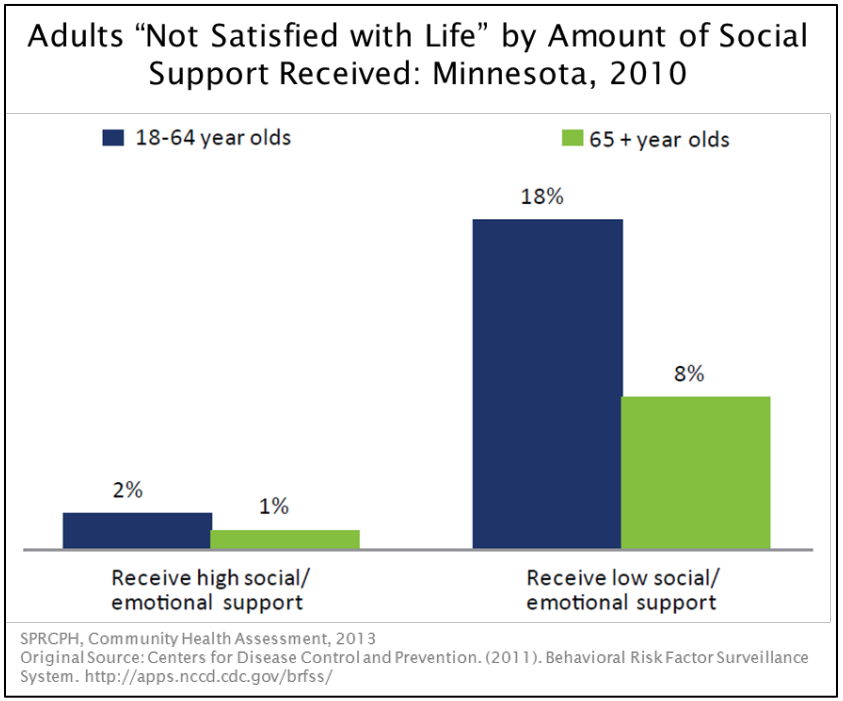


Figure 31. Social and emotional support is an important component in mental health resiliency.

Steps to Prepare for and Mitigate Mental Health Impacts

The American Psychological Association recommends the following steps to prepare for the mental health impacts of climate change:

- Bolster public engagement regarding climate change
- Give residents confidence via focusing on specific solutions to prepare for climate change
- Highlight positive side effects of addressing climate change, such as stronger communities & economic prosperity
- Acknowledge emotions & use personal stories
- Frame solutions in the context of local conditions & cultures
- Emphasize community networks, involvement, & teamwork
- Encourage residents to incorporate mental health in disaster plans
- Develop trusted & action-oriented warning systems
- Foster safety, hope, & optimism
- Bolster community infrastructure, such as energy production, food & water supply, & transportation
- Be sensitive to the needs of displaced individuals
- Pay special attention to vulnerable populations (Clayton, 2014)
- Promote green spaces, especially in a city (Annerstedt van den Bosch, 2015)

While the purpose of this report isn't to plan for adaptation measures to climate change, the previous recommendations put forth by the American Psychological

Association provide a framework from which SPRCPH can expand and articulate based on the specific needs of Ramsey County.

Case Study: Mental Health & Drought

It is often communicated that the effects of climate change are numerous, far-reaching, and, most notably, complex. This motif is no different when approaching mental health, which plays an important role in overall wellbeing.

To demonstrate the complexities of the effects of climate change, Vins and colleagues investigated the mental health impacts of drought. Via conducting a systematic review, the authors developed a causal process diagram, which visually represented the pathways of cause and effect originally initiated by drought (Vins, 2015). **Figure 32** demonstrates the final process diagram. Noting the substantial complexity, one example of a causal process may include the following progression:

> Drought → Declined agricultural production → Employment & financial constraints → Household & family tension → Domestic violence abuse → Depression

This figure highlights the incredibly interactive behavior of the direct and indirect effects of drought. Current and projected changes in the characteristics of precipitation may bring about more frequent and more severe droughts in Ramsey County; thus, a firm understanding of this interconnected process is important to understand, especially in the context of vulnerable populations.

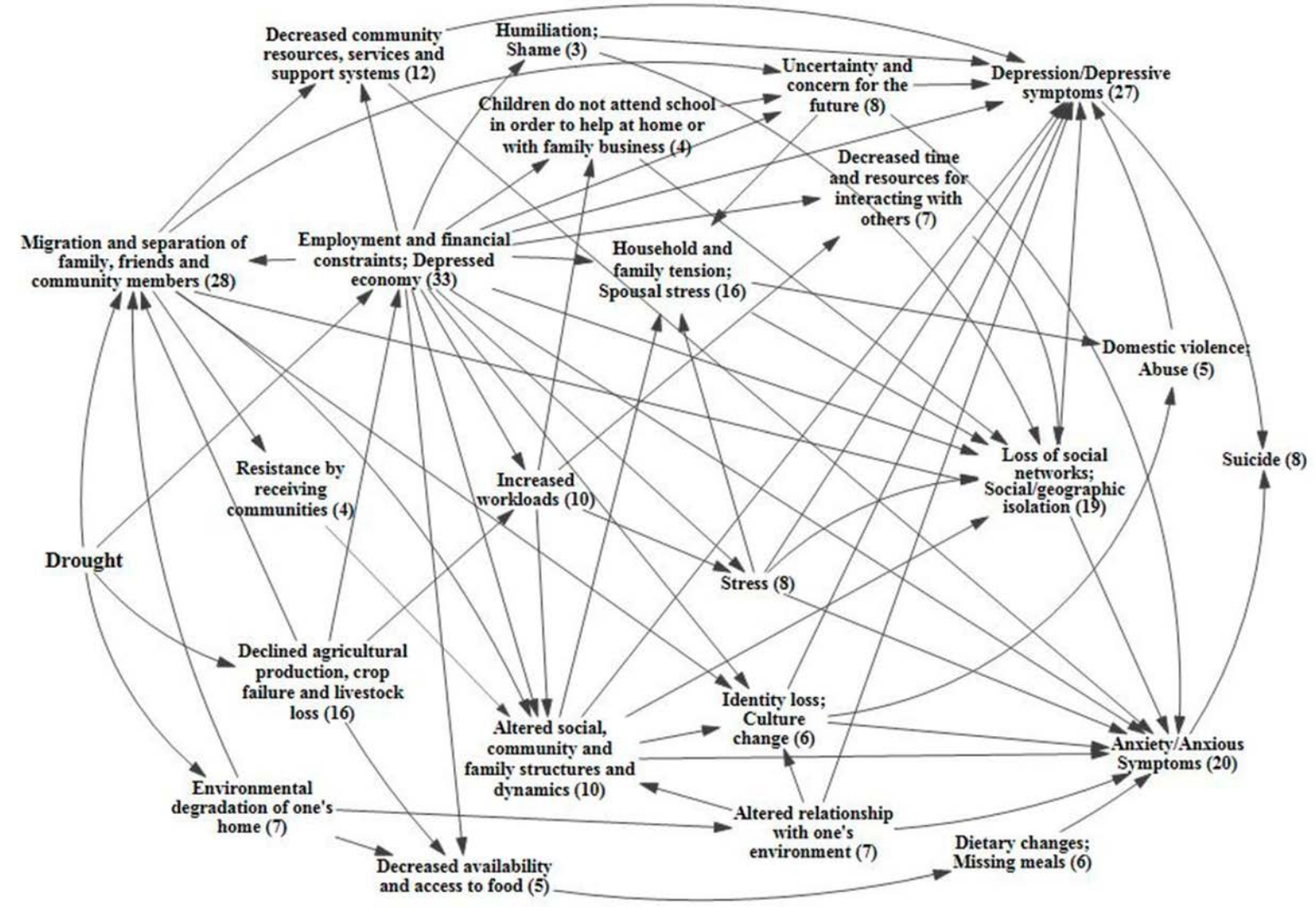
Key Takeaways: *Psychological Impacts of Climate Change*

- The psychology of climate change is complex due to the tendency to view it as far away or in the future.
- Climate change can cause a cascade of direct & indirect mental health consequences, such as
  - Stress, anxiety, depression, PTSD, & complicated grief.
- Vulnerabilities to mental health impacts of climate change include
  - Older adults; children & infants; women; those with disabilities or poor health, pre-existing mental health conditions, minimal education, in poverty, or without health care or health insurance; recently-arrived immigrants or refugees; & those who rely on the climate for their livelihood
- Community level vulnerabilities, such as poor infrastructure, also affect mental health impacts.
- Ramsey County is no exception to the psychological impacts of climate change & should take steps to prepare for these impacts, such as:
  - Bolstering public engagement & confidence regarding climate change
  - Communicating specific solutions in the context of local conditions
  - Developing trusted & action-oriented warning systems
  - Fostering safety, hope, & optimism
  - Bolstering community infrastructure
  - Paying special attention to vulnerable populations

Conclusion: The effects of climate change extend beyond physical health & can greatly affect mental health in a complex manner.

Limitations: A spatial component regarding the psychology of climate change was not included in this assessment.

Causal Processes Diagram for Mental Health Outcomes of Drought



Vins H., et al. "The Mental Health Outcomes of Drought: A Systematic Review and Causal Process Diagram" *Int. J. Environ. Res. Public Health* 2015, 12, 13251-13275; doi:10.3390/ijerph121013251

Figure 32. Drought initiates a complex web of direct and indirect impacts, which can lead to several negative mental health effects.

CONCLUSION

Study Limitations

There are several limitations regarding this assessment which should be noted for future vulnerability assessments conducted by SPRCPH.

A Snapshot in Time

First, it is important to note that this CCVA represents a snapshot in time. For instance, although this report qualitatively refers to current and future climate trends, actual climate projection data were not incorporated. Furthermore, demographic data (such as that used in base vulnerability) represent current and past trends in Ramsey County. It is important for SPRCPH to update this vulnerability assessment regularly in order to capture successive snapshots in time.

Limited by Data Availability & Quality

There are a number of limitations regarding data. First, because this assessment was conducted at the sub-county level, there was not enough variation in the study area to address large-scale climate changes, such as climate projections, annual rainfall, and average temperature. Therefore, SPRCPH relied on general climate trends throughout the state of Minnesota. Also, because of the small-scale geography of this assessment, some data were simply not available at the sub-county level.

Some data analyses were outside the scope of this project, such as a complete assessment of the environmental risk of flash flooding. However, this offers up an opportunity for more detailed and intense spatial analyses in the future.

Many demographic datasets, such as those used in base vulnerability, are based on 5-year average estimates from the American Community Survey. As such, these estimates do not represent true counts, since sample survey technique are used. However, multiyear estimates do provide greater statistical reliability for less-populated areas as well as small subgroups of the population (U.S. Census Bureau, 2016).

Finally, the ozone and $PM_{2.5}$ data used for air quality in Ramsey County were based on the Downscaler model, which uses a combination of monitored and modeled air quality data. While this allows regions without monitors to be assigned a value, this method, nevertheless, relies in part on modeling. Therefore, variations seen using downscaler data may not fully represent the true state of air quality in Ramsey County.

Geographic Presentation

Another limitation of this report includes SPRCPH's decision to show maps based on normal treatment only. Recall that normalized treatment uses a percentage of the total container population while standard treatment uses absolute numbers. Regarding emergency preparedness, standard data may be more helpful to determine resource allocation. However, normalized data allow for comparisons between land areas, regardless of land size or population size. Therefore, maps based on normal treatment may appear different from analogous maps based on standard treatment. For the sake of simplicity, SPRCPH chose to include maps based on only one treatment. However, in the future, both treatments could be included to avoid misconceptions.

Recent Field of Research

Finally, while the momentum of sub-county level vulnerability assessments appears to be increasing throughout the United States, this report joins a relatively new field of research that will likely evolve over time as updated and better data become available and as new and better methodological approaches become standard practice.

Next Steps

While this report represents a step in the right direction, there remains a continued need to investigate vulnerability specific to Ramsey County. This includes the development and inclusion of better datasets and improved spatial methods. This is a report that is meant to evolve over time, and as such, SPRCPH aims to elevate it to a level in which it will regularly inform future adaptation policy.

The following list represents future steps for assessing vulnerability and applying it to adaptation strategies.

- Update the CCVA regularly, incorporating new & better data as they become available.
    - Specific areas to improve:
        - A spatial analysis of the environmental risk of flash flooding, including risk factors, such as sewer systems, soil characteristics, topography, and impervious surfaces.
        - A more detailed geographic analysis of base vulnerability in the county, including additional characteristics, such as immigrant or refugee status, improved housing characteristics, and better measures of poverty
        - The incorporation of sub-county urban heat island data regarding temperature variation during extreme heat events
- Commence the third part of the 3-part series to address the health impacts of climate change in Ramsey County.
    - Part 3 focuses on prioritizing and establishing adaptation efforts.

Conclusion

The information presented in this report characterizes the health impacts of climate change. It does so by incorporating environmental risk factors and individual vulnerabilities within the context of specific climate hazards, such as extreme heat, poor air quality, flooding, drought, and vector-borne disease. These quantitative and qualitative assessments provide a preliminary framework for future discussions regarding adaptation strategies. SPRCPH will regularly update this analysis to improve upon this framework in the future.

The results of this assessment indicate the impact of climate change on human health in Ramsey County is complex and affected by both environmental risk factors and social vulnerability. Understanding how vulnerability contributes to the impact of climate change will prove beneficial as the county continues discussions regarding how it should respond to the health effects of climate change in a manner that protects all Ramsey County residents, including the most vulnerable, to ensure healthy people, healthy communities, and a healthy environment.

Although this document provides a good informational foundation regarding climate change and vulnerability, the true impact will lie within future adaptation plans. In other words, while vulnerability should still be explored, measured, and quantified, the ultimate goal is to take that information and eventually turn it into prudent yet potent action so that Ramsey County is appropriately prepared in the wake of climate change.

APPENDIX A

Case Study: Comparing Other Measures of Vulnerability

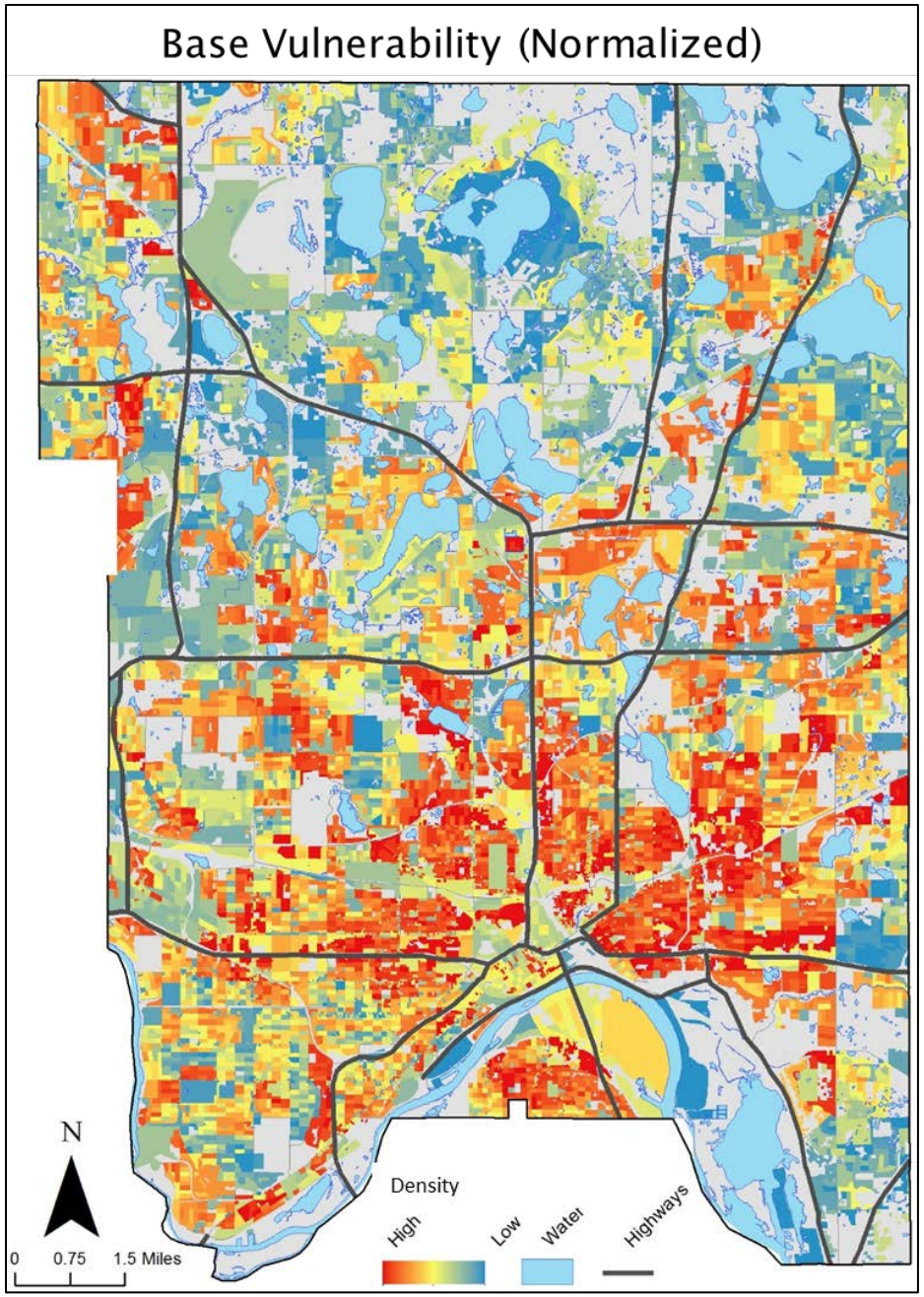
The Agency for Toxic Substances & Disease Registry (ATSDR) at the CDC developed a national social vulnerability index (SVI) to identify regions most likely to need support to prepare for, respond to, and recover from a hazardous event, such as a chemical spill, disease outbreak, or extreme weather event. ATSDR used U.S. Census data (2010) and American Community Survey data (2006-2010) to determine vulnerability at every census tract.

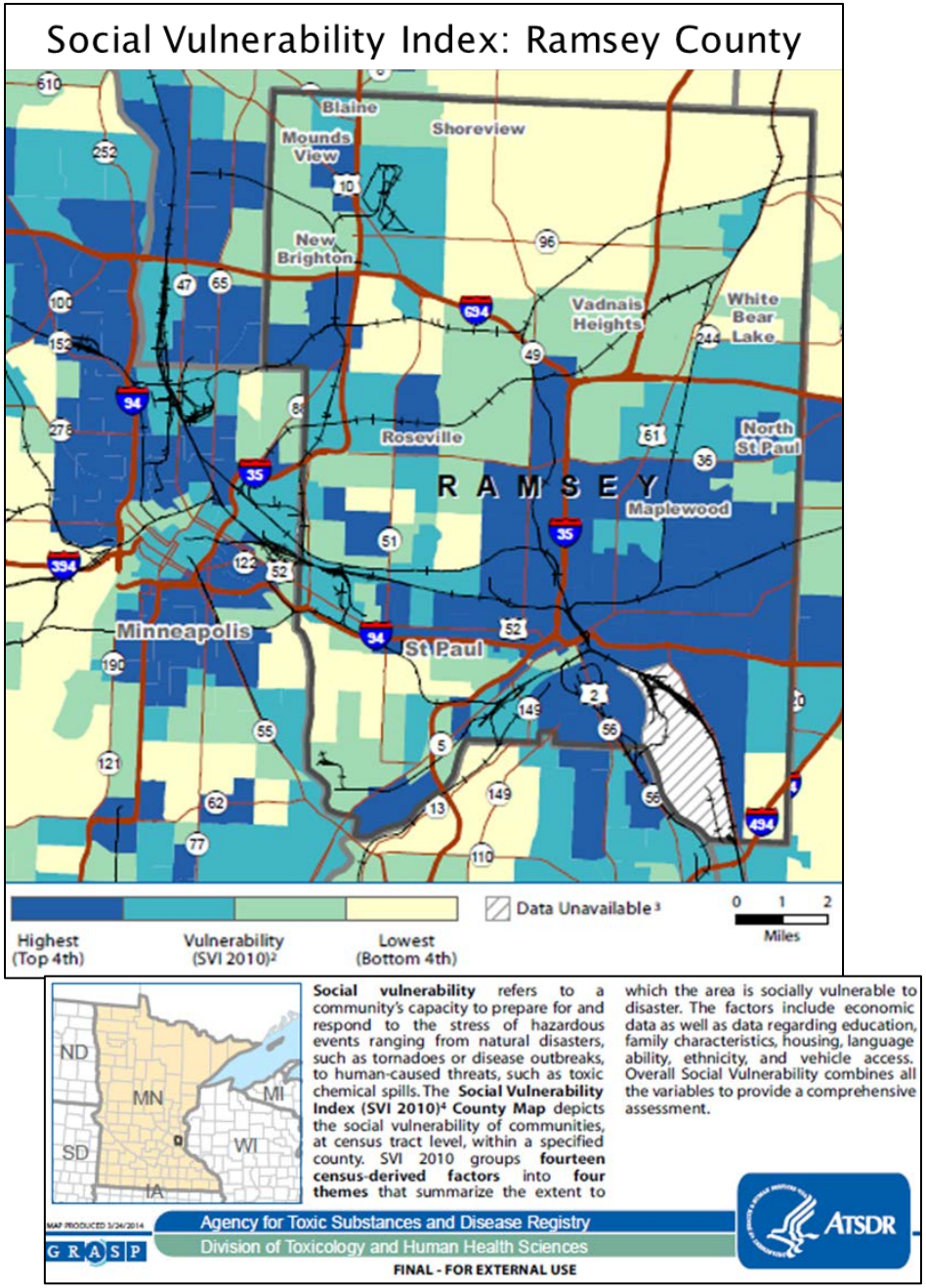
The ATSDR vulnerability index for Ramsey County was generated and included in this report to serve as a comparison for the base vulnerability developed by SPRCPH and used in this report. Refer to the below table for variables used as well as the maps on the next page. (Note: both maps are based on normalized treatment.)

Table I. Variables used to Determine Vulnerability

SPRCPH – BASE VULNERABILITY	ATSDR – SOCIAL VULNERABILITY INDEX
Similar Variables	
Occupied housing units without vehicle access	No vehicle access
Population 85+	Persons aged 65 and older
Occupied housing units in multifamily housing	Housing units with 10 or more units in the structure
People living below 200% of poverty threshold	Persons below the poverty level
People 25+ without a high school diploma	No high school diploma for persons aged 25 and older
People 5+ who speak English < “very well”	Persons who speak English “less than well”
Occupied mobile homes	Mobile homes
Population under 5 years	Persons aged 17 and younger
Other Variables	
People 65+ & living alone People 16+ who walk or bike to work People who work outdoors Occupied housing units without phone access	Single parent households with children under 18 Minority status (i.e., Total population minus white, non-Hispanic population) Civilian unemployed Per capita income At the household level, more people than rooms Persons living in Group Quarters

--Agency for Toxic Substances & Disease Registry, “The Social Vulnerability Index (SVI)” 2014. http://svi.cdc.gov/Index.html
--National Association of County & City Health Officials. “The Social Vulnerability Index” 2014. http://nacchopreparedness.org/the-social-vulnerability-index/
--ATSDR, “SVI 2010 Documentation” 3/31/2015 http://svi.cdc.gov/Documents/Data/2010_SVI_Data/SVI2010Documentation.pdf
--ATSDR, “Social Vulnerability 2010: Ramsey County, Minnesota” 2010. http://svi.cdc.gov/Documents/CountyMaps/2010/Minnesota/Minnesota2010_v2_Ramsey.pdf


Base Vulnerability (Normalized)
N
0 0.75 1.5 Miles
Density
High
Low
Water
Highways


Social Vulnerability Index: Ramsey County
Blaine
Shoreview
Mounds View
New Brighton
Vadnais Heights
White Bear Lake
Roseville
North St Paul
RAMSEY
Maplewood
Minneapolis
St Paul
Data Unavailable³
0 1 2
Miles
Highest (Top 4th)
Vulnerability (SVI 2010)²
Lowest (Bottom 4th)
ND
MN
MI
SD
WI
IA
Social vulnerability refers to a community's capacity to prepare for and respond to the stress of hazardous events ranging from natural disasters, such as tornadoes or disease outbreaks, to human-caused threats, such as toxic chemical spills. The Social Vulnerability Index (SVI 2010)⁴ County Map depicts the social vulnerability of communities, at census tract level, within a specified county. SVI 2010 groups fourteen census-derived factors into four themes that summarize the extent to which the area is socially vulnerable to disaster. The factors include economic data as well as data regarding education, family characteristics, housing, language ability, ethnicity, and vehicle access. Overall Social Vulnerability combines all the variables to provide a comprehensive assessment.
MAP PRODUCED 3/24/2014
GRASP
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences
ATSDR
FINAL - FOR EXTERNAL USE

GLOSSARY & ACRONYMS

Adaptation Strategies to promote risk communication, community & infrastructure planning, and emergency preparedness in response to climate change

AQS Air Quality System

Base Vulnerability The set of characteristics in individuals that are, more or less, equally problematic across all climate hazards

BRACE Building Resilience Against Climate Effects

CCVA Climate Change Vulnerability Assessment

CDC Centers for Disease Control & Prevention

Climate The conditions of the atmosphere over long periods (at least 30 years) of time

Climate Change A significant change in the measures of climate lasting for an extended period of time

CMAQ Community Multiscale Air Quality

COPD Chronic Obstructive Pulmonary Disease

Dew Point Temperature below which water condenses to form dew; dew points ≥ 70°F are uncomfortable for humans

DNR Department of Natural Resources

Drought An extended period of time with below normal amounts of precipitation

EHE Extreme Heat Event

Environmental Risk Factor Aspect of the environment that exacerbates the negative impacts of a climate hazard; is independent of the characteristics of the individuals living there

EPA Environmental Protection Agency

Extreme Heat Event Characterized by an abnormally high heat index

Extreme Weather Event Severe weather event, such as a heat wave, violent thunderstorm, or blizzard

FEMA Federal Emergency Management Agency

Flash Flood Occurs in the summer or early fall due to heavy rains; characterized by a rain event of six or more inches within a 24-hour period

General Flood Occurs during the spring as a result of melting snow & spring rain; usually occurs within floodplains near large rivers & lakes

GHG Greenhouse Gas

GIS Geographic Information System

Global Warming The primary mechanism for climate change; occurs as a result of the accumulation of atmospheric greenhouse gases

Greenhouse Gas Gases, such as carbon dioxide, water vapor, and methane, that trap heat within the atmosphere

Ground-Level Ozone Air pollutant formed when chemical byproducts of fossil fuel combustion react with oxygen in the presence of sunlight and heat

HA Human Anaplasmosis

Hazard	A weather event, environmental condition, or biological threat that can harm individuals, property, ecosystems, or livelihoods
Hazard-Specific Vulnerability	Refers to characteristics in individuals that are particularly pertinent to a climate hazard
Heat Advisory	Refers to less serious conditions; max heat index at MSP is expected to be ≥ 95°F for 1 day OR max heat index is expected to be ≥ 95°F with an overnight low no cooler than 75°F for 2 consecutive days
Heat Index	Measures how hot the weather feels to the body; takes into account temperature and dew point temperature
Heat Warning	Refers to life-threatening conditions; Max heat index at MSP ≥ 100°F for 1 day OR when a heat advisory is expected 4 consecutive days
Impact	In terms of health, the overall severity of a climate hazard; determined by the combination of individual vulnerability and environmental risk factors regarding a specific climate hazard
Impervious Surface	Surfaces that are impenetrable (e.g., rooftops, roads, parking lots)
Invasive Species	Non-native to a given region as well as negatively affect the environment, economy, or human health
MDH	Minnesota Department of Health
Mitigation	The promotion of activities to reduce harmful air emissions
MPCA	Minnesota Pollution Control Agency
MSP	Minneapolis–Saint Paul International Airport
NAAQS	National Ambient Air Quality Standards
Normalized Treatment	Data are manipulated to demonstrate a percentage of the total container population
NWS	National Weather Service
$PM_{2.5}$	Particulate matter 2.5 microns or less in diameter; air pollutant produced directly from fossil fuel combustion and indirectly from atmospheric reactions of precursor emissions
SPRCPH	Saint Paul–Ramsey County Public Health
Standard Treatment	Absolute numbers from census data are used
Urban Heat Island Effect	Little vegetation & ample impervious surfaces in urban areas lead to the absorption of the sun's heat during the day, which is then released at night, resulting in warmer temperatures than in rural areas
Vector-Borne Disease	A pathogen transmitted to humans and animals via the bite of an infected insect, usually a tick or mosquito
VOC	Volatile Organic Compound
Vulnerability	The characteristics and situation of a person or group that negatively affect their ability to anticipate, adapt to, and recover from the effects of a climate hazard
Vulnerability Assessment	Identifies and geographically maps characteristics of vulnerability in a given area
Weather	The conditions of the atmosphere over a short period of time
WNV	West Nile Virus

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