SAINT PAUL

The Most Livable City in America

Strategic Framework for Community Resiliency

Contents

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Preface

Though many of its impacts will create difficulty for Saint Paul residents, climate change also could be an opportunity for the city's neighborhoods and communities to collaborate in ways that enhance the well-being and security of all.

Climate resiliency practice demands that cities hone their resiliency toward environmental threats in order to mitigate the risks posed, as well as to ameliorate the current shocks and stressors currently impacting the municipality's environment. Due to the continued occurrence of extreme weather events in Minnesota and other effects of a changing climate, the City of St. Paul seeks to develop a comprehensive resiliency plan to combat the shocks and stresses it could plausibly endure over the next 30 years. The framework will help the City integrate climate resiliency strategies into existing emergency management and community planning documents and increase the community's adaptive capacity while promoting a healthy and prosperous community and to continue to make Saint Paul "The Most Livable City in America".

Beginning in the spring of 2015, the City of Saint Paul began to undertake a strategic climate resiliency framework initiative which includes conducting an assessment of climate change impacts and forming multi-discipline, multi-jurisdiction working groups to examine the areas of potential hazards, exposures and vulnerability.

The guiding principles through which we invite stakeholders to engage in community resilience are to:

- Incorporate climate change adaptation into relevant local and regional plans and projects.
- Establish a climate change adaptation public outreach and education program.
- Build collaborative relationships between regional entities and neighboring communities to promote complementary adaptation strategy development and regional approaches.
- Establish an ongoing monitoring program to track local and regional climate impacts and adaptation strategy effectiveness.
- Review and update heat response plan in light of climate change (heat events) projections
- Partner with existing public health community outreach and engagement efforts.

Based on this framework initiative, and the input from multiple working groups, the City will develop a strategy to incorporate climate change adaptation into relevant local and regional plans and projects and outline ways to best communicate the climate changes impacts to the broader community. The success of this project will be determined by the City's ability to establish a cohesive cross-disciplined collaborative team that will outline strategies and procedures to better prepare the City to respond and adapt to the changing climate.


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75

Motivation

As with any city in the world, St. Paul experiences a variety of shocks and stresses. To maintain its status as “Most Livable City in America”, the City of St. Paul has worked to understand the range of plausible shocks and stresses it could experience in the next 30-50 years.

The top shocks mentioned were flooding (20%), severe thunder storms (11%), infrastructure failure (10%), and winter storms (9%).

20% 11% 10% 9%

The top stresses mentioned were aging/ overwhelmed infrastructure (17%), insufficient funding (15%), and lack of trained professionals.

17% 15% 10%

Shocks and Stresses

In July 2015, the City of Saint Paul performed an expert elicitation of volunteer stakeholders. Participants were provided with the following definitions but were allowed to determine what they thought were shocks and stresses.

ACUTE SHOCKS: Sudden, sharp events that threaten a sector. Examples include floods, heat waves, infrastructure failures, disease outbreaks, and a terrorist attack.

CHRONIC STRESSES: Ongoing condition that weakens the fabric of a city on a day-to-day or cyclical basis. Examples include unemployment, aging infrastructure, declining/ aging population, and an overtaxed or inefficient public transportation system.

SEVERITY: How bad will it be in your sector if this occurs?

LIKELIHOOD: How likely is this to happen?

Participants were then told to brainstorm first individually and then in a group to determine what shocks and stresses affect the City of St. Paul. In an expert elicitation of St. Paul staff, the top shocks mentioned were flooding (20%), severe thunder storms (11%), infrastructure failure (10%), and winter storms (9%). The top stresses mentioned were aging/ overwhelmed infrastructure (17%), insufficient funding (15%), and lack of trained professionals to support the population (10%). Several of these are climate related, and may worsen in the future.

INFRASTRUCTURE AGING/OVERWHELMED

Infrastructure was rated highly as both a shock and a stress.

Infrastructure in the City of Saint Paul is rated on a 1-5 scale, with 5 being the worst. While the City does not have any infrastructure rated a 5, some structures are rated at a 4. This may be because of the age of the infrastructure; most of the airport infrastructure was constructed between 1950 and 1975, the District Energy St. Paul infrastructure is thirty years or older, the buildings/ facilities owned and operated by the City of Saint Paul are over 30 years old, and the St. Paul Port Authority infrastructure is nearing the end of its intended design life. Furthermore, roadways, traffic signal systems, roadway light, roadways signs, sewer pipeline systems and bridges are rapidly deteriorating and need dollars to catch up to where they should be for transportation and economic growth.

All infrastructure systems are designed and built with reliability and redundancy at the forefront, and thus many utilities, government agencies, and nonprofits investments include maintenance and operations. While some critical infrastructure can be maintained indefinitely, some are aging. For instance, the St. Paul Port Authority is experiencing sink holes behind the dockwalls due to soils seeping out below or through holes in the existing infrastructure, which will continue to get worse until they have the resources to perform repairs and replacement of aged infrastructure.

Needed improvements are being addressed through an on-going $100 million capital improvement program that is focused primarily on rehabilitation. In addition, there are several examples of new infrastructure. For instance, the Energy Park Utility Company has recently upgraded its distribution system and production assets are also closely managed.

The Future Climate

Many of the shocks and stresses identified are related to the weather, and thus the City of St. Paul conducted a comprehensive literature review (aided by experts in the field) regarding what could happen to the future weather and climate.

Climate change is no longer an issue distant in time or geography. Climate scientists have documented that human activity has become the driving agent of global climate change. Global climate change's hallmark is the infusion of additional heat energy into climate systems. Impacts of climate change include melting ice sheets, biodiversity losses, changes in animal migration patterns, changes in extreme weather events, higher food and commodity costs, and increased financial risks for companies.

Though we understand the broad scope of likely changes due to climate change, it is difficult to predict exactly how climate change will impact specific people and places. Even small changes in a single factor from which these storm systems form can have significant consequences. Some changes that will result from additional heat in severe weather patterns are easy to predict, others are clouded by the complexity of the systems we still don't understand well under normal conditions. The City of Saint Paul is just beginning to experience the effects of climate change on citizens' immediate economic, physical, environmental, and psychological well-being.

The two main assessment reports, the National Climate Assessment[1] and the Intergovernmental Panel on Climate Change Assessment Reports[2], are in good agreement on what will happen in St. Paul, MN in the future. Specifically, Saint Paul will become warmer and wetter. Let us review some of the climate science for changes in temperature, precipitation, severe storms, and other impacts.

1 Pryor, S. et al., 2014. Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 418-440.
2 Intergovernmental Panel on Climate Change, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

TEMPERATURE

Summers in the City of St. Paul are often hot, and heat indices can exceed 120°F. Heat waves—defined here as three or more consecutive days of temperatures at or above 90 degrees—are another extreme weather threat to Saint Paul. These events can be even more severe within the city due to the urban heat island effect (where a city's air temperature may be as much as five to ten degrees Fahrenheit warmer than in neighboring counties, particularly at night), disproportionately impacting certain neighborhoods.

Air temperatures are rising, and. In the St. Paul region, the annual average temperature has warmed 3.2°F from 1951 to 2010[3], with eight of the ten hottest years during 1901-2013 occurring since 1979[4]. On July 19, 2011, an extraordinary combination of high heat and humidity made Moorhead the hottest spot on the planet with a heat index of 135oF. Temperatures are expected to rise another 4-5°F by 2041-2070, resulting in 5-10 more days annually reaching over 95°F where heat warnings are triggered, a 200-300% increase over the long-term historical and recent 30-year averages for the Twin Cities[5]. These changes will bring heat waves, increase need for air conditioning, and change the growing season. For instance, over the last fifty years the local growing season has increased by 16 days, and by 2070 the growing season is predicted to be 25-35 days longer[6].

Temperature changes also inversely affect snow and ice cover. Based on data from the National Centers for Environmental Information, although Minnesota is warming in all seasons, winter is warming at ten times the rate of summer[7]. Winter season average temperatures have increased 3°F in the City of Saint Paul from 1951 to 2010[8]. For instance, over the last 20 years April snow cover has declined by 50%. More occurrences of winter rain (instead of snow) or freeze-thaw cycles can damage roads and bridges and lead to increased use of deicer material such as chloride. In addition, warmer winter air combined with greater moisture will likely result in heavy snowfalls, which could increase thawing floods. Furthermore, ice cover on the Great Lakes and other inland lakes has been decreasing, resulting in earlier ice-out dates and less seasonal ice cover. With longer periods between snow fall and wild temperature swings we may see more events like the 2014/2015 issues with deeply frozen ground and no snow cover causing freezing and bursting of deep utility pipes.

Temperature changes will have a multitude of impacts throughout the City of Saint Paul. For instance, scientists expect a warmer world to bring changes in "disease vectors"—the mechanisms that spread some diseases. Insects previously stopped by cold winters are already moving to higher latitudes (toward the poles). Warmer oceans and other surface waters may also mean severe cholera outbreaks and harmful bacteria in certain types of seafood. Still, changes in land use and the ability of public health systems to respond make projecting the risk of vector-borne disease particularly difficult. (http://www.climatehotmap.org/global-warming-effects/health.html). Lack of sufficient winter length to kill pests such as the emerald ash bore or tree coverage, due to both changes in temperature/ precipitation as well as, is expected to change.

3 Pryor, S. et al, 2014. Synthesis of the Third National Climate Assessment for the Great Lakes Region. Available at [http://glisa.umich.edu/media/files/Great_Lakes_NCA_Synthesis.pdf].
4 Harris et al., 2014. Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset. International Journal of Climatology. 34(3), 623-642. Data provided here
5 Minnesota Department of Natural Resources. Retrieve Climate Data from NWS Reporting Stations. Available at [http://www.dnr.state.mn.us/climate/historical/acis_stn_data_monthly_table.html?sid=mspthr&sname=Twin%20Cities%20Area&sdate=por&edate=por&element=maxt&span=annual&counts=cnt_ge_95]
6 Pryor, S. et al., 2014. Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 418-440.
8 Pryor, S. et al, 2014. Synthesis of the Third National Climate Assessment for the Great Lakes Region. Available at [http://glisa.umich.edu/media/files/Great_Lakes_NCA_Synthesis.pdf]. extracted by City of Saint Paul staff.

Other impacts include less tree cover, less big game, and more disease vectors.

PRECIPITATION

Minnesota's climate has grown wetter with time, and the St. Paul region has seen some of the largest changes in the state. Precipitation since 1895 has increased at an average rate of over 1% per decade, with significantly sharper increases since 1950. Since a relatively dry period ended in the 1950s, the St. Paul area's annual precipitation has increased by approximately seven inches, which is equivalent to 7 billion additional gallons of rain falling on St. Paul. With annual precipitation projected to be 3-6 inches higher by mid-century (2041-2070)[9], St. Paul can expect several billion additional gallons of rain over what it currently receives each year.

Additionally, the heaviest rainfalls have become both larger and more common. Since the year 2000, there have been more 2-inch daily rainfalls in the Twin Cities, and more widespread, 6-inch, "mega" rainfall events in Minnesota than at any other time on record, back into the 1800s. Both the frequency and intensity of heavy rainfall are projected to increase as well[10]. The increases in total precipitation and heavy rainfall events mean increased potential for flooding and associated problems within St. Paul.

St. Paul faces three types of flooding threats from increased precipitation: First, prolonged wet periods lasting weeks or months can produce unusually high lake and river levels that flood low-lying areas and shut down recreational opportunities at parks and trails. Next, on shorter time scales, extreme rainfall lasting a period of hours can overwhelm drainage systems, leading to dangerous flash-flooding that threatens human safety and damages public and private property.

Lastly, deep winter snows can melt quickly during spring and overflow the Mississippi River and backwater lakes. Although all three types of flood threatss can be expected into the future, it is the warm-season floods from prolonged wet spells and from extreme rainfall that have increased notably during the past few decades and are projected to worsen in the years and decades ahead. Prolonged wet periods arise when the weather pattern remains favorable for stormy conditions over a large area for a period of weeks or months.

Although these patterns may not lead to individual cases of flash-flooding, the long duration of wetness combined with the large geographic area affected, results in standing water in fields, backed up drainage systems, and an extended period of elevated lake, stream, and river levels. One such instance occurred from May through August of 1993, and produced catastrophic flooding along the Mississippi River from St. Paul through Louisiana[11]. June 2014 was the wettest month on record for the state of Minnesota, and was marked by many different days with heavy rainfall, resulting in flooded basements, damage to some roads, scattered landslides, and a Presidential Disaster Declaration for 36 Minnesota counties[12, 13].

Flash-floods occur when strong thunderstorms stall or regenerate over a relatively localized area for a period of hours, producing excessive rainfall that runs off quickly and leads to rapidly rising water near creeks, streams, and low-lying roadways. The greatest flash-flood in Twin Cities history occurred on July 23-24, 1987, when over 8-12 inches of rain fell over Minneapolis and the southern suburbs, causing two deaths, destroying or stranding thousands of cars, flooding hundreds of basements, and rupturing dozens of storm sewer lines. The storm was part of a trend towards more intense and more frequent heavy rainfalls in Minnesota, with numerous additional mega-rainfalls in Minnesota during recent years. Currently, a 100-year storm—one with a 1% chance of occurring in a given year—would produce over 7 inches of rain in 24 hours[14], and would easily flood all of downtown St. Paul, block roads, destroy infrastructure, and bring transportation to a standstill. Yet the evidence suggests that even these extreme storms will become more common in Minnesota by mid-century[15].

9 P Pryor, S. et al., 2014. Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 418-440.
10 Pryor, S. et al., 2014. Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 418-440.
11 Changnon, S. The Great Flood of 1993: Causes, Impacts, And Responses. Westview Press: Boulder, CO, 1996. AND National Climatic Data Center, 1993. The Summer of 1993: Flooding in the Midwest and Drought in the Southeast. Technical Report 93-04.
12 Minnesota Department of Natural Resources. Record-Setting Rainfall in June 2014. [http://www.dnr.state.mn.us/climate/journal/140630_wet_june.html].
13 FEMA. Minnesota Severe Storms, Straight-line Winds, Flooding, Landslides, and Mudslides (DR-4182). Available at [https://www.fema.gov/disaster/4182].

Even though precipitation has increased and is expected to increase over time, Minnesota still experiences episodes of severe drought and will continue to do so in the future. In fact, it is not uncommon for mega-rainfall events to occur during periods of expanded drought. For instance, the flash flood of July 1987 occurred as a major 3-year dry period was being established. In August of 2007, southeastern Minnesota received the heaviest rainfall ever recorded in Minnesota, at a time when over 85% of Minnesota was "Abnormally Dry" or drier on the US Drought Monitor[16, 17]. Similarly, the catastrophic Duluth-area flood of 2012 occurred immediately between two severe dry periods.

Projections of future climates suggest that even as precipitation and heavy rainfall increase, the number of consecutive days between rain events will also increase, meaning that drought may be present before, during, and after periods of heavy precipitation[18]. With higher temperatures leading to landscape transition and greater potential for vegetation die-offs, St. Paul will likely see additional slope failures during heavy rainfall events, with an increase in landslides and sinkholes. In instances during which flood levels are high enough or slope conditions too dangerous, some residents may need to relocate to temporary or alternative housing. Public works repair costs will increase accordingly, as these events become more common.

14 NOAA. Atlas 14 Point Precipitation frequency Estimates for Minnesota. Available at [http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=mn].
15 Pryor, S. et al., 2014. Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 418-440.
16 Minnesota Department of Natural Resources. 24-hour Minnesota Rainfall Record Broken: August 19, 2007. Available at [http://www.dnr.state.mn.us/climate/journal/24hour_rain_record.html].
17 Minnesota Department of Natural Resources. Heavy Rains Fall on Southeastern Minnesota: August 18-20, 2007. Available at [http://www.dnr.state.mn.us/climate/journal/ff070820.html].
18 Pryor, S. et al., 2014. Ch. 18: Midwest. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 418-440.

1860 1870 1880 1890 1900 1910 1920 1930 19

1866-1965 Four mega-rains in 100 years	**AUG. 6 1866** Killed 16 people in Fillmore County	**JULY 17-19, 1867** Known as the state's greatest flash flood, in central Minnesota.
1966-1999 Three mega-rains in 33 years	**JULY 21-22, 1972** Nearly 11 inches in 24 hours at Ft. Ripley, state record at the time.	**JULY 2** Intense rain in northwestern Minnesota in two events
2000-2014 Five mega-rains in 14 years	**JUNE 9-10, 2002** More than 12 inches in 48 hours in northen Minnesota	**SEPT. 14-15, 2004** More than 1o inches in 46 hours in Faribault and Freeborn counties.

40 1950 1960 1970 1980 1990 2000 2010 2020

JULY 20-22, 1909
Extensive across northern Minnesota, killed 2 children in Duluth.

SEPTEMBER 9-10, 1947
More than 8 inches in five hours at Hibbing.

JULY 23-24, 1987
9 inches at Minneaplois-St. Paul international Airport, a reciord.

AUG. 18-20, 2007
15 inches near Hokah, stae record for 24 hours.

SEPT. 22-23, 2010
More than 10 inches at Amboy.

JUNE 19-20, 2012
7 inches in two days in Duluth, St. louis river at Record level

No Regrets Options yield benefits even in the absence of climate change. Example: Technology for reducing greenhouse-gas emissions offer other benefits such as increase efficiency or reduced energy costs. These other benefits may make the investment worthwhile for those reasons alone.

Our Response

St. Paul is already a leader in resilience.

Many different St. Paul professionals have similar goals of resilience via hazard mitigation, climate adaptation, disaster risk reduction, and sustainability. We can streamline individual efforts within these and other communities by combining resources, using existing climate change data, and coordinating within existing planning processes. In a time of shrinking resources, these connections will help us leverage funding and technical assistance and work together to seize opportunities. In addition, by collaborating with both public and private stakeholders as well as with the everyday citizen, we can increase the opportunity to identify no regrets options that yield benefits even in the absence of climate change.

Strategy for Community Resiliency Project Process

THE MAJOR STEPS IN THE FRAMEWORK PROCESS ARE:

1 RESEARCH

Research and identify best and promising practices, and review case studies and academic papers, to identify the potential impact of climate change and the best of breed resiliency program components to address these impacts.

2 ASSESS

Use available information and data to help identify the hazards impacted by climate change and assess the City's vulnerability to these hazards. Work to identify those most vulnerable groups and sectors and use this information to develop a basis for a resiliency plan.

3 ORGANIZE

An adaptation strategy should be developed with a whole community approach and consider the use of resource-based sector working groups to facilitate stakeholder participation. Work to develop a large group of stakeholders and organize them into working groups. Workshops will be held to engage and educate the stakeholders and to beginning the process of identifying options for adaptation. Each working group is tasked to identify adaptation strategies for short, intermediate and the longer term implementation.

4 PLAN

Develop a Community Resilience Plan based on the assessments of hazards and vulnerabilities, as well as the impact of climate change. Work with the community to develop a Strategy that includes preparedness goals and select priorities for inclusion in an implementation plan based on identified activities. Based on the identified activities and priorities, work with stakeholders to develop adaptation strategies for short, intermediate and the longer term implementation.

5 DOCUMENT

The final Strategic Framework for Community Resiliency Plan (the Framework) will be drafted and circulated for comments before being delivered as a final draft for consideration by the City. The Framework will include the prioritization of actions to include in a Climate Action Plan. Everyone should coordinate and integrate this planning with other efforts such as existing hazard mitigation strategies and other related efforts.


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RIGHT LANE


MINNEAPOLIS
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Implementation Plan

The City of Saint Paul has undertaken a strategic climate resiliency framework initiative which includes conducting an assessment of climate change impacts and forming multi-discipline, multi-jurisdiction working groups to examine the areas of potential hazards, exposures and vulnerability. The areas of focus include Economic and Social Well-Being, Emergency Response and Health Systems, Infrastructure, and Natural Resources. Based on this framework initiative, the City will develop a strategy to incorporate community resilience into relevant local and regional plans and projects and outline ways to best communicate efforts to the broader community.

Project Steps

1. Kick-off meeting and (electronic) document collection for research task and build sector specific working groups *(Held July 9, 2015)*
2. Research climate ristks and impacts, best adaptation and resiliency strategies.
3. Convene core team to share research and assessment findings with core team, City staff and agency representatives – *(September 2015).*
4. Draft initial Climate Resiliency Framework and conduct meetings with all work groups and core team to discuss draft. – *(December 2015; March 2016)*
5. Second draft of Climate Resiliency Framework and review with core team and work groups for comments and finalize draft *(March 2016).*
6. Complete Climate Resiliency Framework; deliver final files *(May 2016).*

Performance measurement and monitoring components

The success of this project will be determined by the City's ability to establish a cohesive cross-disciplined collaborative team that will outline strategies and procedures to better prepare the City to respond and adapt to the changing climate. The framework will help the City integrate climate resiliency strategies into existing emergency management and community planning documents and increase the community's adaptive capacity while promoting a healthy and prosperous community and to continue to make Saint Paul "The Most Livable City in America".

Economic and Social Well-Being

Climate scientists have documented that human activity has become the driving agent of global climate change. In shaping the narrative of the impacts of climate change, the melting of ice sheets, biodiversity losses, and changes in animal migration patterns, etc. are often stressed; yet the effects of climate change are beginning to inflict a mounting toll on our economic physical, environmental, and psychological well-being.

Definition of sector

Economic and social well-being will address quality of life, which includes socioeconomic, political, health, and cultural effects of climate change on residents of Saint Paul, especially on vulnerable populations.

EXAMPLES OF TOPICS INCLUDE:

- Entrepreneurship
- Business generation and development
- Diversity
- Social Equity
- Community Capacity and Social Networks
- Job creation and barriers to job creation
- Career pathways
- Green procurement
- Economic development

The list is not extensive, yet areas such as education and workforce development are not specifically addressed because educational institutions and partners have direct influence in these areas. The City of Saint Paul will continue to work with partners to promote advancements in the space.

What has happened in the past

In 2013, Minnesota had some of the highest weather-related disaster claims in the country[19]. Climate change is extending the growing season in Minnesota, which could be a benefit to a state with a strong agriculture industry, but climate change also is making the state vulnerable to more extreme weather events, invasive species, and plant diseases. Specifically, climate change brings other stressors, such as emerald ash borer, that have the potential to sharply diminish the perceived livability of Saint Paul's neighborhoods. The near certain loss of thousands of ash trees with the potential loss of other mature trees through severe storms could exacerbate urban heat in coming summers by reducing evaporative cooling. Now shady avenues are likely to become stifling streets if the city and citizens do not collaborate quickly on large-scale preemptive tree planting.

What could happen in the future

Climate change will have wide-ranging political, community, and cultural consequences. Climate change has the potential to strain relations between residents and government, if city services fail to respond promptly to resident needs. Impassible or washed out roads from extreme snowfalls or rainfalls falls could be perceived as botched governance rather than a result of climate change. Citizens must be made aware that aging City infrastructure faces growing stresses due to climate change and the infrastructure was not originally designed to accommodate these increased variances. A sense of shared accountability for public infrastructure needs to be cultivated. The City is and will continue to be responsible for large-scale and heavy maintenance but citizens can have roles to play (especially through theirs eyes and ears) in helping to identify small problems before they become large ones.

Climate change has the potential to diminish the city's traditions. The beloved institution of the Winter Carnival, for example, may come to feel anachronistic and awkward as the hard northern winters become increasingly rare and bygone and other Winter celebrations could become increasingly challenging to conduct in a warming world. What city celebration would there be when one of its claims to fame is no longer germane?

The growing disparities among various populations in Saint Paul demands greater attention on minimizing climate-related impacts on at-risk groups. For instance, as the City of Saint Paul continues to experience increasing numbers of days with high temperatures and dew points, air conditioning in the summer is going to become as essential to the livability of a house or an apartment as heat in the winter. More affluent residents likely will have the resources and access to climate change resilient solutions. They can install air conditioning to shield themselves from high heat and humidity. They can invest in on-site backup power generators to defend themselves from power disruptions caused by severe storms. And they can afford sump pumps, larger gutters and downspouts to enhance the protection of themselves and their property from extreme rainfalls. Poorer residents, who cannot afford to invest in air conditioning or backup power generators, will need assistance.

19 CBS, 2014. Minn. May Lead US in 2013 Natural Disaster Claims. Available at [http://minnesota.cbslocal.com/2014/01/09/minn-may-lead-us-in-2013-natural-disaster-claims/]


LANDMARK

Economic well-being often correlates with access to remedies needed in response to climate change. Planting shading trees, access to clean water, and installing mechanical systems to purify the air are examples of coping strategies in an increasingly erratic climate. Even as the City and its partners work to reduce its greenhouse gas emissions, limiting climate change will be largely outside of the City's control. This circumstance mandates that the City design and implement flexible solutions that can benefit all residents without knowing what the future may hold. Equity, ultimately, plays an influencing role in identifying strategies that have multiple benefits at lower-cost and with equal access.

Strategies

Within Economic and Social Well-Being, the City of St. Paul has identified the following strategies:

1. Raise Awareness About Vulnerabilities and Solutions
2. Ensure Financial and Social Access to Energy
3. Communicate About and Help to Prevent Urban Flooding

Initiatives

The largest challenge in identifying mitigation strategies for this sector is that the City is limited in what it is able to control or remedy. The City cannot dictate the markets and control the prices of goods and services. The City cannot create laws to ban fossil fuels. The City cannot hire enough individuals to eliminate poverty.

Racial tensions, yawning disparity gaps, and educational shortfalls are intertwined and finding solutions require multi-stakeholder engagement. This is where the City can be integral to improve the conditions for economic and social wellbeing. Rather than prescribe certain programs or offer particular solutions, we instead suggest a range of strategies guided by a set of principles. We propose that the City explore initiatives that include the following criteria:

- Encourage resident involvement. This has a range of positive outcomes, including helping individual residents build new skills, and encouraging residents to work together to address issues before they become major problems.
- Strengthen existing social networks and facilitate new connections between individual residents across the city. Strengthened social networks will not only help protect against crime, they will also help the spread of important information to residents, and will help ensure that otherwise difficult to reach individuals can be reached in times of emergency.
- Open communication channels between the City and neighborhoods.
- Keep access and inclusion at the forefront. As tensions rise in times of difficulty, research shows that people are prone to inter-group conflict. Thus, some individuals may feel excluded from City services, or fear they will not be welcomed at facilities because of their race, ethnicity, sexual orientation, gender, or gender identity. The City can prepare for this by offering diversity training in advance and adhering to a strong inclusion policy.

Following are some examples of initiatives that the City could pursue by employing the above criteria:

RAISE AWARENESS ABOUT VULNERABILITIES AND SOLUTIONS

An often overlooked element of climate change mitigation is raising awareness and finding a communal answer that fits the needs of those in a specific area. As noted above, the exact impacts of climate change in specific places and on individual people are hard to predict. For example, higher elevated areas of the City may be more vulnerable to particular climate-change related threats like shear winds than areas nearer to the Mississippi River, which are more vulnerable to flooding. Shaping messages, garnering resident participation, and engaging in an ongoing dialogue help move the City and its residents from a reactionary perspective to a proactive one. Options include:

- More PSA and share with partners. Achieve multi-format and recognize saturation
  (Work with schools and cultural group organizations to share information)
- Identify communication networks and work with them on warning and recovery (storms, outreach
  (Community and culturally specific networks must be mapped to better understand how varying groups communicate and receive information.)
  - Cultural
  - Technological

ENSURE FINANCIAL AND SOCIAL ACCESS TO ENERGY

Access to electricity becomes more critical at times of duress such as during heat waves that stress both electrical equipment and citizens. If service disruptions increase due to climate change, then people may seek solutions that exacerbate disparities rather than seeking holistic, long-term strategies. For example, the city cannot prevent people from investing in backup electrical generation but it can take steps to minimize the appeal of this option by working with power companies to enhance the reliability and durability of the electrical grid throughout the city.

A home that lacks adequate heat during winter is not considered suitable for habitation in Saint Paul. A review and adjustment of housing codes may be needed to reflect the growing likelihood that air conditioning will become not just an amenity but increasingly a necessity. Given that low-income populations tend to rent, the City of Saint Paul may want to make minimum requirements for shading and/or cooling for a certificate of occupancy for any rental housing.

COMMUNICATE ABOUT AND HELP TO PREVENT URBAN FLOODING

Extreme rainfall events raise the risk of runoff overwhelming the city's storm water system and causing urban flooding. Residents should be informed about this increased risk and be encouraged to consider taking proactive steps, such as recognizing vulnerable low spots like basement floors and reducing exposure to rising waters, to minimize losses if storm waters gain access to homes and businesses. Looking farther afield, everyone can play a role in helping to ensure that the urban drainage system operates at maximum capacity.

Mature trees are absolutely essential to the livability of the City of Saint Paul in a warming world but the City's urban forest is facing increasing stresses. The City is very effective and efficient at planting trees. The challenge is keeping young trees alive during their first few years when they are getting established. The City does not have the capacity to care for thousands of young trees, especially during dry spells when all of them are stressed at the same time. Saint Paul residents should be encouraged to adopt young trees on both private and public property with the understanding that they will endeavor to keep the trees under their care well-watered and alive for at least five years.

The City of Saint Paul has thousands of catchment basins that collect storm water off of streets and direct it into the underground storm water drainage network. The city does not have the wherewithal to ensure that all catchments are clear of debris at all times. Just as people take responsibility for shoveling out fire hydrants in the winter, Saint Paul residents should be encouraged to adopt catchment basins near their homes, schools, businesses and places of worship and keep them clear of obstructions so as to help reduce the potential for urban flooding during extreme rainfall events.

Other options include:

- Incentives/ reallocate funds for flooding reduction, such as in back flow preventers
- Master pruner program that considers workforce development, equity, and job training
- Adopt a storm drain program that could help in storm cleaning vs. sweeping, and to capture insider knowledge
- Identify City drains with the higher likelihood of stress and create adoption programs in those geographies to help with cleaning and sweeping
- New construction/ retrofitting, including keeping expensive equipment out of basement
- Work with insurance agencies to identify areas and strategies to communicate dangers and avoid unnecessary damages/losses
- If no replacement, leave it out of the basement (family heirlooms that are irreplaceable)


ST. PAUL FIRE
BLS UNIT
51


FIRE STATION
ROAD CLOSED

Emergency Response and Health Systems

The City of Saint Paul and Saint Paul - Ramsey County Public Health have a role in collecting data, conducting surveillance on community health concerns, and tracking trends in environmental risk, health outcomes, and population vulnerability to specific climatic events. Health vulnerability assessments can ensure that climate-related trends are incorporated into broader planning processes, and that interventions designed to address climate change do not further exacerbate existing health disparities in the community. Vulnerable populations at increased health risk from climate change include children, elderly people, those living in poverty, people with underlying health conditions, and people living in certain geographic areas.

Definition of sector

Emergency response and related health systems are critical systems in the City of Saint Paul. Professionals in these areas work to identify opportunities to reduce risks and impacts to people, property and the environment. Efforts and suggestions to adapt to a changing climate can help increase the resiliency of the City of Saint Paul and its community leadership.

The City of Saint Paul and Saint Paul - Ramsey County Public Health use the Building Resilience against Climate Effects (BRACE) framework developed by the Centers for Disease Control and Prevention (CDC) to support health departments in developing their climate change planning and response activities. The framework entails:

- Forecasting and assessing (identifying the scope of the most likely climate impacts, the potential health outcomes associated with those climatic changes, and the populations and locations vulnerable to these health impacts);
- Projecting the disease burden (estimating or quantifying the additional burden of health outcomes due to climate change);
- Assessing interventions (identifying the most suitable interventions for the health impacts of greatest concern);
- Creating the plan (developing and implementing a health adaptation plan for climate change that addresses health impacts, identifies gaps in critical public health functions/ services, and provides guidance for enhancing adaptive capacity); and
- Evaluating (reviewing the effectiveness of the process, and improving the quality of activities undertaken).

What has happened in the past

HEALTH

Many vulnerable populations at increased health risk. Saint Paul – Ramsey County Public Health conducted a social vulnerability assessment to generate maps highlighting areas in the county most affected[20].

Social vulnerability refers to the socioeconomic and demographic factors that affect the resilience of communities and is shaped by a variety of factors, including income, race, health, age, and others. A social vulnerability index can be used to identify geographic areas within a jurisdiction with heightened risk to projected climate impacts, and guide to policymakers as to where to target climate adaptation efforts. Effectively addressing social vulnerability decreases both human suffering and the economic loss related to providing social services and public assistance after a disaster.

A vulnerability assessment uses geographic data on the physical impacts of climate change (such as flooding), combined with data on selected indicators of social vulnerability that relate to these impacts (such as reliance on public transportation), and creates a composite picture of where exposure and vulnerability come together within a jurisdiction, showing the areas with heightened risk of being impacted by climate-related impacts.

[20] For questions or comments on data and methods, please contact Saint Paul - Ramsey County Public Health.

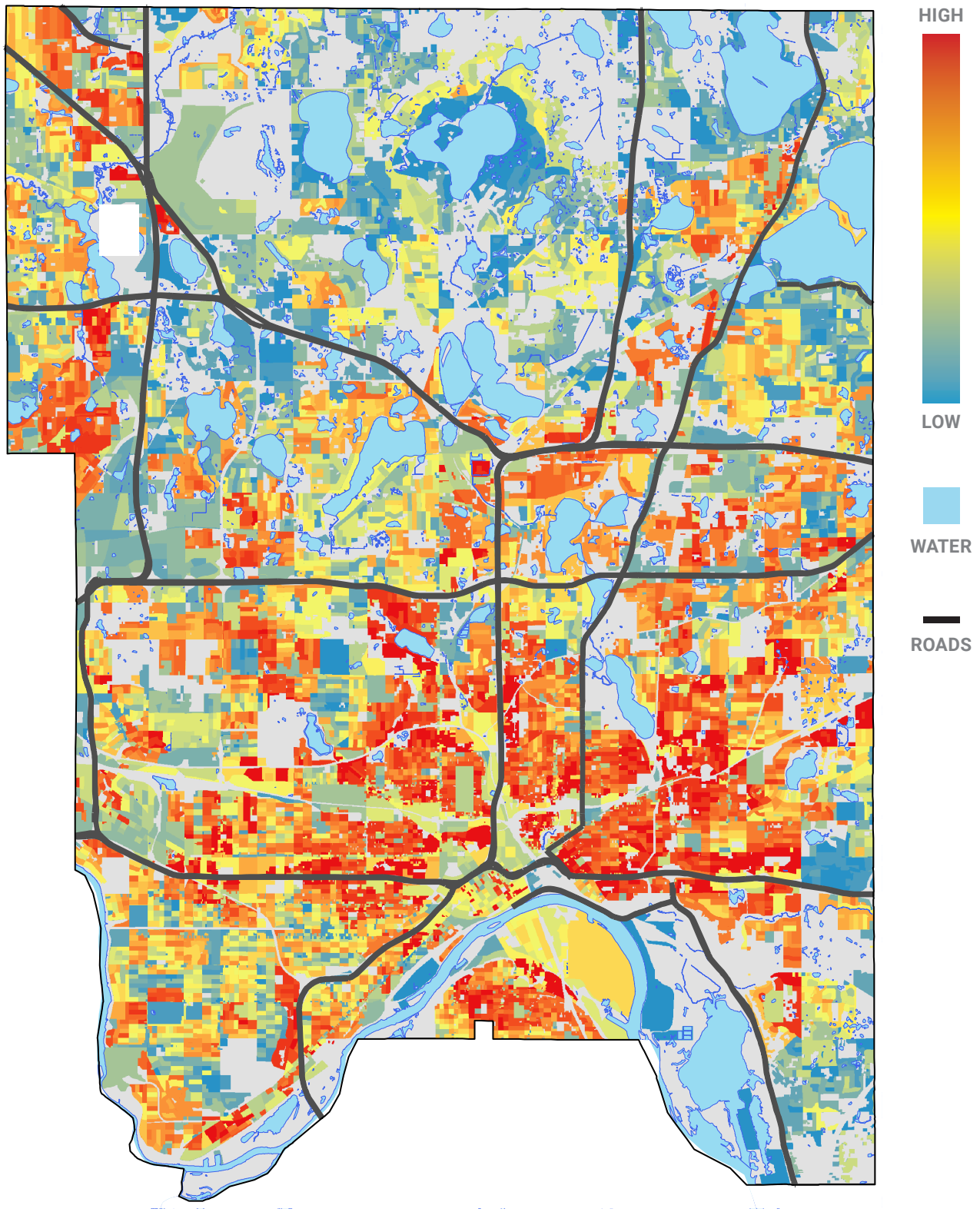
FACTORS TO CONSIDER IN A VULNERABILITY INDEX MAY INCLUDE:

- Unemployment
- Have jobs working outdoors (such as agriculture, forestry, mining, or construction
- Households in poverty
- No high school diploma
- Lacking health or home insurance
- Receiving disability benefits
- Households without a vehicle
- Single vehicle for multiple adults
- Households with limited English
- Single parents
- Adults over 65
- Adults over 65 and living alone
- Children under 1
- Children under 5
- Pre-term births
- Living with chronic health conditions
- Lacking access to health services
- Homelessness
- Renter-occupied households
- Subsidized housing
- Mobile homes
- Multi-unit dwellings
- Households without air conditioning
- Residents living in institutions (such as correctional facilities, nursing homes, hospitals, college dormitories, military housing, and shelters.
- Recent immigrants
- People identifying as any other race or ethnicity besides white.
- Impervious areas
- Tree canopy cover

A number of indicators were identified to represent the many contributors to social vulnerability within Ramsey County. The following table outlines each indicator as well as a justification for its selection (see Table A). The 13 indicators are categorized into five broad classifications (Socioeconomic Status, Age, Communication, Mobility, and Additional Indicators). An analysis of all 13 of the vulnerability indicators combined produces the following composite map of "base vulnerability" (figure 1). This map also reflects a consideration of land use in the county, with the assumption being that those living in residential areas are more vulnerable than those in commercial/business or vacant areas, as described in Table A under "Multiplier."

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.
Air			
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.
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.
People 16 years and older who walk or bike to work1	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.



Base Vulnerability of Ramsey County Residents (including indicators related to socioeconomic status, age, communication, mobility and other factors) *N = normalized treatment of the data, which reflects the percent of people in that geographical area displaying a given characteristic, as opposed to an absolute number. A technical report is available from Saint Paul – Ramsey County Public Health that provides more detailed data on standard versus normal measurements and the value of each kind of analysis for planning purposes.

Ramsey County's 2013 community health assessment identified air quality, extreme heat events, changes in the distribution and incidence of vector-borne diseases, and flooding as key climate-related issues that impact the health of our residents[21]. To assess the degree of impact each of these issues might have, risk factors and vulnerabilities specific to each one were combined to produce the impact assessment maps.

We note when looking at the impacts of climate change specifically, certain additional factors can also be considered, such as spending a lot time outside or lacking access air-conditioned environments (when it comes to extreme heat), or chronic respiratory diseases (when it comes to poor air quality).

AIR QUALITY

Ozone and particle pollution are specific components of air quality that are likely to be worsened by climate-related changes. Breathing air containing elevated ozone concentrations can reduce lung function, aggravating asthma and other existing respiratory conditions. Ozone exposure has also been associated with increases in respiratory infection, medicine use by asthmatics, doctor and emergency room visits, and hospital admissions. Small particulate matter is associated with cancer, cardiopulmonary disease and respiratory illness. For vulnerability to air quality, extra weight is applied to the selected indicators: people who spend relatively more time outside, children and the elderly, and those living with chronic health conditions such as asthma and COPD.

EXTREME HEAT

Air quality and extreme heat events are interconnected in that poor air quality often exacerbates health conditions caused by extreme heat and vice versa. Furthermore, heat and sunlight facilitate the production of ozone – an air pollutant. For extreme heat, specific vulnerabilities include: the elderly (especially older adults who live alone), children, people living in poverty, those without vehicle access, people who spend relatively more time outside, and those living with chronic health conditions such as asthma and COPD.

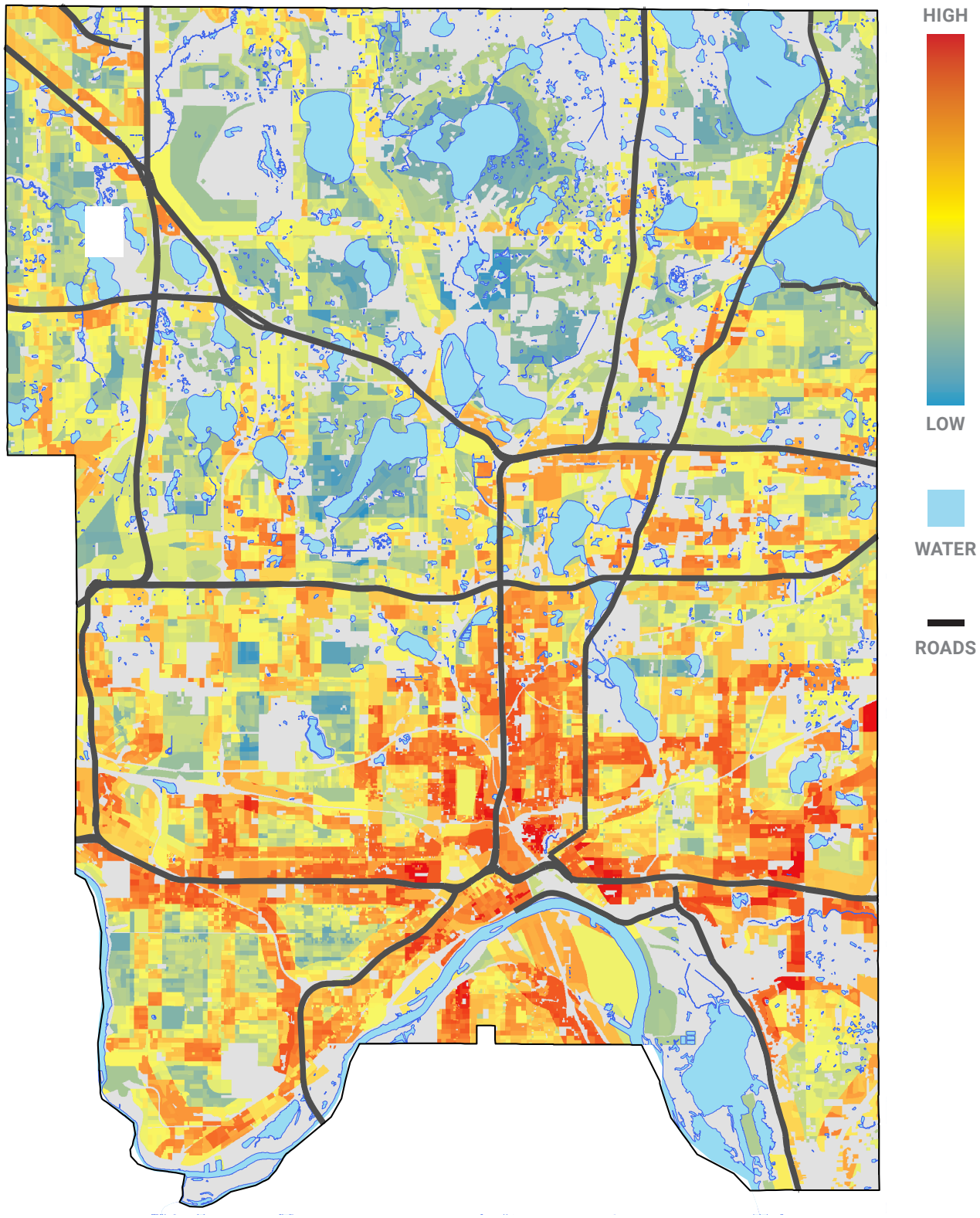
VECTOR-BORNE DISEASE AND FLOODING

Mapping vector-borne diseases such as West Nile Virus (WNV), the most commonly reported mosquito-transmitted disease in the state, are not particularly useful for public health planning purposes at the city or county level as exposure may or may not have taken place where the infected individual lives. While there has been at least one confirmed case of WNV in Ramsey County or an adjacent county every year since 2002 (when the first case was reported), areas of Minnesota with the highest incidence of WNV cases are stretched along the western border of the state. Saint Paul and Ramsey County may experience increased impact over time, as climate changes that facilitate transmission (such as rising temperatures and heavy rainfall events with interceding dry spells) intensify and thereby increase the risk of exposure. In that event, the elderly and people with certain medical conditions, such as cancer, diabetes, hypertension and kidney disease, would be especially vulnerable to severe manifestations of WNV.

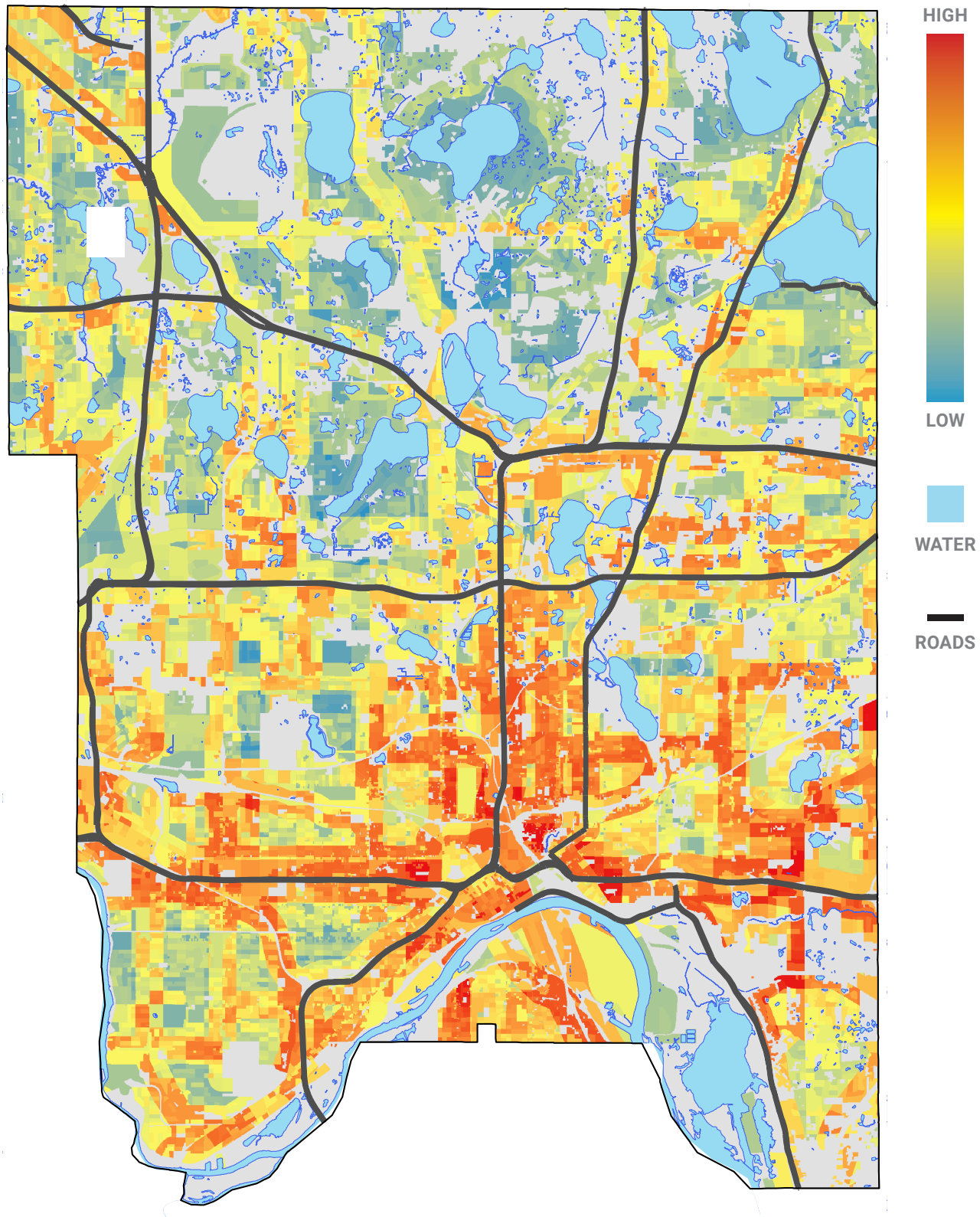
VIOLENT CRIMES

The City of Saint Paul Police Department has relied on the cold winters, to force people to retreat inside as opposed to committing violent crimes. For instance, the demand for service is very low in the cold winter months. As temperatures warm, the number of emergency (9-1-1) calls increase. An example of this was this the extraordinarily warm November and December 2015, when the City of Saint Paul experiences a rise in homicides to four in one week. Similarly, large groups of roving juveniles, rioting and committing crimes, are another call for service that increase during warmer months (starting in April and running through September).

21 Ramsey County. Public Health Data. Available at [https://www.ramseycounty.us/your-government/open-government/research-data/public-health-data].



Impact of Exposure to Air Pollutants Combined with Threat-specific Vulnerabilities of Ramsey County Residents



Impact of Extreme Heat Risk Factors Combined with Threat-specific Vulnerabilities of Ramsey County Residents

What could happen in the future

CLIMATE CHANGE AND HEALTH IMPACTS

Ultimately, what most concerns mental health professionals is the breadth of human suffering that will arise from climate change as its devastation unfolds. Millions of people are likely to exhibit some of the following symptoms in response to climate change's stressors: anxiety, post-traumatic stress, depression, interpersonal conflict and societal conflict, family stress, persistent grief, child behavioral and developmental problems and academic decline, eco-anxiety, hopelessness, and avoidance from the awareness of climate change. Some of these can persist for years after experiencing loss of homes, livelihoods, and community resources.

For instance, six months after the 2004 tsunami off the coast of Thailand, 57.3% of Thai students surveyed displayed symptoms of PTSD[22]. Five years later, 2.7% of victims still continued to suffer from PTSD . In another instance, from 1970 to 2007 in New South Wales, Australia, suicide in rural men correlated strongly with the drought index[23].

THE HEALTH EFFECTS OF WARMING

Extreme heat has important physiological effects. Thermoregulation becomes more difficult, particularly when the humidity level, and thus the heat index, is also high. This scenario substantially reduces the efficacy of the body's primary cooling mechanism—namely, sweat doesn't evaporate as quickly. Incidence of heat stress and other heat-related illnesses increase, particularly among vulnerable populations: the elderly, those with chronic illnesses, the mentally ill, the poor, those without a high school education, social isolation, etc.[24]. An example of a severe heat wave is the European heat wave of 2003 that killed more than 45,000 people and created a host of human stressors, anxiety, and depression for those who survived.

Climate change also affects air quality. While the mechanisms are complex, it is widely accepted that smog generally, and thus exposure to particulate matter and other pollutants, will increase with climate change. Smog aggravates respiratory conditions such as asthma and bronchitis. Worldwide air pollution causes around 41 thousand Americans to die prematurely each year[25]. Further, warmer temperatures and higher concentrations of carbon dioxide in the atmosphere stimulate some plants to grow faster, mature earlier, or produce more potent allergens. Common allergens such as ragweed seem to respond particularly well to higher concentrations of carbon dioxide, as do pesky plants such as poison ivy.

THE CRIMINAL EFFECTS OF WARMING

Increases in temperature are associated with increased aggression and higher rates of assaults, burglary, collective violence, domestic violence, and rape[26, 27]. Thus extreme temperatures render the job of first responders particularly difficult. Any extreme event manifests its impact most prominently within marginal demographics. In particular, while extreme temperatures affect the general population in important ways, those inclined toward criminality and citizens whose physical or mental health status is vulnerable are disproportionately affected. This means that a relatively small event has pronounced effects in the tails of a distribution: crime and health-related 911 calls increase disproportionately. The practical policy conclusion is that the emergency response system must have built-in excess capacity if the impacts of an increasingly variable climate are to be managed. Estimates suggest the size of the police force would need to increase by some 4% to mitigate the prospective increase in crime[28].

Clearly warmer temperature put added stresses and demands on Law Enforcement in the City of Saint Paul, including both the patrol division and also on the Homicide Unit. With there being limited over-time funding, the districts do not currently have the resources with only the patrol officers to a) prevent, intervene and apprehend these quality of life crimes, b) manage the district's call load, and c) keep burn out low among officers and Sergeants.

22 Climate Nexus, February 2015. Mental Health Report. Available at [http://climatenexus.org/mental-health-impacts].
23 Climate Nexus, February 2015. Mental Health Report. Available at [http://climatenexus.org/mental-health-impacts].
24 Bradford, K. et al., 2015. A Heat Vulnerability Index and Adaptation Solutions for Pittsburgh, Pennsylvania. Environmental Science & Technology. 49(19), pp 11303–11311.
25 World Health Organization (WHO). 7 million premature deaths annually linked to air pollution. Available at:[http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/]
26 Cohn, P.J., 1990. Preperformance routines in sport: theoretical and practical applications. The Sport Psychologist. 4, pp. 301-312.
27 Baron, R.; Bell, P., 1976. Aggression and heat: the influence of ambient temperature, negative affect, and a cooling drink on physical aggression. Journal of Personality and Social Psychology. 33(3), pp:245-55.
28 Statistic provide by City of Saint Paul Office of Emergency Management.

THE DISEASE EFFECTS OF WARMING

Disease occurrence is linked to climate. As the climate changes, adverse impacts to public health and the environment will occur. For example, warmer weather and precipitation changes are associated with the increase in West Nile virus. Extreme weather events impacting Saint Paul such as heat waves and severe droughts will trigger heat stress, heat-related illness in vulnerable populations and scarcity of safe food and water. Long-range changes in temperature and precipitation may result in increased respiratory illness, increased allergic reactions in response to environmental triggers such as pollen and mold, insect-borne infectious disease outbreaks, and food- and waterborne disease outbreaks. Short-term impacts include injury and death due to exposure to extreme weather, as well as mental and emotional stress in response to experiencing extreme weather-related emergencies.

Strategies

Within Emergency Response and Health Systems and the BRACE framework, the City of St. Paul has identified the following strategies:

1. Enhance Health and Wellness of Staff Supporting the City
2. Expand Current Green Infrastructure
3. Continue Community Outreach

Initiatives

ENHANCE HEALTH AND WELLNESS OF STAFF SUPPORTING THE CITY

A citizen's quality of life is strongly influence by health and wellness. These include innate characteristics, as well as city, state, and federal efforts to support health and wellness. In order to best support the City, our staff need to be well supported. This strategy needs to be considered in depth before pursuing, and could include some options such as:

- Improve stress management for public safety & public health personnel (talk to City Risk Management/EAP)
- Increase staffing and update workload expectations – doing more with less is not working – the new millennium generation does not want to work overtime, they want to be with their families
- Expand Psychological First Aid Programs (e.g., PFA Training)

EXPAND CURRENT GREEN INFRASTRUCTURE

Green infrastructure plays an important role in preparation for and recovery from natural disasters. The Environmental Protection Agency refers to green infrastructure as "storm water management practices that mimic natural processes by absorbing water, such as green streets, green roofs, rain gardens and pervious pavement[29]." Aquifer storage and recovery protects water from pollutants and evaporation yet takes advantage of seasonal variations in surface water runoff and high precipitation events. This strategy requires collaboration with other groups/departments. Factors to consider are:

- Storm water management, e.g. through permeable pavement or rain gardens
- Habitat for pollinators
- Natural landscape preservation and habitat for trees
- Soil stabilization
- Maintenance and job creation
- Changes in property value

22 Climate Nexus, February 2015. Mental Health Report. Available at [http://climatenexus.org/mental-health-impacts].
23 Climate Nexus, February 2015. Mental Health Report. Available at [http://climatenexus.org/mental-health-impacts].
24 Bradford, K. et al., 2015. A Heat Vulnerability Index and Adaptation Solutions for Pittsburgh, Pennsylvania. Environmental Science & Technology. 49(19), pp 11303–11311.
25 World Health Organization (WHO). 7 million premature deaths annually linked to air pollution. Available at:[http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/] EPA. What is Green Infrastructure? Available at [https://www.epa.gov/green-infrastructure/what-green-infrastructure].

Laying porous asphalt at the Saint Paul's first green alley, Hamline Library, October 2012. Courtesy Wes Saunders-Pearce.

Continue Community Outreach

UPDATE AND COMMUNICATION SOCIAL VULNERABILITY INDICES

Ramsey County's vulnerability mapping and threat assessment is a very useful tool for citizens to understand their relative vulnerability. One potential next step strategy is to share these vulnerability mapping tools of Saint Paul residents with community organizations such as District Councils, faith based organizations, and other community organizations that serve these vulnerable populations. These organizations can collaborate on risk communication in a culturally appropriate manner to the vulnerable populations to prepare them for the future health consequences of climate change.

In addition, a next step strategy could be to shift from a negative to a more positive framing that could help to empower people and provide a more fruitful discussion for ways to enhance resilience[30]. Their researchers note:

"Climate change work has traditionally emphasized vulnerability and has used a deficit-based approach to assess the ability of communities to adapt to climate change. However, vulnerable populations might possess a broad range of skills or qualities that make them more resilient to climate impacts. For example, those who have access to grocery stores but are also able to rely on local food production may be better able to weather disruptions in food systems. Likewise, those who have struggled to make ends meet with limited material resources under current socio-economic conditions may be better able to cope during disaster."

In the City of Saint Paul, some recent immigrants may benefit from strong social ties and culture-based networks of support that help meet the needs of daily living, which can offset the vulnerability these communities might otherwise be expected to experience during an emergency event.

CONDUCT TARGETED ENGAGEMENT ACTIVITIES

Government agencies can partner with community-based organizations and coalitions to conduct assessment and develop education and outreach campaigns that support community-led efforts to build resilience and are appropriate to the needs and characteristic of targeted audiences. The same communities considered most vulnerable to climate change can serve as a resource, given their knowledge about how to connect with social networks, coordinate with culturally-based practices and skills, and capitalize on existing resources.

Many communities produce fact sheets and other educational materials specific to extreme heat, flooding, poor air quality and other local climate change impacts. These can be used by community leaders and residents to learn more about the actions they can take to prepare for, respond to and recover from climate change impacts, such as joining neighborhood groups involved in disaster management and climate adaptation planning, establishing a system of community outreach to inform and check in on elderly and others with specific vulnerabilities, and working to ensure that land-use planning decisions consider opportunities to mitigate climate-related impacts (e.g., by promoting green space and limited building in flood-prone areas). A creative tool out of California for engaging the public in learning more about climate change impacts and strategies to address them is the "Climate Survivor Workbook," a collection of guided activities to build a community's resilience[31].

Next step strategies may take the lead from targeted engagement activities occurring in other communities throughout the U.S. These include:

- Opening cooling centers aligned with where residents already identify as gathering places in the community
- Working with community coalitions to encourage neighbors to check on each other during extreme heat events and help those who need assistance accessing cooler environments or other safe locations

30 E.g., see the work of the Pacific Institute. Available at: [http://pacinst.org/issues/climate-change-vulnerability-and-resilience/community-resilience-to-climate-change/].
31 Pacific Institute. Available at: [http://pacinst.org/wp-content/uploads/sites/21/2013/04/climate_survivor_workbook.pdf].

- Establishing a broader and more formal system of neighborhood outreach workers – either agency staff, volunteers (such as CERT members) or partner agency staff – to disseminate information and check in on especially vulnerable residents
- Relying on existing networks to share real-time information on current environmental conditions and appropriate behaviors to ensure safety
- Establishing systems to alert public health officials about high-risk individuals or those in distress during a weather event (such as phone hot lines, building relationships with community leaders such as religious elders and others who know their local populations well)
- Engage in community-based participatory research practices (which directly involve impacted community members in collecting, analyzing, interpreting and acting on data)
- Developing partnerships with community-based organizations that serve members of vulnerable communities, so that relationships are well established prior to an emergency event
- Providing financial resources, such as through a mini-grant program, to community-based organizations to host community workshops on climate adaptation and to help identify impacts of primary concern to vulnerable communities through informal surveys or other means.
- Working with organizations based in vulnerable communities to design climate adaptation strategies
- Providing accessible and culturally relevant information needed to meaningfully participate in the planning discussions (considering people with a diverse range of physical, cognition and emotional abilities)
- Educating at-risk groups and their caregivers in the symptoms and treatment of heat-related illness.
- Leverage existing community health programs as a dual use opportunity to address vulnerable populations

Community health programs in the City of St. Paul may be key potential partners in building resiliency of those populations most vulnerable to the consequences of climate change. Strategies around building awareness of the relationship between climate change and health is a crucial first step in this process.

Risk communication to vulnerable populations in Ramsey County in advance of extreme weather events so they may be better prepared is one example of a public health adaptive approach to climate change. Health department staff who already spend time in direct contact with residents (such as home-visiting nurses, health educators and inspectors) can be used to share audience-appropriate messages about protective measures individuals and communities can take. Strengthening relationships with community partners who can help develop and disseminate messages that will resonate with our various audiences, some of whom have limited English proficiency, are socially isolated, distrust governmental agencies, lack access to a computer or phone, or experience other communication barriers, continues to be a core strategy for local public health in addressing climate change vulnerability.

Other approaches include working with communities to build resiliency to the effects of climate change by developing awareness of those most at risk in extreme weather events, identifying and promoting public cooling centers during extreme heat events, announcing “ozone action days” in response to high levels of air pollution, and educating businesses and residents about how to keep food and drinking water safe during flooding and other emergency events.

Infrastructure

The infrastructure sector team is concerned primarily with the climate resilience of the City of Saint Paul's infrastructure. Particularly of concern is Saint Paul's critical infrastructure. Saint Paul must be able to sustain the many challenges posed by a rapidly changing climate. As such, this sector will focus primarily mitigation of risk factors posed to critical infrastructure by climate change.

Definition of sector

Infrastructure refers to the fundamental facilities and systems serving a country, city, or area, including the services and facilities necessary for its economy to function. It typically characterizes technical structures such as roads, bridges, tunnels, water supply, sewers, electrical grids, natural gas systems, telecommunications, and so forth, (e.g. rail, airport terminals, shipping ports, wastewater treatment plants, drinking water supply, etc.) and can be defined as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions[32]".

There are two primary classifications of infrastructure: hard and soft. Hard infrastructure refers to the large physical networks necessary for the functioning of a modern industrial nation. Due to its location on the Mississippi river, the City of St. Paul has several unique hard infrastructure systems including a large rail and port transportation system. Soft infrastructure refers to all the institutions which are required to maintain the economy, health, and cultural and social standards of a country, such as the financial system, the education system, the health care system, the system of government, and law enforcement, as well as emergency services.

The term critical infrastructure has been widely adopted to distinguish those hard and soft infrastructure elements that, if significantly damaged or destroyed, would cause serious disruption of the dependent system or organization, possibly further resulting in a public safety hazard. Storm, flood, or earthquake damage leading to loss of certain transportation routes in a city, for example bridges crossing a river, could make it impossible for people to evacuate, and for emergency services to operate; these routes would be deemed critical infrastructure. Similarly, an on-line booking system might be critical infrastructure for an airline. These elements of infrastructure are often the focus of recovery efforts in the aftermath of natural disasters.

What has happened in the past

The City of Saint Paul's critical infrastructure is highly sensitive to many shocks and stresses.

VULNERABILITY TO ELECTRIC OUTAGES

Critical infrastructure is highly vulnerable to electric outages. While the electric infrastructure is designed and built with reliability and redundancy at the forefront, on a case-by-case basis officials evaluate issues and can switch loads or make other operational adjustments as needed to resolve outages. Many of these systems have remote-management capability, so access to offices would be less critical than on-site access to the production assets for management. Power outages would impact the airport, public transit, and some parking facilities.

INSUFFICIENT FINANCIAL RESOURCES

Funding for use on capital improvements is usually an issue for City owned facilities. With over 200 buildings/structures and 2 million square feet of space there will always be a need to upgrade and improve the buildings. With changing technology, upgrades will continue to be a priority. Utilities continue to work diligently within our regulated framework using a cost-based rate structure and long-term planning and financing mechanismsto secure the needed resources for infrastructure investments. The primary challenge is major infrastructure projects initiated by other parties that may impact useful assets and require assets not included in long-range planning.

TEMPERATURE

Temperatures extremes, whether hot or cold, are a constant load on facilities. Keeping a stable interior temperature working environment can be difficult and can cause premature failures in related equipment. For instance, the potential of rolling brownouts or other regional implications may impact the ability to power the facilities and provide adequate services. Extreme temperatures can also cause expensive overruns on an operating budget if the temperatures last for long periods of time. Heat-related illnesses are also a concern for outdoor workers.

32 Wikipedia. Infrastructure. Available at: [https://en.wikipedia.org/wiki/Infrastructure], n.d., para. 1

PRECIPITATION/ DROUGHT

Flooding, heavy precipitation, and drought events may impact operations, infrastructure, employees, and general accessibility to properties throughout the City of Saint Paul. This may compromise the ability to play an active role in helping the area recover from an event.

Flooding events can cause issues for freight transportation on the inland waterways in a couple of ways. The first would be during flooding safety issues associated with high volume flows need to be addressed. This often results in suspending barge loading/unloading. But perhaps even more significant is that when the flood waters recede, the flow decrease and the suspending solids being carried by the water drop out of the water column creating impassable areas on the waterways system. This results in the need for emergency dredging and a delay of commodities into and out of this market.

Flooding has varying degrees of impact on our airport system. The St. Paul Downtown Airport (STP) has a deployable flood wall that has been deployed several times over the past five years to keep the airport operational - including key corporate clients with aircraft based at STP. More broadly, flooding is manageable across our campuses, with some challenges related to low-lying infrastructure, sanitary systems, mold and pest issues, and travel delays.

Infrastructure is protected by dikes and floodwalls up to the level of the severe flooding that occurred in 1965, or higher than the 100-year flood level.

Flooding has been an ongoing concern for the central plant that serves District Energy St. Paul, with major access points on Sheppard Road. Each year they work closely with the City and other local stakeholders to understand potential water level peaks and scenario build for barrier installations and plant access for staff and fuel deliveries. Fuel deliveries can be inhibited or halted based on water level and road closures, and the fuel processing facility can also be affected by high water levels, primarily due to access restrictions. The heating system has alternative energy sources available, but prolonged delivery restriction can be tremendously disruptive to business.

Communities participating in the Metropolitan Council's Inflow/Infiltration (I/I) Reduction Project over the past several years have completed over $120 million in infrastructure improvements and eliminated millions of gallons of excess flow in the system. Reduction of I/I preserves needed water resources and avoids about $1 billion in unnecessary capital spending for the regional sewer system. Combined Sewer Overflow events that were once over a billion gallons a year have been reduced to a total of 211,000 gallons over the past five years, with the last three years having none. In addition, the Metropolitan Council has two generators that back-up the electric connection to our pumps and can be used to pump flow over the flood wall and into the effluent channel. They have never come close to using all the stored fuel in the history of the plant.

EXTREME WEATHER

In June 2013, the Twin Cities metro area was hit with three storms over a single weekend delivering copious volumes of wind, rain and hail that saturated the ground and uprooted more than 500 public trees and thousands of private trees throughout the City of Saint Paul. Over 610,000 of Xcel Energy's metro electric customers were impacted by outages, the largest such event in the company's history. Pre-storm preparations days in advance and a highly coordinated restoration effort involving more than 1,800 field personnel replacing 460 poles and nearly 300,000 feet of power lines resulted in 96% of electric customers restored within 3 days. It took the City almost two weeks to clear streets and public right-of-way of debris, another 2 weeks to clean up piled debris on boulevards and the rest of the summer to remove tipped up stumps.

Historically, the City of Saint Paul has fought rising flood waters within the Lowertown area using emergency methods that are temporary in nature. Construction of emergency flood fight facilities has been necessary six times since 2001, with a declared state of emergency by Mayor Chris Coleman on June 25, 2014 due to rising water on Mississippi and flooding. Earthen levees and sandbag levees have been constructed at the intersections of Jackson Street and Shepard-Warner

Road, as well as at Sibley Street and Shepard-Warner Road. Municipal ball-type valves and sandbags are used to block existing storm sewer outlets along Shepard Road and temporary pumps are used to pump interior drainage at the intersection of Broadway Street and Kellogg Boulevard. Currently, there is one storm water pumping station located to the west of Jackson Street on the north side of Shepard Road. At times the temporary emergency systems cause disruption to the traffic in Lowertown and in Downtown St. Paul. Within the last few flood events, the City has spent several hundred thousands of dollars in planning, construction, and removal of the emergency facilities. In 2014, Minnesota documented at least $32 Million in damage to public infrastructure .

Several plans exist to prepare for extreme weather. Most entities run exercises to prepare staff and tenants on how to manage debris, life safety, access, and infrastructure damage during an emergency. In addition, extreme periods of cold or heat are an integral part of the peak and capacity planning for energy infrastructure. Thermal tanks are utilized to help manage high dew point and extended periods of heat, and the cooling system has both electrical and absorption chiller assets to utilize, as well as backup assets in customer buildings that can dispatch to the system in extreme conditions. The heating system maintains a flexible fuel approach that allows flexibility in the case of major impacts to fuel availability or market conditions that limit use of particular fuels. As a result, the current system maintains a peak capacity well beyond the peak demands of the current heating grid.

What could happen in the future

More and greater floods, more snow storms, increases in ice storm and landslide hazards, longer thunderstorm season with more frequent and possibly stronger storms and tornadoes are significant enough concerns on their own. In addition to their individual hazards, the cumulative effect of more frequent and more intense event responses will put an enormous logistical and financial strain on government and residents alike. Impacts include dealing with the competing concerns of non-disaster caused emergency housing and increased disaster related emergency housing demands, loss of locally owned businesses after single, much less repeated events (40% of small businesses impacted by disaster fail within 1 year of the event[34]), repair costs for weather stressed and disaster damaged infrastructure, personnel burn out and work stress, and response costs could cripple agencies and jurisdictions. Even for uncertain impacts, such as the strength of future storms under climate change, we know we will be dealing with more frequent and greater severe weather hazards.

For all shocks, stressors, and climate impacts, infrastructure will face similar situations. Groups will be faced with scarcity of resources that raises costs, and lack of access to sites that when possible may result in the need to work remotely. For some events, it may be possible to obtain outside funding, such as FEMA aid.

32 Wikipedia. Infrastructure. Available at: [https://en.wikipedia.org/wiki/Infrastructure], n.d., para. 1
34 FEMA. Protecting Your Business. Available at: [http://www.fema.gov/protecting-your-businesses].

FLOODING

Severe flooding will result in a wide range of infrastructure damage, including washed out roads, reduced access to some gas and electric facilities, washed out/damaged airport runways, structural bridge damage, dam failures, overloading to storm sewer systems, roadside slope failures and corrosion and short/long term damage to signalized traffic and street lighting systems. Flash flooding caused by large amounts of moisture in a short time period can be an issue for just about any City owned facility and would be difficult to combat. Some few City buildings, such as the Parks and Recreation buildings located on Raspberry Island and Harriet Island, could sustain long term foundation erosion issues after years of repeated flooding if flooding was to become a common occurrence. The risk to public safety will increase, along with the risk of major economic impacts from closures, delays, and maintenance costs. Severe flooding will trigger use of FEMA contract language and procedures.

For example, flooding could have a huge impact on commodities shipping on the river. If major flood stage is reached, the Southport (Barge Channel Road) and the Barge Terminal 1 (Childs Road) get shut down due to facilities and or road becoming partially submersed. Additionally if the water overtops the dockwalls/bulkheads, there can be significant structural damage from flood waters. Once the flood waters recede there are often multiple areas of sediment deposition that require dredging to keep the navigation channel and docking areas open.

GRID FAILURE

Grid failure causes a multitude of problems, including street lighting blackouts, signalized intersection traffic control outages and sewer pump and lift station outages. Grid failure would mean our technology for navigation and communication would be significantly limited. This will result in neighborhoods and transportation systems being unlit, traffic congestion, delays at bus, rail and airport terminals, and greater volumes of traffic accidents/deaths and structures being flooded from being unable to pump water. With grid failure, port facilities would convert to using mobile equipment and excess fuel to allow for product transfer. A grid failure could also halt aircraft operations, especially if navigational and safety aids, FAA towers, or other key infrastructure were impacted. In addition, Grid failure would mean our technology for wastewater treatment would be significantly limited. Without backup, there would not be the ability to treat wastewater beyond (24-28) hours of use. In most locations, computers would be down, and ability to provide purchase orders and contracts with vendors may not be possible.

Grid failure has complex interdependencies. For instance, District Energy St. Paul's cooling system primarily relies on electricity derived from the Xcel Energy's power grid. The Energy Park Utility Company (owned by the Saint Paul Port Authority and managed by Ever-Green), would also have dependencies on grid function, and has backup generation on-site, although less capacity than the District Energy St. Paul system. Damage assessment in coordination with St. Paul Emergency Management greatly aids in the expedient restoration of our gas/electric services.

Reliability is the local utilities' number one priority. Utilities invest significant time and resources to both harden our existing infrastructure and develop plans including holding frequent drills and exercises on weather events and a variety of other scenarios. Any event impacting the transmission or distribution assets would be immediately addressed and restored as soon as possible. In the event of a grid failure, back-up generators can be used to provide power. In addition, the stakeholders are considering alternative back-up, such as a local 33 MW turbine that could serve critical functions in the city in the event of a grid failure. To aid in this, utilities have a robust Mutual Aid program that taps resources from other utilities at the regional and national (if needed) levels, which has been enacted for disasters such as Superstorm Sandy and Hurricane Katrina.

EXTREME WEATHER

Extreme cold and heat will result in their own specific problems. Extreme temperatures will test the infrastructure systems beyond its capabilities. High temperatures will over heat power grid systems, resulting in grid failures. Impacts to multiple fuel sources during a potential event could pose challenges and rely on communication and planning between utilities and fuel providers.

Roadway pavement and sidewalks will buckle as a result of extreme heat. Extreme cold reduces the already limited shipping season in St. Paul, and prolonged or severe storms prevent commodities from being loaded or unloaded. Work crews will be required to start earlier in the day to avoid the high afternoon temperatures and more frequent breaks will be required with both extreme warmer and colder temperatures. Furthermore, all extreme weather events increase emergency purchases through scarcity of resources and buying at times when resources are expensive.

Public safety is paramount in the restoration process following an extreme weather event. Scenario development can help ensure provision of critical services for life, health, and safety that are aligned with other major stakeholder plans and to maximize the potential of our existing assets. Partnering with St. Paul Emergency Management on a variety of responses will hopefully continue to be very successful.

Strategies

Within Infrastructure, the City of St. Paul has identified the following strategies:

1. Enhance Coordination Planning & Resources
2. Protect & Maintain Critical Assets
3. Ensure Financial and Social Access to Energy

Other secondary goals include:

Initiatives

ENHANCE COORDINATION PLANNING & RESOURCES

Resilience requires a systems level approach, which in turn requires a large number of different entities to work together. The City of Saint Paul works to ensure all relevant stakeholders are invited to the table. For instance, for the Resiliency Framework working groups includes city staff from the Mayor's office, the city council, public works, parks, planning, water, safety & inspections, emergency management, public health, libraries, schools, finance, human rights and procurement departments as well as participants from the Metropolitan Council, Xcel Energy, Saint Paul Regional Water Services, Minneapolis-Saint Paul International Airport, Saint Paul Port Authority, Macalester College, University of Minnesota, Capitol Region Watershed District, the Science

Museum of Minnesota, Gillette Children's Specialty Healthcare, HealthEast, ECHO, HealthPartners, Minnesota Department of Health, Children's Hospitals, HREEO, Ramsey County Health, Ramsey Washington Metro Watershed District, Minnesota Department of Commerce, Xcel Energy, District Energy, and more. Possible initiatives include:

- Maintain open dialogue regarding planning and emergencies
- Hold joint meetings so stakeholders can be aware of projects and have the opportunity to communication.
- Pursue joint funding opportunities
- Consider franchises, a community clean water fund, or other innovative funding opportunities
- Consider resource sharing between stakeholders, such as sharing fuel resources in the event of critical situation or failure
- Improve transportation options and reduce potential impacts
  - Increase public transportation
  - Use next generation vehicles
  - Alter citywide garbage hauling to reduce impact on infrastructure and reduce emission of trucks by having efficient routes
  - Alter citywide snow plowing to reduce impact on infrastructure and reduce emission of trucks by having efficient routes
  - Maintain light rail, which can provide the needed transportation to move a large number of people in the event of an energy shortage

PROTECT & MAINTAIN CRITICAL ASSETS

A second strategy seeks to protect and maintain critical assets. This overlaps with the first strategy, as many efforts to protect and maintain critical assets require coordination across stakeholders and additional funding. Options include:

- Conduct additional research and analysis of options
  - Assess current inventory and define/prioritize critical assets, including mitigation or improvement opportunities
  - Analyze systems effects of new infrastructure, such as how flood walls may reduce flooding in one area and increase it in another
  - Look at flood threats beyond traditional assessment
  - Conduct greenhouse gas emissions inventory
  - Study of the ratio of hard/paved surface to organic/ permeable space.
  - Research improvements and best practices that have been done by other agencies across the country
- Reduce local flooding
  - Install permeable pavement
  - Work to reduce local temperatures and the urban heat island
  - Install white roofs
  - Paint bike paths green/ white to reduce heat island effect
  - Improve plant management to both a) control water where it falls and b) reduce local temperatures
  - Install more new organic green space/green roofs, including on City structure
  - Convert existing hard surface to more organic green space/green roofs
  - Decrease the width of roads to decrease the amount of asphalt and concrete and increase green space in the boulevards
  - Improve tree trimming and greenery maintenance
  - Enhance green building code
  - Improve communication on City efforts to the general public including stronger campaigns, greater incentives, or just more reminder

ENSURE FINANCIAL AND SOCIAL ACCESS TO ENERGY

Energy reliability offers various benefits for emergency response and climate change adaptation and mitigation as well as social and economic benefits. For example, energy efficiency can reduce strain and demand on the power system, reduce exposure to energy cost volatility and provide backup energy sources as well as provide public health, safety and quality of life benefits. By reducing electric demand through energy efficiency programs implemented by the city it is more likely that there will be increased reliability during times of stress on the electric grid and increase ability to respond to system emergencies. Having backup power supply systems in the form of diesel and/or natural gas generators increases the ability of a facility to maintain energy supply during emergencies and disruptions. Those same efficient buildings can shelter residents and vulnerable populations and avoid dangerous and life threatening weather situations as long as the structural integrity of the building is maintained. Energy efficiency measures in buildings like LED lighting, high efficient heating and air conditioning units reduce the amount of energy buildings need to operate. This is important during emergency situations as these energy efficient buildings will require less backup power and can continue to operate longer during power outages. Energy efficient building envelopes designed to higher building codes will provide a more habitable area for longer periods of time in both heat and cold related emergencies.

INITIATIVES INCLUDE:

- Conduct additional research
  - Identify energy resources, their interdependencies, and their alternatives to determine risk
  - Evaluate use of next generation technology, such as distributed solutions of a microgrid or solar arrays with battery backup
  - Improve energy efficiency of existing and new buildings
  - Enact aggressive codes relating to energy and sustainability
  - Fuel flexibility, cleaner and longer in the long run
  - Increase renewable resources, such as solar energy in the form of community solar gardens


PLEASE
KEEP OUT OF
PLANTED AREAS

Natural Resources

The infrastructure sector team is concerned primarily with the climate resilience of the City of Saint Paul's infrastructure. Particularly of concern is Saint Paul's critical infrastructure. Saint Paul must be able to sustain the many challenges posed by a rapidly changing climate. As such, this sector will focus primarily mitigation of risk factors posed to critical infrastructure by climate change.

Definition of sector

The City of Saint Paul has multiple environmental assets embedded in local land and water systems, at varying geographic scales. These assets and features include land forms, vegetation, and water.

Land forms include bluffs, steep slopes, ravines, gullies, floodplains and flats/terraces. Vegetation includes park and open spaces (including city boulevards and private yards), urban canopy, forbs/grasses, and food production. Water includes ground water and surface water (rivers, wetlands, lakes, riparian areas) resources.

True natural systems are complex and interdependent. The above categories are operationally defined and simplified for the purposes of resiliency planning. Wildlife is not categorized because the city does not specifically manage fisheries, birds, or mammals. However, wildlife will indirectly benefit by improving resilience in the three categories. Green infrastructure consists of approaches and practices applied to landscape and building design that use soil, vegetation and natural processes to mimic the natural hydrology of the site, and is considered a resiliency strategy rather than an asset category.

What has happened in the past

Less than a half-inch of rain was recorded the afternoon of Sunday, June 10th, 2012. However, wind gusts peaked over 60 knots and numerous large trees and tree limbs were blown down in a large swath from near the Highland Park area, northeast toward Randolph Avenue. Two rounds of severe thunderstorms occurred between Friday afternoon, June 21st and early Saturday morning, June 22nd. Substantial rain (2.5") was recorded June 21, 2013 and winds up to 56 knots were recorded. Again, numerous large trees (and power lines) were blown down in Highland Park. Last, a complex of thunderstorms during June 14, 2014, developed an area of damaging outflow winds. In addition to 1.6-inches of rain, there was a measured wind gust at the Saint Paul Airport of 46 knots. There were reports of downed trees with areas of power outages.

What could happen in the future

The City of Saint Paul's natural resources are highly sensitive to temperature and precipitations, including extremes in both.

HEAT WAVES

Heat waves can cause sudden impacts to natural resources. Prolonged higher temperatures can decrease oxygen available in aquatic systems. Shallow wetlands are particularly vulnerable. Aquatic organisms perish or are significant stressed, reducing available food supply for other fauna.

Prolonged higher air temperatures can lead to warm water temperatures. This is in turn can release internal nutrient loads from lake bottom sediments and produce more algal blooms.

Extreme heat events can impact a wide variety of tree functions. At the leaf level, photosynthesis is reduced. At the whole plant level, heat stress can decrease growth and shift biomass allocation. When drought stress accompanies heat waves, the negative effects of heat stress are exacerbated and can lead to tree mortality. The (UK) Arboricultural Association said it was aware of a number of reports of branches dropping off trees, an event it says is associated with prolonged hot spells. Generally, heat waves are suspected to dramatically increase insect mortality. However, species' tolerance to very cold or hot days is what defines their present distribution . The impact may be uncertain, with changing ecology and potentially the introduction of new pests.

WARMER MEDIAN TEMPERATURES

Climate data for the Midwest show observed increases in average temperature. This chronic stress also translates to a change in seasonality. According to the National Climate Assessment, the Midwest growing season has lengthened by almost two weeks since 1950. By the end of the century, summers in the local community will feel more like current-day Kansas.

Many weeds, pests, and fungi thrive under warmer temperatures and wetter climates. The range of species will expand and encroach into Saint Paul. Some pests currently established may gain a competitive ecosystem advantage due to chronic temperature shifts, displacing more desirable species. This may hold true for terrestrial as well as aquatic species such as carp which tolerate warmer water with less dissolved oxygen. Additionally, shifts may occur in the timing of bud break, flowering, and leaf drop for some species. Ultimately, impacts may result in increased fertilizer and pesticide use; new and increased cases of disease; increased cases of invasive plant species or new exotic pests; change in plant zones resulting in migrating of historical species; and, loss of beneficial trees or other vegetation.

SEVERE STORMS - HIGH WINDS

Most intense precipitation events are accompanied by high winds (and potentially tornadoes). High winds can create substantial damage to trees. Limbs and branches can be broken from the main structure greatly stressing the tree and reducing canopy cover. Trees can be uprooted causing fatality and loss of stability in the landscape making it more vulnerable to erosion.

High winds can destabilize lakes which have thermally stratified. This can cause anoxic water, with concentrations of dissolved nutrients, to mix into the upper lake. Nuisance algal blooms can occur.

SEVERE STORMS - HEAVY DOWNPOURS

Heavy downpours can cause sudden impacts to natural resources. Typically damage occurs in the form of erosion and sedimentation to downstream resources. The many gullies and ravines which exist in Saint Paul are worsened during heavy downpours. The stability of the landscape is threatened, jeopardizing soil strength and tree canopy. Water resources, especially wetlands and lakes, experience elevated turbidity and stress from other pollutants conveyed by sediments. Total failure (collapses or landslides) could be a potential impact of heavy rain, creating significant natural resource trauma. This might be apparent following periods of prolonged rain creating saturated soils.

It increases peak storm flows, which leads to higher volumes of runoff and delivery of pollutants and then poor water quality of water resources. It also leads to flooding that can affect habitat, including loss and degrade quality, and plant and wildlife species diversity shifts to invasive and non-native species.

DROUGHT CONDITIONS

Drought has significant impacts on water quality. For example, stream flow (i.e. Battle Creek, Fish Creek) lowered by drought reduces dilution of water pollutants, negatively affecting fish and other aquatic organisms. Newly established trees or plantings installed as part of redevelopment or public improvement projects become jeopardized, risking loss of important investment.

GROUNDWATER IMPACTS

Groundwater resources are connected on a regional scale and help support many surface water resources. While Saint Paul's drinking water is predominantly supplied by the Mississippi River, groundwater impacts due to climate change is a serious issue.

Unsealed wells in the city—many undocumented with their locations unknown—are direct conduits to groundwater. These wells may be buried by urban fill or redevelopment. However, changes in precipitation and runoff patterns, or unusually high seasonal (spring) soil water levels, may elevate risk of water and potential pollutants flowing into these casings, often several hundred feet deep.
In the north and east metro region, for instance, a growing population, increasing demands on groundwater, and areas of aquifer contamination could pose problems for the area's water supplies, and its valuable lakes, streams and wetlands. This has led DNR to propose a groundwater management area for the north and east metro which includes Ramsey County.

New commercial groundwater well construction continues within the city. Some emerging businesses such as aquaculture need a water source free from chlorine or other municipal additives. Although not prohibited, and a minor impact relative to major withdrawals by large well fields, it creates some confusion with plumbing code compliance. More importantly, a resilient community should look strategically at how to balance the number of existing wells (permitted and unsealed) with the demand for potential new services.

35 Nature World News. Climate Change Affects Insect Distribution. Available at [http://www.natureworldnews.com/articles/6135/20140221/climate-change-affects-insect-distribution.htm].

ORGANIZATIONAL IMPACTS

In order to respond to climate change shocks and stressors, the organizational resources of a municipality are impacted. The impacts include a need for developing new information, deploying new or enhanced services, and devising new teams, personnel, or approaches to support implementation. Essentially the impacts affect budget, staff, and assets. Identifying stable funding sources, establishing long-term provisions for maintaining natural resource resiliency as a priority, and strengthening community engagement can offset challenges and impacts at the local scale.

Strategies

Within Natural Resources, the City of St. Paul has identified the following strategies:

1. Conduct Landscape Management
2. Develop and Align Organizational Capacity
3. Increase Awareness

Initiatives

The natural resource resiliency strategies are inter-related tools. The division of initiatives into separate strategies is mainly done to organize and prioritize activities. The fundamental core tools of education, incentives, policy, regulations, funding, etc. to address resiliency are connected. Similarly, the resiliency activities of various governmental agencies are connected. Meaningful partnerships and dedicated collaboration for natural resource resiliency is an overarching expectation for all the strategies below.

CONDUCT LANDSCAPE MANAGEMENT

Landscape management is a direct link between people and their natural environment. This strategy aims to improve, increase or augment landscape management in order to mitigate existing impacts and better position to adapt to impacts. This strategy encompasses initiatives for landscape managers, such as municipal staff, as well as landscape users such as citizens or businesses. For resiliency planning purposes, this landscape strategy is split between green infrastructure approaches and initiatives that are specific to natural resource conditions. The distinction is subjective but, in general, green infrastructure differs by virtue of being oriented towards linear systems and low impact land uses.

GREEN INFRASTRUCTURE

- Green infrastructure maintenance approach
- Adopt green infrastructure approach in redevelopment and retrofit scenarios
- Use rain water to recharge groundwater
- Street tree and boulevard establishment (strengthen specifications)
- Explore water harvesting and reuse opportunity
- White roofs
- Adopt a stormwater drain/curb

NATURAL RESOURCES

- Control deer population to protect trees (<$20,000 per year for control)
- Shift turf grass to more native plantings
- Protecting existing open space, enhancing open space (public/private land)
- Re-evaluate planting palette (drought tolerant)
- More comprehensive approach to manage unstable land (ravines)
- Comprehensive unsealed groundwater inventory citywide
- Inventory and stabilization plans for unstable ravines and areas

DEVELOP AND ALIGN ORGANIZATIONAL CAPACITY

A critical strategy involves evaluating ways to develop and align organizational capacity to address natural resource impacts due to climate change. While climate resiliency awareness and actions must be ingrained in the traditional ways the city does business, a clear issue is the anticipated added demands to deliver new or different services, as well as lack of funding for staff or assets, create an intractable dilemma at the local government scale. This strategy is a broad umbrella to foster a framework that may consider policy changes, incentives, regulations, staffing, team structure, and revenue streams to provide a stable and meaningful long-term alignment towards a resilient community.

FUNDING

Public money to plant trees on private land
Revisit city's stormwater utility fee program to better enhance/motivate stormwater management on private land
Taxing authority (for natural resource needs)

GOVERNANCE

- Change policy to increase funding (maintenance, staffing, etc.)
- Department/commission on climate / natural resources
- Restructure internal divisions to better align with changing needs for natural resources
- Policy about new groundwater wells
- Working groups to achieve targets for resiliency / natural resources
- Punch list for resiliency strategies to be checked off for any public project
- Single family residential property greenspace targets / tree canopy

INCREASE AWARENESS

Increasing awareness about natural resource impacts from climate change, and influencing behaviors to support resiliency outcomes, is a key strategy for this sector.

EDUCATION

- Identify opportunities to engage/utilize public (residents, civic, businesses)
- Develop "branding" for resiliency (like recycling logo)
- Implement "ready and resilient" youth outreach
- Add city communications staff to climate adaptation committee to translate efforts for public
- Inventory or comparison analysis of other cities (in 7-county metro area) with climate change/sustainability/ resiliency commission or department


EMS ACADEMY

Working Together

This Strategic Framework for Community Resilience seeks to conduct an assessment of climate change impacts and form multi-discipline, multi-jurisdiction working groups to examine the areas of potential hazards, exposures and vulnerability. Based on this framework initiative, the City will develop a strategy to incorporate community resilience into relevant local and regional plans and projects and outline ways to best communicate efforts to the broader community.

By working together, the City of Saint Paul can identify synergies and leverage existing work to improve resiliency and truly be “Most Livable City in America”.

Cross-cutting themes

In March 2016, groups were asked to identify their group's "Quick Wins": strategies possible immediately with few additional resources. Many of the quick wins collected into cross-cutting themes that spanned multiple groups. Specifically, five cross-cutting themes were identified.

TABLE 1: CROSS-CUTTING THEMES

Cross-cutting theme	Economic and Social Well-Being	Emergency Response and Health Systems	Infrastructure	Natural Resources
Governance, Oversight, Coordination			X	X
Education & Training Awareness	X	X		X
Energy Reliability	X	X	X	
Plant management/ greenery		X	X	X
Programs for Vulnerable Populations	X	X		

CO-BENEFITS

We note that many best practices, such as green infrastructure, can partially mitigate multiple hazards. The ability to provide multiple benefits across a variety of stakeholders is sometimes called "co-benefits". Where possible, the City could consider solutions with co-benefits, thus identifying and implementing low-hanging fruit that could mitigate hazards, save money, and improve the quality of life. The table below shows sample co-benefits for various resilience initiatives.

In addition, many existing efforts could be leveraged to increase resilience. For instance, some federal, state, county, and local efforts that could be leveraged include Hazard Mitigation Plan and Strategies, Local Comprehensive Plans, Emergency Management Plans, Infrastructure Protection Plans, Threat and Hazard Identification and Risk Assessments, and State Preparedness Reports.

TABLE 1: CROSS-CUTTING THEMES

Initiative	Funding	Governance	Education	Green Infrastructure	Natural Resources
Department/commission on climate / natural resources		X			
Protecting existing open space, enhancing open space (public/private land)				(X)	X
Adopt green infrastructure approach in redevelopment and retrofit scenarios				X	
Restructure internal divisions to better align with changing needs for natural resources		X			
Use rain water to recharge groundwater				X	
Single family residential property greenspace targets / tree canopy		X			
Revisit city's stormwater utility fee program to better enhance/motivate stormwater management on private land	X				
Identify opportunities to engage/utilize public (residents, civic, businesses)			X		
Green infrastructure maintenance approach	(X)			X	
Change policy to increase funding (maintenance, staffing, etc.)	(X)	X			
Re-evaluate planting palette (drought tolerant)					X
Street tree and boulevard establishment (strengthen specifications)				X	
Explore water harvesting and reuse opportunity				X	
More comprehensive approach to manage unstable land (ravines)					X

Initiative	Funding	Governance	Education	Green Infrastructure	Natural Resources
Taxing authority (for natural resource needs)	X				
Comprehensive unsealed groundwater inventory citywide					X
Policy about new groundwater wells		X			
Develop "branding" for resiliency (like recycling logo) [new item]			X		
Implement "ready and resilient" youth outreach [new item]			X		
Public money to plant trees on private land	X				(X)
Working groups to achieve targets for resiliency / natural resources		X			
punch list for resiliency strategies to be checked off for any public project		X			
White roofs				X	
Shift turf grass to more native plantings			(X)		X
Control deer population to protect trees (<$20,000)	(X)				X
Add city communications staff to climate adaptation committee to translate efforts for public			X		
Inventory or comparison analysis of other cities (in 7-county metro area) with climate change/ sustainability/resiliency commission or department			X		
Inventory and stabilization plans for unstable ravines and areas					X

ADDITIONAL MATERIAL

The City of St. Paul, Ramsey County, and the state of Minnesota have collected numerous fantastic resources and maps on city structures and vulnerabilities, amounting to more than 20 online databases and 20 City plans. Most of these sources contain online GIS mapping capability, although some few sources have only tables, charts, and maps. A research report summarizing these capabilities is available upon request to:

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APPENDIX 2: GLOSSARY

Acute Shocks: Sudden, sharp events that threaten a sector. Examples include floods, heat waves, infrastructure failures, disease outbreaks, and a terrorist attack.

Adaptation refers to efforts by society or ecosystems to prepare for or adjust to future climate change. These adjustments can be protective (i.e., guarding against negative impacts of climate change), or opportunistic (i.e., taking advantage of any beneficial effects of climate change). EPA Website http://www.epa.gov/climatechange/impacts-adaptation/adapt-overview.html

Adaptation to climate change is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." (IPCC 2007, Glossary.)

Adaptive capacity is the capacity of a system to adapt if the environment where the system exists is changing.

Chronic Stresses: Ongoing condition that weakens the fabric of a city on a day-to-day or cyclical basis. Examples include unemployment, aging infrastructure, declining/ aging population, and an overtaxed or inefficient public transportation system.

Critical infrastructure has been widely adopted to distinguish those hard and soft infrastructure elements that, if significantly damaged or destroyed, would cause serious disruption of the dependent system or organization, possibly further resulting in a public safety hazard.

Disaster risk reduction is the concept and practice of reducing disaster risks through systemic efforts to analyze and reduce the causal factors of disasters. Reducing exposure to hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events are all examples of disaster risk reduction" (UNISDR 2012).

Green infrastructure is a way to manage stormwater. It mimics nature by soaking up and storing water in vegetation, soils, and natural processes. Examples include yards, rain barrels, and roads that allow water to seep through them (EPA).

Grey infrastructure is a way to manage stormwater. It uses pipes and sewers to move stormwater away from urban areas to nearby bodies of water. Examples include underground pipes, sewers, and a wastewater treatment plant (EPA).

Hard infrastructure refers to the large physical networks necessary for the functioning of a modern industrial nation.

Hazard mitigation is sustained action taken to reduce or eliminate long-term risk to people and their property from hazards and their effects (Federal Emergency Management Agency 2013).

Likelihood: How likely is this to happen?

No regrets strategies/actions are options that yield benefits even in the absence of climate change or extreme weather events.

Resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events (National Academy of Sciences, 2012).

Severity: How bad will it be in your sector if this occurs?

Soft infrastructure refers to all the institutions which are required to maintain the economy, health, and cultural and social standards of a country, such as the financial system, the education system, the health care system, the system of government, and law enforcement, as well as emergency services.

Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations" (Environmental Protection Agency 2014).

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